THE ECONOMICS OF SMALLHOLDER IRRIGATION WATER MANAGEMENT: INSTITUTIONS, WATER-USE VALUES AND FARMER PARTICIPATION IN KWAZULU-NATAL, SOUTH AFRICA

by

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ABSTRACT

In recognition of the role of smallholder irrigation farming in ensuring better rural livelihoods, the South African government has made substantial public investment in irrigation infrastructure. The most important perceived problems of communally-managed irrigation schemes in South Africa are the provision of an assured water supply and institutional support relating to water and land allocation, appropriate management, managing local conflicts and farmer participation and collective action in managing water resources. However, if one is to consider international standards as a yardstick, most communally-managed irrigation schemes in South Africa are undergoing Irrigation Management Transfer (IMT), where the responsibility of managing, operating and maintaining irrigation schemes becomes that of the farmers instead of the state.

The most critical issue, given the history of poor performance of smallholder farmers in South Africa, is the extent of users' involvement in irrigation water management. While user participation in water resource management is a South African and international principle, the question is whether smallholder farmers appreciate the importance of and possible benefits to be accrued from the participation. The objectives of the study were: to assess water governance and institutional arrangements and their effects on irrigation management in the Mooi River Irrigation Scheme (MRIS) in KwaZulu-Natal, South Africa; to assess the implication of institutional and management systems on water-use security; to assess the level of farmer participation in collective agricultural water management and the factors affecting users' willingness to do so; and, lastly, to estimate and explain the variation in average irrigation water values as a basis to understand the water management challenges at smallholder farm level. The study used a number of data collection and analytical techniques to achieve the specific objectives. Participatory rural appraisals, which included focus group discussions and key informant interviews, and three household surveys comprising of 60, 71 and 307 respondents were conducted to answer the specific questions.

Water governance and institutional arrangements are critical in shaping the long-term sustainability of smallholder irrigation schemes. The Institutional Analysis and Development (IAD) framework and Ostrom's eight institutional design principles were applied for assessing the linkages and effectiveness of institutions governing the management and use of irrigation water resources in the Mooi River Irrigation Scheme. The study found that water user participation was hindered by farmers' lack of understanding of water policies that are driving the formalisation of local water management systems, which include the registration of water user associations and the requirement for farmers to contribute towards the sustainability of such associations. The role and relevance of water-user associations as formal local water governing institutions and their linkages to informal management structures like local irrigation committees and traditional leadership are weak and require farmer training to enhance coherent institutional linkages at local level. Weak regulatory instruments characterised by poor rule enforcement mechanisms, lack of secured property rights (especially for land) and lack of water security impact irrigation water management among smallholder farmers negatively.

Irrigators in community-managed schemes have varying levels of water access. However, the greatest challenge in these schemes is lack of understanding of the level of water-use security and the influence of local management systems. As such, the study assessed the implications of institutional arrangements on agricultural water-use security. The study recognised the multifaceted nature of agricultural water-use security and therefore applied the Lancaster-Maler model in the conceptualisation of water use at farm level. After applying Principal Component Analysis (PCA) to construct water-use security indices based on the desired attributes of irrigation water, the Ordinary Least Square (OLS) regression technique was applied to identify factors affecting water use at farm level. The results show that agricultural water-use security can be grouped into three main dimensions, namely: physical on-farm availability of irrigation water, existence of effective enforcement mechanisms pertaining to water appropriation, and effective involvement of water users in decision-making processes. The study points to the fact that water-use security at farm level is relative and therefore no absolute measures can be applied. Furthermore, the three dimensions of agricultural water-use security are affected by, among other things, farmers' experience in irrigation, household income, effectiveness of irrigation committees to enforce appropriation rules, membership of an irrigation scheme, membership of a water user association, as well as resource and cost sharing. To ensure improvement in agricultural water-use security among small-scale irrigation farmers, institutional arrangements that promote the effective participation of farmers in decision-making and conflict management mechanisms are recommended. This can be augmented by creating mechanisms that ensure equitable sharing of resources and costs among common pool resource users. Improving the capacity of local institutions and management structures to minimise unsanctioned access to common pool resources (CPRs) may also improve water-use security.

In line with current focus by most developing countries, including South Africa, to transfer management of communal irrigation schemes from state to farmers, an understanding of the determinants of farmer participation in collective activities forms the basis for improving the management of previously government-funded schemes. Empirical results of Tobit and the Ordered Probit models, estimated using cross-sectional data from 307 randomly selected smallholder irrigators, suggest that collective activities are negatively affected by low farmer-literacy levels. Furthermore, the number of consecutive days per week that farmers go without access to irrigation water was used as a proxy for water scarcity, and was a significant determinant of farmer participation. The existing incentives for water-users in the Mooi River Irrigation Scheme were weak and need to be improved to encourage farmer participation in collective water management. This calls for strengthening of local water management systems and institutional policies to ensure maximum benefits from participating in collective activities.

In a bid to understand on-farm water utilisation and management processes, water valuation was performed using irrigation data collected from 60 farmers over a single production cycle spanning the time from planting to harvesting. Furthermore, the SAPWAT 3 model was used to generate secondary data on irrigation water requirements for selected crops predominantly grown by farmers in MRIS. The residual value method was applied to both primary and secondary data to estimate water values and understand the factors affecting the magnitude of the values across irrigation plots.

The results indicated that most farmers in the Mooi River Irrigation Scheme applied less water (average of 61.4%) to their potato crop, ranging between 14% and 174%, when compared to the irrigation water requirements. Crops with relatively low gross margins like maize and dry beans yielded lower average water values of ZAR1.31/m^3 and ZAR1.09/m^3 respectively, while tomatoes yielded ZAR11.78/m^3. Based on primary data gathered over the entire production cycle, the average water value for potatoes was ZAR0.50/m^3, ranging from negative ZAR17.57/m^3 to +ZAR12.66/m^3, which were lower than that imputed from secondary provincial budget estimates, i.e. ZAR2.10/m^3. This suggests poor performance by farmers in the study area. The variability of water value was significantly influenced by the location of the irrigated plot along the main canal, which accounted for 12.5% of the variation. The number of irrigation cycles and education level of the farmer explained 5.8% and 5.9%, respectively, of the variation in average water values. The study illustrates that where water is provided free of charge to a large group of users, unequal distribution, poor management and inefficient use are the challenges commonly encountered. Negative water values also revealed under-performance and the potential high level of indirect government subsidisation of smallholder farmers, mainly through provision of irrigation infrastructure.

In sum, the study has shown the complexity of managing common pool resources at a localized level, and pointed to the need to further understand the institutional dynamics in which smallholder irrigation farmers operate. In view of the parallel arrangements between formal and informal water management structures in communally managed schemes, it is recommended that the traditional authorities be incorporated in the water-user associations as *ex-officio* members and be the custodians of rule enforcement at community level. This might improve compliance to appropriation rules, where the traditional courts can be used concurrently with water user associations to settle local water disputes at community level. Furthermore, communally-managed irrigation schemes still lack capacity for self-management and the negative water values signify poor performance. It is therefore recommended that both human and financial resources as well as technical backup still need to be provided through government support programmes to avoid the widespread collapse of communally-managed irrigation schemes in South Africa. However, such support should mainly be through capacity building, training and provision of expertise in irrigation management to enable the users to manage the scheme on their own, while putting mechanisms in place to ensure that irrigators pay for the maintenance of the infrastructure using returns from irrigation farming.

DECLARATION 1 - PLAGIARISM

I, *Binganidzo Muchara*, declare that:

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II. This thesis has not been submitted for any degree or examination at any other university.

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Signed: ________________________________ Date: ________________________
Binganidzo Muchara

We hereby agree to the submission of this thesis for examination:

Signed: ________________________________ Date: ________________________
1. Professor GF Ortmann (Supervisor)

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2. Professor E Wale (Co-supervisor)

Signed: ________________________________ Date: ________________________
3. Dr M Mudhara (Co-supervisor)

DECLARATION 2 - PUBLICATIONS

The following publications (published and under review) form part of the research presented in this thesis.

Publication 1 - Chapter 5 of this thesis
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Manuscript 1 - Chapter 3 of this thesis
Muchara B, Ortmann GF, Wale E and Mudhara M. Water governance and institutional arrangements in Mooi River Irrigation Scheme, KwaZulu-Natal, South Africa: implications for smallholder irrigation water management. (Under review: *Water Policy*)

Manuscript 2 - Chapter 4 of this thesis
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Manuscript 3 - Chapter 6 of this thesis
Muchara B, Ortmann GF, Mudhara M and Wale E (forthcoming). Valuation and management of smallholder irrigation water in the Mooi River Irrigation Scheme of KwaZulu-Natal Province: a residual value approach. (Provisional acceptance pending corrections: *Agricultural Water Management*)

Conference Papers

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DEDICATION

This thesis is dedicated to

My family

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CGE	Computable General Equilibrium
CMA	Catchment Management Agency
CNI	Change in Net Income
CPI	Consumer Price Index
CPR	Common Pool Resources
CPRM	Common Property Resource Management
CVM	Contingent Valuation Method
CWR	Crop Water Requirement
DAEA	Department of Agriculture and Environmental Affairs
DAFF	Department of Agriculture, Forestry and Fisheries
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
FAO	Food and Agricultural Organisation of the United Nations
FGD	Focus Group Discussions
GDP	Gross Domestic Product
GLM	General Linear Model
GM	Gross Margin
GS	Governance System
GWP	Global Water Partnership programme
IA	Institutional Arrangement
IAD	Institutional Analysis and Development
IDA	Institutional Development Analysis
IE	Institutional Environment
IMT	Irrigation Management Transfer
IWR	Irrigation Water Requirements
KMO	Keiser-Meyer-Olkin
LP	Linear Programming
MNL	Multinomial Logit Model
MRIS	Mooi River Irrigation Scheme
MV	Marginal Value

NGO	Non-Governmental Organization
NIE	New Institutional Economics
NWA	National Water Act
NWRS	National Water Resource Strategy
OLM	Ordered Logit Model
OLS	Ordinary Least Squares
OPM	Ordered Probit Model
PC	Principal Component
PCA	Principal Component Analysis
PE	Physical Externality
PI	Participation Index
PIM	Participatory Irrigation Management
RESIS	Rehabilitation of Smallholder Irrigation Scheme
RIM	Residual Imputation Method
RS	Resource System
RSA	Republic of South Africa
RU	Resource Unit
RVM	Residual Value Method
SA	South Africa
SES	Social-Ecological System
SIS	Smallholder Irrigation Scheme
SSA	Sub-Saharan Africa
TEV	Total Economic Value
VIF	Variance Inflation Factors
VMP	Value Marginal Product
WRC	Water Research Commission of South Africa
WTP	Willingness to Pay
WUA	Water User Association

CHAPTER 1
INTRODUCTION

1.1 Background

Increasing food production through efficient utilisation of productive resources like land and water is a global challenge. Low resource use efficiency in agriculture is particularly perturbing in Sub-Saharan African countries, whose climate exposes them to the vagaries of nature, such as droughts, high temperatures, limited rainfall and occasionally floods (FAO, 2012; Rampa and van Wyk, 2014). South Africa, like many other Sub-Saharan African (SSA) countries, faces challenges of food insecurity and increasing poverty levels in the lower income households (Vink and Van-Rooyen, 2009). This is compounded by water scarcity and low productivity levels in critical food security sectors like smallholder agriculture (Backeberg, 1997; Turton, 2009). In order to improve water access for consumption and production purposes, the South African (SA) government embarked on a process of reforming the water sector post-apartheid in 1994. Although the focus of the reform process was driven by the scarcity of the resource, Ashton et al. (2006) highlighted that it was also driven by the need to redress the inequalities of previous political dispensations and to ensure that sufficient water supplies were made available to meet the agricultural and domestic water demand in communities.

Key to South Africa’s water sector reforms is the white paper of 1997, which gave rise to the National Water Act (Act 36 of 1998) (NWA). The NWA is founded on the principle that the South African government has the overall responsibility for and authority over water resource management, including equitable allocations and beneficial use of water for the public interest (RSA, 1998). A number of statutory instruments, therefore, were developed to improve water access, for example, the National Water Resource Strategy (NWRS) (DWAF, 2004a), Policy on Financial Assistance to Resource Poor Irrigation Farmers (DWAF, 2004b) and Water Conservation and Demand Management Strategy for the Agricultural Sector (DWAF, 2004c). Furthermore, the main institutions that give execution to the NWA include the Catchment Management Agencies (CMAs), Water User Associations (WUAs) and the Water Tribunal (Backeberg, 2005). While the purpose of establishing CMAs is to delegate water resource management to regional levels, the WUAs operate at localized or community level. On the other hand, the Water Tribunal is meant to handle appeals and all aspects of dispute-resolution among various water users, CMAs, WUAs and any other water management institution (Gillitt et al., 2005). Key to the formulation of these policies and organizations was the realization that water was becoming scarcer within the South African economy, yet, according to Backeberg (2005), the economy was moving from an expansionary phase of development to a maturing phase of water allocation and management.

The NWA, therefore, recognises the importance of water within the agricultural sector (Backeberg, 2005). As such, South Africa's water policy reforms were aligned with the agricultural policy through the irrigation policy (Backeberg, 2005), which sought to create opportunities for smallholders and resource-poor farmers. Furthermore, South Africa's irrigation policy dwells more on revitalisation of existing schemes, development of new schemes, establishment of effective management institutions and improvement of water resource use (Backeberg, 2005). This was in response to concerns by some researchers, e.g., Backeberg (1997), Bembridge (2000) and Perret (2002), that publicly-financed irrigation schemes in South Africa were not performing according to expectations. This was echoed by Yokwe (2009) and van-Averbeke et al. (2011), who noted that most smallholder irrigation schemes (SISs) in South Africa have been inactive for many years. Some of the challenges leading to the collapse of SISs include lack of infrastructure and inappropriate planning and design of the irrigation schemes (Yokwe, 2009). Poor management structures, lack of technical knowledge and inappropriate land tenure arrangements also negatively affect the performance of SIS (Bembridge, 2000).

However, due to continued failure of engineering approaches to address the challenges bedevilling the smallholder irrigation sector, Backeberg (2005) suggested that management of irrigation schemes should emphasis the use of institutional and economic instruments of balancing water demand with water supply (Backeberg, 2005). This involves the coordination of institutions and individuals to govern water resources and ensure long-term sustainability of irrigation farming and availability of water resources. However, the level of governance at smallholder level is determined by factors like the existence of consensus, compliance, and the availability of management systems, which enable, within a sustainable framework, the implementation and follow-up of policies (Ostrom, 2009). On the other hand, water institutions should have the capacity to enforce exclusivity and accountability, and ensure compliance to water use regulations (Ostrom, 1994). All these aspects must be attained at minimal costs to minimise free-riding, hence the need for collective participation in water management (Dietz et al., 2003).

While stakeholder participation in irrigation management is a strong South African and international principle**,** the question of who benefits from this participation is not always clear (Orne-Gliemann, 2009). Some believe that participatory approaches, like Irrigation Management Transfer (IMT), reduce government bureaucracy in irrigation management (Vermillion, 1997). Others view IMT as a way of improving management of scheme infrastructure by instilling accountability and eliminating government dependency syndrome by the irrigators (Denison and Manona, 2007). However, from a farmers' perspective, it has been viewed as a way of cutting public expenditure on irrigation at the expense of irrigators, by WUAs that could pay the full operating costs of the schemes (Van der Zaag and Rap, 2012). Several studies, for example, Chandran and Chackacherry (2004), Bandarogoda (2005), Ginster et al. (2010), Jayne et al. (2010) and Ghazouani et al. (2012), suggest that institutions that can ensure effective water management might not be adequate for most SISs in developing countries. This has led to poor performance of communally owned smallholder schemes in Africa (Svendsen et al. 2009), consequently leading to water insecurity, poor farmer participation and low water productivity levels (Speelman et al., 2011). As such, Cleaver and Franks (2005) recommended the continuous use of *ad hoc* rules and organizations, whereas Perret (2002) called for the establishment of multi-functional institutions to improve management of SISs in South Africa.

Although smallholder irrigation schemes in South Africa are governed by both formal and informal institutional arrangements (IA), Orne-Gliemann (2009) argues that formalised institutions are needed at scheme level for small-scale users and policy makers to interact with each other. This comes at a time when the management of natural resources in developing countries is shifting from the centralised and state-driven regimes of the colonial periods towards decentralised and mainly community-based management regimes (Dorward and Omamo, 2009). In irrigation farming, the shift is influenced by the IMT and Participatory Irrigation Management (PIM) approaches (Perret, 2002; Perret and Geyser, 2007; Gomo et al., 2014a), articulated in theories of collective action (Olson, 1965) and common property resource management (CPRM) (Ostrom, 1990), which focus on getting the institutions right. On a similar note, Gakpo et al. (2001) highlighted that water allocation in South Africa is more supply-side dominated, hence the establishment of CMAs and WUAs to address the institutional challenges. However, according to Gakpo et al. (2001), the decision support and management tools for the proper functioning of the CMAs and WUAs in South Africa may be inadequate. This is also evidenced by the response of the South African Directorate of Catchment Management under the Department of Water Affairs and Forestry (DWAF) in capacity building and education of water users to enable the water management institutions to function effectively (Backeberg, 2005; DWAF, 2006). Considerable time is, however, required before the WUAs can allocate water efficiently, considering that institutional arrangements governing use of community water take long to adapt to changes (Nemarundwe and Kozanayi, 2002; Saleth and Dinar, 2004; Backeberg, 2005).

Since irrigated agriculture in most countries often use the bulk portion of the harvested fresh water resources (DWA, 2013), this study sought to understand the embedded governance systems and institutional arrangements which provide incentives to use water more effectively and aid in the successful uptake and implementation of best water management practices. It must also be acknowledged that the benefits of an irrigation system depend mainly on the rules that govern it and the nature of production undertaken by the irrigators in terms of crop types, intensity of production and resource use efficiency (Hussain et al., 2009). The accrual of benefits are constrained by a number of factors, summarised by Dietz et al. (2003) as increasing human population, growing consumption and the rapid deployment of advanced resource-using technologies when governance institutions are absent or maladapted. They further argued that the way governance institutions value water informs the way people manage the resource; the challenge for good management lies in the mechanisms to devise institutional arrangements that help to improve resource access and utilisation. Analysis of the implications of water governance systems on South Africa's smallholder irrigation sector might improve an understanding of the dynamics of water institutions over time. Furthermore, the role of informal institutions, such as traditional leadership, local irrigation committees and individual involvement in water governance, forms an integral part of the IAs governing water resources in South Africa also require further scrutiny. The study also sought to unpack the challenges around irrigation governance systems, participation of irrigators in irrigation management according to the IMT approach, variations in average water values and water-use security at farm level, which have all been contextualized in the following section.

1.2 Justification for studying the smallholder irrigation sector

The selection of smallholder irrigation for this study stems from the importance of the sector in contributing towards household food security and reducing rural poverty in South Africa (Oni et al., 2011), particularly in regions associated with low and erratic rainfall and high evaporative demand, which limits dry land crop production (Hassan, 2011). Furthermore, more than 60% of the population of Sub-Saharan Africa (SSA) live in the rural areas and depend on smallholder agriculture (Panin, 2010). In South Africa, the importance of smallholder irrigation schemes arises primarily from their location in the former homelands, where more than 1.3 million poor households reside (Vink and Van-Rooyen, 2009). Irrigation farming is, therefore, viewed as one of the strategies that can potentially contribute significantly to food security and income of participating households (van-Averbeke et al., 2011; Sinyolo et al., 2014a). Of concern is the fact that agriculture (irrigation in particular) is the sector that uses the majority of harvested fresh water, accounting for more than 60% of the total water use in South Africa, yet its contribution to Gross Domestic Product (GDP) is only 3% (DWA, 2013). Nonetheless, the forward and backward linkages are important since agriculture provides inputs for the manufacturing / processing sector and also creates a demand for agricultural inputs.

However, despite the substantial government investments in the establishment and refurbishment of smallholder irrigation schemes, some schemes faced collapse soon after the withdrawal of state support (Cousins, 2013). This is despite the fact that many countries, including South Africa, embarked on a process to transfer the management of state-managed irrigation systems from government agencies to water-users through IMT and PIM policies (Perret, 2002; Arun et al., 2012; Gomo et al., 2014a). The rationale for IMT is to relieve the government of the financial burden of funding recurrent expenditures for irrigation, improve the maintenance of irrigation facilities, promote a culture of self-reliance among farmers in irrigation schemes and enhance the productivity of irrigated land and water (Vermillion, 1997; Hassan, 2011). The implementation of IMT in most countries confronted numerous challenges. For instance, Fujiie et al. (2005) noted that service of national irrigation systems deteriorated after the reduction in state agencies' operation and maintenance activities because irrigators in south and southeast Asia could not meet all the costs of operation and maintenance from their farming activities. Similarly, smallholder irrigation schemes in South

Africa were planned and established following a centralised state design system (Fanadzo et al., 2010). High levels of dependence on government support among smallholder irrigation farmers, accompanied by weak local institutions, lack of information regarding farmers' production strategies, low participation, poor maintenance of infrastructure and poor performance when farmers are left to manage previously government-funded schemes, are recurrent problems in South Africa (Perret, 2002; Mnkeni et al., 2010; Fanadzo, 2012; Reinders et al., 2013). The aforementioned challenges of managing SISs have given rise to the need to explore the governance systems, institutional arrangements, water-use security, the level of participation in collective activities, and variability in water-use values at scheme level, as a basis for ensuring effective smallholder irrigation management.

1.3 Problem statement

Communal irrigation systems are such that common pool resources like land, water and infrastructure are the focus of efforts to organize and coordinate their activities (Ostrom, 2000). The challenge of joint management of canal water emanates from its multiple uses and the high cost of excluding landowners with commandable land. The fact that consumption is subtractive in the sense that water applied to one farmer's land is not simultaneously available for other plot holders makes management of canal water complex (Lecler, 2004). When water is scarce, congestion is likely, manifesting itself in conflict, hoarding, and yield reductions (Wade, 1987). It is also important to note the possibility of overuse or destruction of a common-pool infrastructure if its use is unregulated. The governance of community irrigation water and its access to members differ depending on the type and the water source (Saleth and Dinar, 2004; Backeberg, 2005). Drawing from several cases that attempted to contextualise the challenges of SISs in South Africa (Perret, 2002; Denison and Manona, 2007; Fanadzo et al., 2010), weak participation of irrigators in water management, inadequate institutional structures and inappropriate land tenure arrangements were identified. Furthermore, the scheme revitalisation and rehabilitation programme that aims to upgrade the technical, managerial and institutional arrangements of the schemes to enhance resource utilisation and water delivery is yielding minimal benefits (Perret, 2002; Gomo et al., 2014a). The programme tends to be biased towards irrigation infrastructure and technology improvement through scheme rehabilitation and less focus is given on addressing human capacity and institutional development at local level (Denison and Manona, 2007; Maepa et al., 2014). The approach fails to address institutional challenges at scheme level and contributes to repeated failure of state-funded interventions due to perverse behaviour by water users (van-Averbeke et al., 2011). While several studies have scrutinised the implications of national water policy reforms on agriculture in South Africa, for example Backeberg (2005), Gillitt et al., (2005) and Reinders et al. (2013), there still exist gaps with regard to understanding the impact of local governance systems and various institutional arrangements on irrigation scheme management, which this study seeks to explore.

The other aspect affecting smallholder performance in South Africa is water-use security at farm level. Water-use security has important economic and social impacts at both national and household level and contributes towards sustainable economic development (FAO, 2012; GWP, 2012). Its context varies widely across sectors, e.g. manufacturing, processing, production and domestic (Cook and Bakker, 2012), and at national level it underpins securities for health (through water quality), energy (through hydropower and biofuels), environmental (through ecological services) and food (through crop and livestock farming). Despite the contested definitions of water security, one commonly adopted definition of water security is by Grey and Sadoff (2007), who broadly 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. The operational definition of water security used in this study was confined to access and use of water for agricultural purposes. In this context, agricultural water-use security refers to an adequate and reliable supply of water at affordable prices and the availability of rules and water-use rights to ensure that agricultural water needs of farmers are met. GWP (2012) added that water security, or the lack of it, is felt at the household level, among farmers and industries, in cities, in the natural environment of river basins, and in communities, hence analyses, on a case-by-case basis, at international, national and local levels are essential.

Water security is closely associated with the rules, laws and organizations managing water resources (Shah, 2005). Within the irrigation water sector, the institutional environment (IE) focuses on law, policy and administration, while the IAs focus on the operational level of institutions that include rules in use and structures that humans impose on their dealings with each other (Shah, 2005). IAs are, therefore, critical in shaping water access and consequently water-use security at farm and household level. Despite the substantial recurrent public expenditures on the development of irrigated agriculture (Perret, 2002), there is dissatisfaction with the performance of irrigation projects in South Africa (Perret and Geyser, 2007; Speelman et al., 2008). Challenges for communal irrigation schemes in South Africa are either technical, such as infrastructure collapse and inadequate design, or institutional, which includes poor management systems, lack of property rights and poor regulatory mechanisms at scheme and field level (Perret, 2002). While the technical issues are relatively easy to address, the institutional problems are recurrent. Consequently, without adequate institutional mechanisms to improve performance, most irrigation schemes fail to meet the household food security targets for which they were designed.

Water-use security goes beyond just water access (Turral et al., 2010), and is one of the several indicators of irrigation performance at farm level (Namara et al., 2010; Hall and Borgomeo, 2013). While a number of studies have focused on the assessment of the performance of irrigation management processes using financial and engineering indicators (e.g. Doppler et al. (2002); Arun et al. (2012); Reinders et al. (2013); Gomo et al. (2014b)), limited research has dealt with the linkages between IAs and water-use security at farm level. Paying attention to the influence of water management systems and IAs on water security at farm level provides better understanding of water access issues for smallholder irrigation schemes in South Africa. It also provides different irrigation stakeholders, such as government, water suppliers and farmers, with a better understanding of how particular irrigation systems operate as well as identifying ways of improving performance (Bacha et al., 2011). This follows some criticisms of water-security policies in most developing economies, which are viewed as weak due to narrow approaches that separate biophysical and social processes governing water resources (Zeitoun, 2011). In South Africa, considerable attention has focused on irrigation infrastructure development to improve access, storage, regulation, movement and conservation of water (Denison and Manona, 2007). The challenge with this approach is that institutions dealing with water allocation, quality, rights, pricing, asset management and service delivery have often been poorly developed (Grey and Sadoff, 2007). Research has shown that poor institutional arrangements have often led to unequal distribution of common pool resources (CPRs) (Shah et al., 2004; Ostrom, 2007; Rampa and van Wyk, 2014), and in the case of irrigation water, it results in some users being water insecure. However, quantitative measurement of water-use security among irrigators is a relatively new approach and builds on the existing body of literature, which is mainly based on qualitative analysis.

The reasons attributed to water insecurity at a local level include: unreliable water supply, lower water availability in the irrigation scheme than estimated during the allocation process, unexpected water demands arising from sectors other than irrigation, inappropriate consideration of the capacity of the water distribution system, canal breakage and management capacity or capability of the farmers to manage the scheduled supply (Komnenic et al., 2009; Hall and Borgomeo, 2013). However, from an engineering design perspective, most irrigation infrastructures are commissioned by experts and therefore suffice their command areas, if managed properly (Gomo et al., 2014a). This leaves institutional arrangements as the major factors possibly hindering access and agricultural water-use security at farm level.

Due to institutional failures and lack of compliance with rules governing schemes, some schemes degenerate into open access resources, a problem defined by Hardin (1968) in the 'tragedy of the commons' model. Hardin's model assumes the inability of individuals to cooperate to achieve outcomes superior to those achieved by individual actors. However, Hardin's theory was strongly contested by Ostrom through her Common Pool Resource Management theory, which was founded on the collective action theory by Olson (1965). The underlying assumption about collective participation is that those who participate have a stake in the final outcome (Ostrom, 2010). Therefore, it can be argued that collective rules and agreed norms in rural communities result in preservation of CPRs by local appropriators (Ostrom, 1991; Ito, 2012). Canal water has a potentially high transaction cost of excluding a landowner with commandable land. Management even becomes more complex where users do not pay for the resources, and government is involved in the provision of the public good, a situation prevailing in most government-funded irrigation schemes in South Africa.

Since 1997, the South African Government has focused on IMT of smallholder schemes from itself to plot holders and the rehabilitation of infrastructure (Cousins, 2013). The emphasis on farmer participation in irrigation water management through WUAs came as a realisation that most irrigation agencies (e.g., government departments, NGOs) cannot manage schemes efficiently without farmer support (Bacha et al., 2011). The Mooi River Irrigation Scheme (MRIS) in KwaZulu-Natal Province is one of several government SISs developed in former homeland areas of South Africa during the apartheid era, mostly for food supply purposes. As noted by Perret (2002), from the early 1990s most of such schemes in South Africa faced serious problems and an uncertain future, owing to low yields, deteriorating infrastructure, limited access to services, weak and unclear institutions regarding water and land, and lack of support. The need for collective participation in canal water management in MRIS is increasingly visible and is mandatory, unlike in the marketing of produce where farmers have a choice of participating or not. The assessment of farmers' responses to the need for collective management of schemes is critical. However, participation is popularly measured as a binary outcome, especially in market participation studies, and applying the same approach in irrigation management participation poses a challenge due to the multiplicity of activities that include infrastructure maintenance, financial contributions, decision making, etc. An irrigator might participate in one activity and not in another, hence better approaches to measure the intensity of individual participation in the wide range of activities was explored.

The challenge confronted by smallholder irrigators is low water productivity and unequal sharing of the resource. Hussain et al. (2009) noted that, although most uses of water yield high economic returns, the lowest valued uses of water are in the production of agricultural crops. Although estimates of the average value of water use are critical indicators of the scarcity of the resource, such estimates are not easily available for smallholder irrigation farmers in South Africa and hence variability in water use among irrigators is often not explained. Besides some attempts being made to estimate the economic value of irrigation water, for example, Young (2005), Lange and Hassan (2006), Yokwe (2009) and Speelman et al. (2011), the valuation process at smallholder level is hampered by data deficiencies. Young (2005) and Lange and Hassan (2006) attributed this gap to a lack of markets for water in communally managed farming systems, poor record keeping and lack of water measurement devices in most schemes. Adoption of global values of water has also been a challenge at smallholder level because water values are highly site-specific due to large regional variations in water availability and opportunities for alternative uses of water (Lange and Hassan, 2006). As such, there is need to generate site-specific water values, which can contribute towards the national averages and inform water policies. The average water values can also explain the variation experienced in water use among irrigators sharing the same irrigation infrastructure. Unlike in domestic and industrial water sectors, research on smallholder agricultural water values in developing countries is hampered by lack of reliable data on water consumption and pricing at farm level (Wang and Lall, 2006); hence the need for continued and improved research on water valuation that can inform irrigation water management practices across farming regions.

To summarise, the challenges faced by smallholder farmers in the MRIS include high institutional failures leading to poor access of irrigation water and poor collective management of the scheme. The recurrent challenges of accessing irrigation water at farm level has led to high water insecurity as evidenced by high crop failures and increasing underutilisation of irrigable land, thereby exposing farmers to food insecurity. Volumetric measurement of water is difficult due to inadequate infrastructure; hence, possible factors affecting variation in water-use values among irrigators had to be explored as a basis to explain the management challenges in smallholder irrigation schemes. Given the challenges of poor performance and low productivity associated with community irrigation schemes in most developing countries, findings of this research can inform irrigation and water management policies beyond South Africa. The general and specific objectives aimed at answering the above challenges are presented in the following section.

1.4 Research objectives

This study is part of a broader five-year project initiated and fully funded by the Water Research Commission (WRC) of South Africa through project number K5/1879//4, entitled "Analysis of food value chains in rain-fed and irrigated agriculture to include emerging farmers in the mainstream of the economy". Though duplication has been kept to a minimum, some sections of the thesis could have contributed towards some reports compiled to meet specific objectives of the sponsor. However, this specific study, focused on the MRIS, seeks to contribute to knowledge on how smallholder irrigation farmers can effectively participate in the management of irrigation schemes as common pool resources. The research, therefore, anchors on four pillars, namely: water institutions and governance systems, water-use security, farmer participation in collective management of schemes, and the economic valuation of agricultural water. The main assumption of the study was that smallholder irrigators are rational and sought to maximise their returns from farming activities. However, a wide range of institutional arrangements affects water-use security, collective action as well as the average water values.

This study relies on primary data collected from smallholder farmers in the MRIS to answer the following specific objectives:

1. To assess water governance systems and their effect on irrigation water management;
2. To assess the implications of institutional arrangements on water-use security;
3. To assess the level of farmer participation in collective irrigation management and the determinants thereof; and
4. To explain the factors affecting variability in average water values at farm level and implications for irrigation water management.

1.5 Outline of the thesis

The thesis consists of seven chapters, including the introductory and concluding chapters. The body of the thesis comprises of one literature review chapter and four empirical chapters. Two of the empirical chapters - Chapters 4 and 5 - share the same household survey data of 307 respondents. The other two empirical chapters - Chapters 3 and 6 – are based on separate data sets and the collection methods are discussed in the respective chapters. The study was conducted at one study site (MRIS), hence the description and the map is presented in Chapter 3, to which all other chapters refer.

In terms of outline and content, Chapter 2 presents a review of the existing literature on smallholder irrigation schemes in the context of irrigation water governance, institutional arrangements, collective action, water-use security and water values. The chapter also reviews some empirical methods often used to analyse each component of the water management systems. Chapter 3 focuses on the governance issues around irrigation water management. The “institutional analysis and development” framework together with Ostrom’s eight institutional design principles were applied to assess the performance of local level water governance systems. This is followed by Chapter 4, which assesses the implications of institutional arrangements on agricultural water–use security. Chapter 5 applies the collective action theory to understand the extent of farmer participation in water management. The dimensions of participation were identified and the factors affecting participation intensity were estimated using an ordered Probit model. This is followed by Chapter 6 that focuses on the economic valuation of irrigation water by applying the Residual Value Method (RVM). The conclusions, policy recommendations and direction for further research are presented in Chapter 7.

CHAPTER 2
OVERVIEW OF THE LITERATURE

2.1 Introduction

The chapter presents an overview of the literature on smallholder irrigation farming, from a South African perspective. It starts discussing the importance of smallholder irrigation farming as a cornerstone of agro-based economies and then narrows down to the issues of governance in the sector, with a specific focus on irrigation water. The other four sections of the chapter review the concept of governance, collective action, water-use security and water valuation, with reference to smallholder irrigation farming.

2.2 Overview of South Africa’s smallholder agriculture sector

The importance of smallholder agriculture in most developing economies is substantial. However, the sector is often faced with challenges of inadequate resources, technology deficiencies, shortage of inputs, lack of infrastructure, and poor access to credit and markets (Nieuwoudt and Groenewald, 2003; Ortmann and Machethe, 2003; Ortmann and King, 2007). In South Africa, the agricultural sector is dualistic in nature, made up of a highly advanced commercial sector and a poorly developed smallholder sector (Vink and Kirsten, 2003; Aliber and Hart, 2009).

The definition of smallholder farmers is a challenge due to multiple criterion adopted by various researchers, including land size, purpose of production (subsistence or commercial), and income levels (poor or rich) (Fanadzo et al., 2010). In South Africa, the definition goes further to include the historical context of whether someone was previously disadvantaged or not, hence the issue of race (that is black or white) comes into play (Fanadzo et al., 2010). As such, the most commonly used definition of smallholder farmers in the South African context refers to black farmers, most of whom reside in the former homelands (Vink and Van-Rooyen, 2009; Fanadzo et al., 2010). Due to the heterogeneous nature of the production systems, multiple strata exist for defining this group of farmers and there is no clear distinction among them. For example, some authors refer to these farmers as smallholder, small-scale, subsistence, communal or emerging farmers (Crosby et al., 2000; van-Averbeke, 2008; Vink and Van-Rooyen, 2009). Within these groups, two main categories exist, namely those who practice rain-fed agriculture and those who practice irrigated agriculture. This study focuses on the latter group. According van-Averbeke (2008) and Fanadzo et al. (2010), there are numerous classes that further categorise smallholder irrigators, including farmers in irrigation schemes, independent/private irrigation farmers, community gardeners and home gardeners. This review and study are focused on smallholder farmers operating in irrigation schemes in former homeland regions of SA.

Smallholder irrigation schemes in South Africa were first established during the colonial era around the early 1900s (van Averbeke, 2008), after which further developments and improvements on the schemes continued. Between 1930 and 1960, the focus was mostly on development of canal irrigation schemes (van-Averbeke, 2008). As expansion of scheme development continued, a shift of focus towards different forms of overhead irrigation occurred between 1970 and 1990, and this drive continued until 1994 (van-Averbeke, 2008). However, the major challenge affecting smallholder irrigation was sustainability, hence post-1994 provincial governments dismantled agricultural homeland parastatals that were inherited from the apartheid government (van-Averbeke et al., 1998). This affected the performance of most schemes, especially the large and complex schemes that had been centrally managed from inception (Laker, 2004; van-Averbeke, 2008). Some schemes collapsed and others faced management challenges following the end of support from the government (Bembridge, 2000; Laker, 2004).

Central to poor scheme performance was poor management of infrastructure and water resources (Crosby et al., 2000). Low irrigation efficiencies due to poor irrigation scheduling techniques were identified in Zanyokwe Irrigation Scheme in Eastern Cape Province (Fanadzo, 2012). At Tugela Ferry Irrigation Scheme in KwaZulu-Natal Province, Monde et al. (2005) and Sinyolo et al. (2014a) reported high competition for water among farmers, such that farmers in some blocks could not receive water at certain times. Lack of certainty with regard to water availability and supply exposes smallholder irrigators to water-use insecurity and consequently affects their production and household food security status (Sinyolo et al., 2014b). Due to the challenges associated with irrigation water management, market access and other agronomic aspects of production, yields obtained were generally below optimum in most irrigation schemes. Crosby et al. (2000) cite low yields as the main reason for scheme failures, while Machethe et al. (2004) highlighted poor irrigation practices that led to low yields in under-performing schemes, whereas those that performed relatively well were attributed to better irrigation management. In this respect, Machethe et al. (2004) noted that smallholder farmers tended to apply the same amount of irrigation water regardless of plant growth stage, resulting in over-irrigation during early crop growth stages and under-irrigation during advanced growth stages as irrigation water requirements increase.

Drawing from case studies in the Eastern Cape, KwaZulu-Natal and Northern Provinces, Bembridge (2000) reported that crop yields were poor and extremely variable, though smaller schemes performed better than larger schemes. Bembridge (2000) identified weed management, general lack of technical skills, poor extension support, poor irrigation management, as well as in-field water-use inefficiency as the main causes of uneconomic yields. Due to the above challenges affecting smallholder irrigation schemes, the South African government adopted strategies to improve performance of the sector. The most recent approach includes the Irrigation Management and Transfer (IMT), which seeks to transfer the responsibility of managing, operating and maintenance of schemes from the government to the farmers (van-Averbeke, 2008). This is also in line with the South Africa's NWA of 1998, which seeks to empower local water users to manage water. As such, the process of IMT includes formation of water user associations, development of local management institutions and transfer of scheme ownership from government to farmers (Perret, 2002).

Within the IMT framework, the South African government also embarked on a scheme revitalisation process, that includes whole enterprise planning, human capital development, sustainable financial development strategy for schemes alongside repair and re-design of existing infrastructure (Denison and Manona, 2007). Although the South African government has initiated IMT in SIS, most transfer operations are still unsure how to design and implement the process (Fanadzo, 2012). This is also worsened by poor participation of farmers in irrigation, which has led to continued failure of government initiatives towards IMT (Denison and Manona, 2007). Furthermore, the government programmes are biased towards scheme rehabilitation and irrigation technology improvements with minimum focus on human capacity and institutional development (Denison and Manona, 2007; van-Averbeke et al., 2011). There is a growing need to improve farmer participation in irrigation management in South Africa, and closer synergies have to exist between the irrigation policies and water policies (Backeberg, 2005). As such, the following sections review the governance issues around irrigation management, in which concepts of collective action, water use security and water-use values are revisited.

2.3 Irrigation water governance

2.3.1 An economic perspective of the complexities of water management

The generic economic problem of water management is the need to match demand with supply, and ensuring that there is water of a suitable quality at the right location and the right time, and at a cost that people can afford and are willing to pay (Hanemann, 2006). According to Hanemann (2006), the most prevailing problem of water is not one of physical shortage but institutional, which includes problems of governance. Governance has broadly been defined in the literature as the process whereby societies or organisations determine how power is exercised, whom they involve and how they render their activities (Graham et al., 2003). Governance includes decision making processes and capacity of groups to implement their decisions, and is characterised by the level of transparency (openness), accountability and participation (North, 1990). Together with good institutions, good governance has been the foundation of successful cooperatives and agricultural projects (Ortmann and King, 2007; Chibanda et al., 2009).

Good governance systems at times resolve economic problems associated with resource sharing. For instance, the presence of fixed costs in surface water supply creates an economic problem of cost allocation which has no satisfactory technical solution, other than improving the governance systems (Hanemann, 2006). According to Young (1986:2-29), the most common solutions to water management are rooted in bargaining theory that seek to allocate costs based on relative bargaining strength, which is more of a political than an economic approach. Furthermore, the predominance of economies of scale and the need to ensure equitable participation by all beneficiaries of a common pool resource create a need for collective action in the provision and financing of water supply. However, the challenge of collective management of water arises from the attributes of the resource that include rival-ness /non-rival-ness in benefits combined with excludability/non-excludability in costs. Where costs of participation outweigh their benefits, free-riding by members of the group who withhold their individual contribution and still expect to benefit from the results of their colleagues' efforts becomes a governance challenge (Olson, 1965).

The nature of the institutional arrangements, which Ostrom (2007) defined as the set of rules for supplying and using irrigation water in a particular area, is a crucial water governance tool. If the rules are simple, transparent and devised locally, then, monitoring and enforcement are relatively cheap, graduated sanction for non-compliance is clearly defined, low-cost and fair adjudication is available, then, *ceteris paribus*, successful governance and collective action is more likely (Shah et al., 2004). The effectiveness of the institutional arrangements is also dependent on a set of clearly defined policies and legislative frameworks that constitute the institutional environment (Shah et al., 2004). The extent to which these conditions are met depends on people's outlook and disposition (Hanemann, 2006), and on the performance of organisations that are meant to improve access to resources, reducing transaction costs and promoting efficient economic performance (Kirsten et al., 2009). Institutional performance in irrigation management is therefore measured by the capacity of water institutions to protect water resources, enforce exclusivity, accountability and ensure compliance to water use regulations (Hassan, 2011). On the other hand, inefficient institutions are characterised by weak enforcement mechanisms, unequal distribution of resources, lack of accountability, wide-spread free-riding, and tend to discourage user participation and investment in the management of common pool resources (Gadzikwa, 2008; Dorward and Omamo, 2009).

2.3.2 Empirical approaches for assessing institutional performance

Measurement of institutional effectiveness is complex and cannot be attributed to the existence of private or public institutions, neither to those of formal or informal institutional arrangements (Saleth and Dinar, 1999). The complexity stems from the fact that institutions function within a specific environment in which they are expected to lower transaction costs, hence their performance also depends on the behaviour of the environment (Saleth and Dinar, 2004). As such, attempts to measure institutional performance quantitatively has been questioned since it involved quantification of the performance of rules, norms of behaviour and traditions (Saleth and Dinar, 2004). Furthermore, institutions can be evaluated indirectly by analysing their impact on the state of water management or on the well-being of the target groups (Bandarogoda, 2005; Madani and Dinar, 2013).The argument put forward is that it is not the institutions that perform, but their presence influences the performance and efficiency of natural resource management (Jain and Gandhi, 2012).

Although most studies in institutional analysis are descriptive, analytical or theoretical in orientation, few studies attempted a quantitative or numerical analysis of different dimensions of the process of institution–performance interaction within the water sector (Saleth and Dinar, 2004). The general approach for most quantitative analysis is either on game theory (Saleth et al., 1991) or optimization-based simulation models (Sampath, 1990). Such studies focus on the evaluation of alternative rules in terms of their impact on the efficiency properties of the water market from a micro perspective.

Sarker (2013) applied Ostrom's Social-Ecological System (SES) approach (Ostrom, 2007) to illustrate how user self-governance in the management of irrigation schemes in Japan occurs with strong state involvement. The SES relies on a qualitative approach (Poteete et al., 2010) to scrutinize four subsystems: a resources system (a designated area that covers the irrigation system), a resource unit (volume and flow of irrigation water), a governance system (state-reinforced self-governance), and users (irrigators) (Sarker, 2013) The strength of the SES lies in its ability to link the effects of social, economic, political and related ecosystems on the entire pattern of interaction generated outcomes (Sarker, 2013). By applying the SES approach in Japan, Sarker (2013) concluded that the state and users resolve provision problems by investing in the resource system and by combining physical capital with social capital so that irrigation water is allocated fairly and efficiently by all registered irrigators.

Quantitative assessments of governance performance have also been attempted. Chibanda et al. (2009) applied cluster analysis to identify institutional and governance factors influencing the performance of selected smallholder agricultural cooperatives in South Africa. The study concluded that institutional problems give rise to low levels of equity and debt capital, reliance on government funding, low levels of investment, and subsequent loss of members by most cooperatives. At the same time, governance problems were strongly linked to the absence of a secret ballot, low levels of education, lack of production and management skills training, weak marketing arrangements and consequent low returns to members as patrons or investors. These are important findings that can inform policy around smallholder irrigation management in South Africa, whose model of formation and operation conforms to the cooperative concept. However, the technique applies well where a large number of cases are being investigated to introduce heterogeneity in the governance systems, hence cannot be used in a case study type of research.

Mbatha and Antrobus (2008) applied the physical externalities (PE) model to assess irrigation water allocation challenges among farmers along the Kat River Valley in South Africa. The geographical location of farmers along a given watercourse, in which water is diverted by individuals, leads to structural inefficiencies that negatively affect the whole farming community, with more severe effects felt at downstream sites than upstream (Mbatha and Antrobus, 2008). Poor coordination and lack of compliance with institutional and regulatory instruments lead to such water allocation inefficiencies.

Some empirical measures for assessing interaction between formal and non-formal institutions include estimating costs of creation and management (collecting information, monitoring and decision making) of a formal institution instead of naturally occurring informal institutions (Pagan, 2010). Impact of interactions on institutional performance in the context of water development can indirectly be assessed using the indicators of institutional performance, namely: improvements in water availability; scarcity; equity; environment; and financial viability (Kerr, 2007).

In Sub-Saharan Africa (SSA), continuous assessment of irrigation governance institutions is crucial given the shift from the state-driven management regimes towards community-based management regimes (Dorward and Omamo, 2009). In irrigation management, the paradigm shift is influenced by the IMT and PIM approaches within the water sector (Perret and Geyser, 2007; Gomo et al., 2014a). As such, several frameworks borrowed from ecological, sociological, political and economics schools have been applied to assess institutional performance. In some instances, frameworks have been merged to analyse complex governance systems. Due to complexity of institutions and the need to streamline the focus of the analysis to local water management issues, this study applied the Institutional Development Analysis (IDA) approach (Ostrom, 1990; Kirsten et al., 2009).

2.4 Agricultural water-use security

2.4.1 Conceptual issues around water-use security

Based on the literature, it has been noted that the concept of water-use security is dynamic and its definition varies per sector, geographical location and time of assessment. Furthermore, some definitions describe it as a process and not an absolute measure. For example, Muller et al. (2009) consider water security as something that is achieved when social and productive potential/benefits of water have been harnessed adequately and its destructive potential (e.g. floods, contamination) sufficiently contained. In this context, Muller et al. (2009) argued that water insecurity is not primary the result of not having enough water, but the incapacity to fully realise the beneficial uses of water due to a set of constraints (e.g. individual attributes, environmental, physical, socio-economic, etc.). Similarly, Grey and Sadoff (2007) defined water security as the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks. Again, this definition has attracted critics, e.g. Muller et al. (2009) because of its focus on national water security and neglecting the detailed organisational requirements at local government level to achieve household water-use security.

The definition of water-use security may gain significant relevance when contextualised within a micro-economic set-up, such as an irrigation scheme, domestic use of water, processing, etc., because adopting the national level definitions makes local level analysis complex and yields general results. As such, this study sought to pursue an understanding of agricultural water-use security at a localised level, bearing in mind that a measure like, for example, clean water for agriculture, might not be clean enough for domestic or processing uses. Such differences in standards and contexts attract sector-specific analysis of water-use security. Besides the broader framing of the concept, the other challenge of defining water-use security partly stems from the qualitative nature of the indicators; hence, Cook and Bakker (2012) recommended narrowing the definition in order to operationalize the concept. As such, the study adopted a definition by Komnenic et al. (2009), who defined water security from an insecurity perspective, as the perceived difficulty farmers face in securing adequate and reliable access to water for agricultural production. A related definition of water security by Sinyolo et al. (2014b) refers to reliable 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. The two definitions above have informed this study. The following section, therefore, discusses some measurement issues around water-use security.

2.4.2 Measurement and quantification of agricultural water-use security

The complexity of water-use security measurement stems from the heterogeneity of water as a resource, the qualitative nature of the variables and the relativity of water-use security contexts among users within the same sector. Several studies have described water security in qualitative terms; for example, Grey and Sadoff (2007), Muller et al. (2009) and Norman et al. (2010). Others have quantified water security by defining it synonymously with scarcity, and per capita measures were applied; for example Falkenmark (1986) and Chenoweth (2008). Per capita measures categorise the nation into a water scarce nation if it has less than 1000 cubic meters per capita and an absolutely water scarce nation if water resources are below 500 cubic metres per capita (Falkenmark, 1986). Muller et al. (2009) argued that this measure does not reflect the intensity with which water is used; for example, some nations have lower per capita levels of water resources, yet they have high productivity and that ensure high food security (e.g. Singapore, which has 139m^3 per capita and a booming economy), and others have higher water levels of resources per capita, yet they face higher food insecurity due to factors like geography of the nation, condition of land resources, human capacity and institutional environment (e.g. Botswana, which has 8820m^3 per capita). Cullis and Van-Koppen (2007) used Gini coefficient to measure water security and its welfare impacts at national level, while Sinyolo et al. (2014b) computed an index of water security that was then used to measure its impact on household food security.

The concept of measuring agricultural water-use security is informed by the thinking that water access alone is not a sufficient condition for security, but how the water is used and by whom, and how well the variability of the resource is managed. This study deviates from the traditional engineering approach, which focuses on water supply enhancement and addressing physical scarcity of water, by focusing on institutional arrangements and management processes that deal with distributive issues at farm level. Poor coordination of institutional processes often leads to power asymmetries, such that water-use security for some rests on the water insecurity of others (Zeitoun, 2011). This is a major challenge in community irrigation schemes in South Africa, where lack of volumetric measurement of irrigation water results in unequal distribution at farm level; hence, measurement of water-use security of irrigators at farm level based on engineering techniques may not yield consistent results. By applying Likert scales to capture the qualitative indicators of water-use security and computing indices, the study sought to measure the relative water-use security status of irrigators and identified the factors affecting variation in the water-use security status.

2.5 Farmer participation in collective irrigation management

2.5.1 Collective action theory

Farmer participation in collective irrigation management is critical for the long-term sustainability of community irrigation schemes. Participation is well defined using the concept of collective action, which has a strong theoretical grounding in New Institutional Economics (NIE). According to Scott and Marshall (2009), collective action refers to action taken by a group (either directly or on its behalf through an organisation) in pursuit of members' perceived shared interests. The theory of collective action, first coined by Olson (1965), has widely been applied in the management of common pool resources like irrigation schemes, community forests and commodity marketing. The basis of collective action is to solve problems of sharing by a group of individuals, by encouraging cooperation among users. The underlying assumption about collective participation is that those who participate have a stake in the final outcome (Ostrom, 2010). The effectiveness of this approach and the theoretical assumption of cooperating members or users attracted critics. Hardin (1968), through the theory of 'tragedy of the commons', contended that due to the inherent selfishness of humans, rational self-interest will always prevail over the interest of the common good. Hardin's model assumes the inability of individuals to cooperate and the problem of 'free-riders' who cause collapse of the system (Hardin, 1968). However, in Ostrom's seminal work (1990) she refutes the position that common pool resources are problematic. Drawing on a large number of examples throughout the world, Ostrom identifies situations where local people have come together in agreement to restrain their consumption of a resource that is scarce. However, due to institutional failures and lack of compliance to rules governing schemes, some schemes degenerated into open access resources, a problem defined by Hardin (1968) in the tragedy of the commons model. Contrary to this view, Ostrom (1991) and Ito (2012) argued that customary rules and agreed norms in rural communities result in common property resources (CPRs) that are well preserved and utilized through the collective action of local appropriators.

Although collective action is not a new concept among smallholder irrigation farmers in South Africa, application of the concept is complex in water management due to the attributes of the resource. According to Hanemann (2006), some attributes that complicate the collective management of irrigation water include:, the mobility of water, the variability in supply, the cost of supplying water, the price of the water, and lastly the heterogeneity of the water in terms of quality, location and timing of supply and its properties as a public good, especially where weak management systems fail to manage rivalness and excludability in consumption. According to Wade (1987), canal water has a potentially high transaction cost of excluding a landowner with commandable land, yet consumption is subtractive, i.e. water applied to one farmer's land is not simultaneously available to other farmers or users.

2.5.2 Importance of social capital in collective irrigation management

While water irrigation water has been called 'the dividing line between poverty and prosperity' (Wenhold et al., 2007), in practice many irrigation schemes in South Africa are failing and do not provide the anticipated benefits (van Averbeke et al. 2011). It is recognized that a range of capital assets are required to improve smallholder irrigation performance (Namara et al., 2010). Access, control, and ownership of productive assets such as land, labour, finance, and social capital enable people to create stable and productive lives. However, social capital is necessary if other forms of capital are to have real benefits, especially in performing collective action activities, where a number of individuals must contribute to achieve the desired outcomes (Ostrom, 2004). Social capital, which is defined as either cognitive (for example norms, values and beliefs) or structural (for example roles, networks and relationships) (Liverpool-Tasie et al., 2011), considers the nature of the relationships that exist between members of the schemes as well as the relationships that exist between scheme members and the broader community. As such, effective collective management of irrigation schemes can be achieved if there is good relationship between scheme members and the hosting communities (Muchara et al., 2014).

Namara et al. (2010) highlighted that despise high failure rate of community managed schemes, technical interventions such as rehabilitation of scheme infrastructure or introducing new crops need to be complemented by institutional interventions such as improving water management processes to ensure equity in water distribution along the scheme. It can be argued that the success of most institutional interventions depends on the social networks within the respective communities. Furthermore, the extent to which collective action facilitate access to inputs like water is partly influenced by the social network structures such as informal groups, kinship, trust and leadership. However, informal groups are often common among farmers and lack of trust is generally the reason for individual farming and failure most collective activities, besides practical considerations such as the timing of activities not allowing for collective action (Muchara, et al. 2014). Social capital has therefore been explored in the upcoming sections from the angle of group formations and farmers' involvement in group activities, to better understand its role in collective irrigation management.

2.5.3 Measurement of participation in collective activities

Based on the NIE literature, success or failure of collective action is determined by the following: (i) characteristic of the collective action problem; (ii) attributes of the group (members and non-members); (iii) attributes of the institutional arrangements; and (iv) external factors (Sekher, 2001). As such, the differences in group members' understanding of collective action are influenced by their perceptions of the problem, and the individual perceptions towards solving the collective action problems (Meinzen-Dick et al., 2000). Heltberg (2001) and Gadzikwa (2008) attribute such differences to structural differences like age, education, gender, occupation, values, beliefs, ideas, and economic status.

Mills et al. (2011) applied the collective action concept to investigate the effect of co-operative working on the farm and the impact on group members' lives. The study concluded that locally adaptable engagement strategies, working with group members previously known to each other, institutional arrangements that limited group size and which allowed groups to develop their own solutions and implementation rules, and external support offering the services of a local facilitator and funding for both planning and management stages were critical for the success of collective action.

Another challenge of collective irrigation management pertains to the sharing of benefits and costs among participating members (Meinzen-Dick et al., 2001). Olson (1965) has shown that successful participation of members in group activities depends on the expected benefits and costs, hence rational individuals will free-ride whenever an opportunity arises so as to achieve personal benefits at the expense of the group. This phenomenon is more common in larger groups than smaller ones, which are easy to monitor individual activities (Agrawal, 2001; Meinzen-Dick et al., 2004). Furthermore, social networking promoted trust among group members thereby enhancing the chances of success in carrying out collective activities (Mills et al., 2011; Mabuza et al., 2012)

Econometric analysis of participation in irrigation management goes further than the binary approach commonly applied in market participation (e.g. Fujiie et al. (2005); Fischer and Qaim (2012)). The multiple activities involved in irrigation management, which include canal repairs, cleaning of canal, financial contributions, etc., require more robust approaches to measure participation. This was also necessitated by the current focus on the implementation of IMT policy in most countries. To date, the IMT has been faced with numerous challenges; for instance, Fujiie et al. (2005) noted that service of national irrigation systems deteriorated after the reduction in state agencies' operation and maintenance activities because irrigators in South and Southeast Asia could not meet all the costs of operation and maintenance from their farming activities. Similarly, high level of dependence on government support among smallholder irrigation farmers, accompanied by weak local institutions, lack of information regarding farmers' production strategies, low participation as well as poor maintenance and performance when farmers are left to manage previously government-funded schemes, are recurrent problems in South Africa (Perret, 2002; Mnkeni et al., 2010; Fanadzo, 2012; Reinders et al., 2013). The aforementioned challenges of managing SISs have given rise to the need to explore the level of participation in collective activities at scheme level, as a basis for ensuring effective smallholder irrigation management.

2.6 Economic valuation of water

2.6.1 The concept of economic value of water

The economic concept of water valuation varies depending on the sector and the use of the water. There is utilitarian approach, which is based on the assumption that humans have a quantitative utility scale against which they measure the relative degree of satisfaction (Hanemann, 2006). This satisfaction is derived from consumption of alternative goods or a combination. Based on the utilitarian approach, water attains an economic value when users are willing to pay for it rather than do without (Lange and Hassan, 2006). As such, the various economic concepts of value are those relating to total, marginal, and average water values (Ward and Michelsen, 2002), whose application depends on the objective of the valuation process. Therefore, it is important to define the specific value being derived during any valuation exercise.

The total economic value (TEV) of water is measured by the total willingness to pay for a given level of water used (Ward and Michelsen, 2002) and includes an economic consumer surplus component in addition to the price paid or received (Lange and Hassan, 2006). As such, the TEV measures total utility from water consumption or total economic benefits derived from using water as a production factor (Lange and Hassan, 2006). This measure often overstates the value of water compared to other measures like marginal productivity values (Hanemann, 2006).

The marginal value (MV) of water represents the contribution of an incremental unit of water used in the production process, which is measured by the slope of the demand curve (Lange and Hassan, 2006). The MV concept is embedded in the economic principal of diminishing marginal returns and is important for water allocation decisions. The marginal value of water provides important information for policy analysis of water development or allocation (Ward and Michelsen, 2002). Furthermore, the concept is based on neoclassical economics, whose thrust is on economic efficiency. Although data deficiency affect computation of MV at smallholder level, the values are more informative than other valuation estimates (Young, 2005). Based on accurate marginal water value estimates, development practitioners' decisions on increased water supply may require that water infrastructure be expanded as long as the marginal value of the added capacity exceeds its marginal cost (Ward and Michelsen, 2002). As such, policies aimed at improving economic efficiency of reallocating water among users do so based on the marginal value of the water.

The average economic value of water is defined as the total value of water divided by the quantity of water supplied (Ward and Michelsen, 2002). Although the measure gives higher estimates compared to marginal values, its conceptual simplicity and ease of calculation may engage the policy analyst into using it to approximate marginal value (Ward and Michelsen, 2002). However, since average value is typically much larger than marginal value, use of estimated average value, when marginal value is the needed measure, usually leads to an over-investment in water supply capacity or over-use of water (Ward and Michelsen, 2002; Lange and Hassan, 2006).

Investment in agricultural water seeks to improve human well-being through increased agricultural productivity (Svendsen, 2009). Agricultural productivity is indicated by value of production over different types of agricultural activities from a given set of inputs including water (Turral et al., 2010). By examining individual factors of production over time, it is possible to measure their overall impact on agricultural output. Although numerous studies examine demand and value of water for domestic and industrial use, research on smallholder agricultural water value in developing countries is hampered by lack of reliable data on water consumption and pricing at farm level (Wang and Lall, 2006). From the above water value concepts, it is clear that assigning an accurate economic value to a unit of water requires informed choices of measurement techniques as the different estimated unit values of water can potentially affect allocations, equity and efficient utilisation of resources.

2.6.2 Empirical approaches of valuing agricultural water

Economists categorise the value of natural resources like forests and water into two main groups, i.e. use values and non-use values. According to Lange and Hassan (2006), use values refer to the use of the resources to support human life and economic activity, while non-use value refers to uses that aim to sustain the ecosystem and recreational purposes. In economic theory, the value of water as a productive input can be treated as an ‘economic rent’, used as an input factor similar to land (Berbel et al., 2011). The complexity of water valuation emanates from lack of data, cost of data collection, relative absence of markets for water rights and the fact that water values are site specific (Lange and Hassan, 2006).

Several water valuation techniques are available depending on the specific use of the water and the purpose for which the information is required. Al-Karablieh et al. (2012) noted three groups of water valuation methods, namely (1) methods that infer water value from information based on water-related markets and benefits where value is derived from rentals and sales of water rights; (2) methods that estimate water values from direct consumer demand; and (3) methods relying on the use of derived demand for water as an intermediate good, where water is assessed from the producers’ point of view as in the case of agricultural and industrial use.

Some of the methods that are widely applied in water valuation, where water markets are non-existent or dysfunctional, include the production function method, RVM, change in net income approach (CNI), conjoint analysis, cost-based approaches, optimisation methods using mathematical programming, and the value-added method derived from computable general equilibrium (CGE) (Young, 2005).

The economic valuation of water can also adopt environmental approaches like hedonic pricing and contingent valuation method (CVM). However, most of these techniques try to derive a financial value to a commodity whose market is not perfect. For instance, hedonic price analysis relates to property prices to water-related attributes in order to estimate a shadow price for those attributes. Hedonic methods for valuing irrigation water is rarely found in the agricultural economics literature; for example, Berbel et al. (2009) used quasi-hedonic prices to estimate the value of irrigation water in Guadalquivir Basin in Spain. The technique often fails to adequately value community resources whose value goes beyond the financial price, but also encompasses non-financial or social values of the resources.

Stated or revealed preferences have also been used to value water resources. The revealed preference methods are based on analysing user behaviour in surrogate markets. For example, willingness to pay for improving drinking water quality or irrigation water supply can be inferred by the money households spend on bottled water or household treatment to purify water (González-Gómez et al., 2012). On the other hand, stated preference methods estimate willingness to pay by asking the users of the water service directly, based on choice experiment methods or bidding game techniques of services associated with different prices so that survey respondents can chose the option they prefer. However, the most frequently used technique to analyse willingness to pay for water services is the Contingent Valuation Method (Young, 2005; González-Gómez et al., 2012). In this approach, the survey respondents state the maximum amount of money they would be willing to pay an irrigation water service on the basis of a hypothetical situation for decision making. It is important to note that each technique has its challenges. Besides, reliability of data for most contingent valuation techniques is questionable. Furthermore, the technique gives estimated financial values and may not reflect the variation in water distribution and utilisation by individual irrigators.

Most experimental research in agriculture estimates water values from crop-water production functions, where demand functions are constructed using an output price with variations in the cost of water (Scheierling et al., 2004; Young, 2005). Similarly, mathematical and linear programming (LP) approaches are widely applied to value irrigation water. These involve the use of demand functions for irrigation water and its price elasticity for valuation of irrigation water. A model of a representative farm usually is specified to maximize returns subject to constraints to some production resources (Berbel et al., 2011), and the results are often used to analyse the decisions made about irrigation problems. As mentioned above, LP has been frequently used for the valuation of water and, generally, mathematical models are based on the single criterion of ‘maximizing profits’; but the quality of the model may be improved by maximizing a utility function representing the farmer’s preferences. However, optimisation techniques have been criticised for over-estimating water values (Young, 2005; Al-Karablieh et al., 2012), while CGE specification requires aggregation which may not be sufficient for local conditions (Al-Karablieh et al., 2012).

The Residual Value Method , also called the Residual Imputation Method, is a technique applied to value water used as an intermediate input in production (Hanemann, 2006). Valuation of water in production is based on the idea that a profit-maximizing firm will use water up to the point where the marginal revenue gained from one additional unit of water is just equal to the marginal cost of obtaining the water (Hanemann, 2006). However, recent studies that have employed the RVM are limited; for example, Bate and Dubourg (1997) and Moran and Dann (2008), whose studies estimated the residual value of water used for irrigation in East Anglia and Scotland, respectively. Where data about actual water use are unavailable, the residual value can be calculated based on the amount of water needed to cultivate a hectare of a given crop (Lange and Hassan, 2006). As such, Lange and Hassan (2006) used this technique in the Orange River basin (Namibia), while Moran and Dann (2008) applied the residual technique on secondary data to derive economic values for water on a sector basis. Speelman et al. (2011) assessed irrigation water values at small-scale irrigation schemes in South Africa.

Differences between the methods are wide as the production function allows obtaining the marginal value of water for individual crops, mathematical programming estimates the marginal value of a crop mix that maximized a farmer’s objective, and RVM gives an average value of the water. The total value of output is allocated against each of the resources (inputs) used in the production process, including water as the ‘residual’ input. In RVM the results are an estimation of average values, because the total value is divided by the quantity of water used. Due to lack of primary data for specific locations, all the studies that have been reviewed, e.g., Hassan and Mungatana (2006), Berbel et al. (2009), Yokwe (2009), Speelman et al. (2011) and Berbel et al. (2011) used secondary data to estimate average water values. Since smallholder farmers in South Africa are not paying for irrigation water, concerns are more on distributional and equity challenges at scheme level, and not the price of water. As such, the RVM was adopted to estimate average water values and explaining the variation of water values among irrigation farmers. In this study, primary data were collected for an entire cropping season and were used together with secondary data to estimate average water values.

2.7 Summary

Failure of water management institutions are blamed for the poor performance of smallholder irrigation schemes in South Africa. Institutions are defined as humanly devised constraints and rules that govern and limit human behaviour and interactions, which include rules, organisational forms, and norms of behaviour as well as enforcement mechanisms. The study of institutions is embedded in the neo-classical and New Institutional Economics theories. The literature has revealed that governance systems directly or indirectly impact on collective action, water-use security or the level of water distribution and utilisation. Collective action has been found to be difficult to organise where poor institutional arrangements exist, including lack of defined property rights, large differences in water supply between upstream and downstream farmers, and poorly coordinated formal and informal institutions. The water governance literature is also dominated by national level studies and less on site-specific information on the implications of various governance and institutional arrangements on irrigation water management; hence, the analysis in the following four chapters

CHAPTER 3

IMPLICATIONS OF WATER GOVERNANCE SYSTEMS ON IRRIGATION WATER MANAGEMENT[1]

3.1 Introduction

The objective of this chapter is to provide a broad understanding of the implications of the governance and institutional arrangements on irrigation water management systems at smallholder level. The Institutional Analysis and Development (IAD) framework and Ostrom's eight design principles were applied to characterise the governance systems, resource systems, resource users, resource unit and evaluate their implications on smallholder irrigation management systems. The chapter is organised as follows: Sections 3.2 presents the research methodology, where-in the conceptual and analytical frameworks are discussed. This is followed by the results and discussion in sections 3.3 to 3.7. A summary of the results is presented in section 3.8.

3.2 Methodology

3.2.1 Conceptual and analytical framework

To enhance understanding of the governance systems in water management, the study applied the Institutional Analysis and Development approach. The IAD framework, developed by Ostrom (1990), has been widely applied, for example, by Kirsten et al. (2009) and Sserunkuuma et al. (2009) to analyse the management of Common Pool Resources (CPRs). The IAD framework presented in Figure 3.1 enables the organisation and analysis of variables that affect patterns of interactions and outcomes observed in an irrigation scheme.

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[1] This chapter gave rise to the following manuscript: Muchara B, Ortmann GF, Wale E and Mudhara M. Water governance and institutional arrangements in Mooi River Irrigation Scheme, KwaZulu-Natal, South Africa: implications for smallholder irrigation water management. (Under review: *Water Policy*)

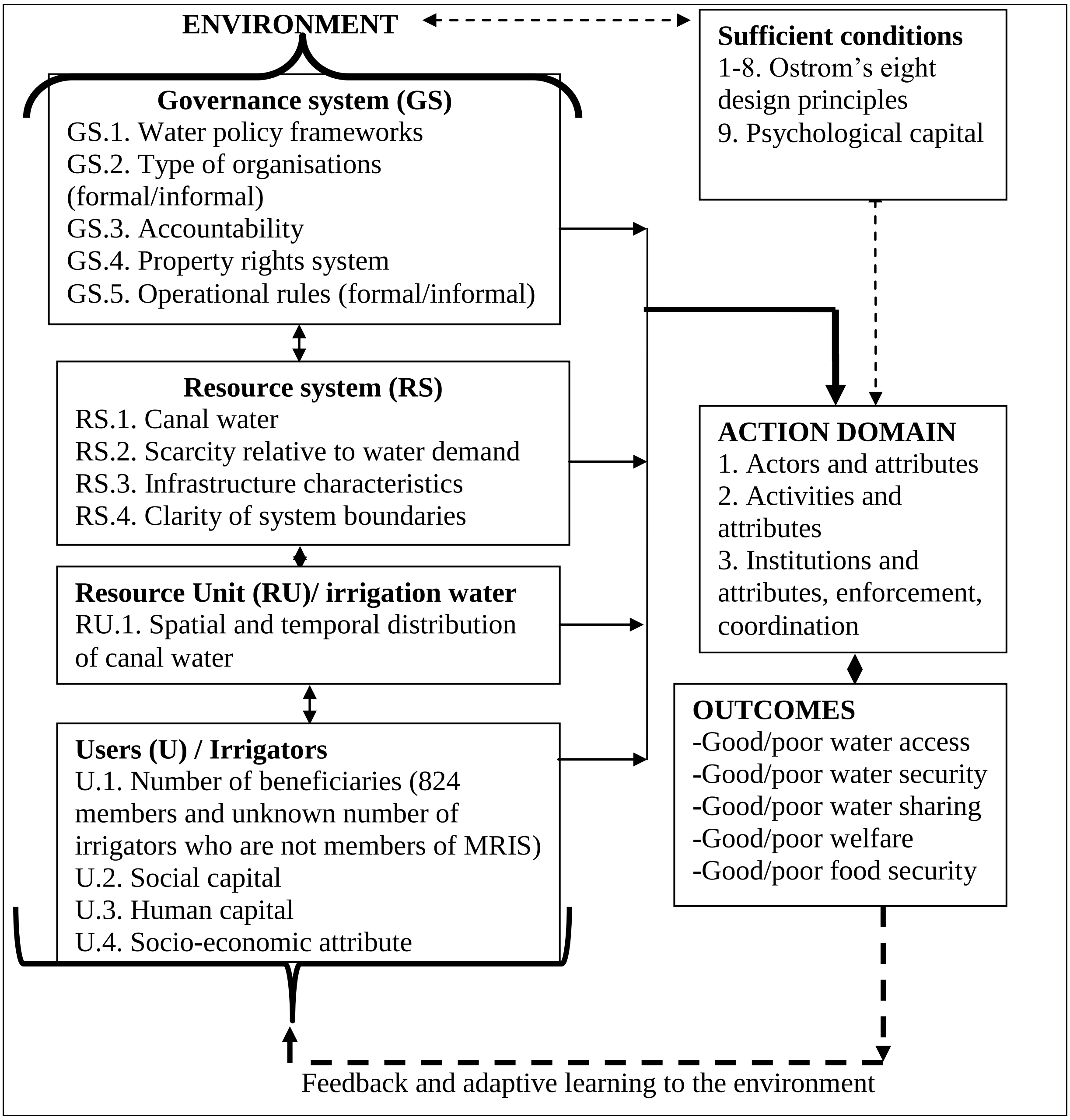

Figure 3.1. IAD framework showing institutional linkages in canal water management

Source: Adapted from Ostrom (1990) and Sarker (2013)

Ostrom (1990) argued that the environment, which includes the governance system, resource system, resource unit and the resource users, can only have positive impacts if sufficient conditions exist in the management of CPRs (Figure 3.1). As such, Ostrom (1990) developed eight design principles that create sufficient conditions for effective management of CPRs: (1) the existence of clearly-defined boundaries, (2) clarity on proportional sharing of costs and benefits, (3) mechanisms facilitating collective-choice autonomy to serve as necessary conditions to deal with appropriation and provision problems, (4) congruence between resource appropriation and provision rules, (5) graduated sanctions, (6) establishment of dispute-resolution mechanisms, (7) recognition of user rights to self-organize, and (8) the need for appropriate coordination among relevant groups. The core design principles have a wider range of application and are relevant when people must cooperate to achieve shared goals (Wilson et al., 2013). In the case of canal irrigation management, absence of principles 1, 2 and 3 lead to collapse of CPRs due to poor maintenance, while lack of sanctions and monitoring mechanisms may lead to free riding and unfair distribution of canal irrigation water.

However, limitations of both the IAD framework and the design principles should be noted. For instance, Wilson et al. (2013) highlighted the lack of emphasis on social variables and its failure to incorporate the impact of global problems, such as climate change, water scarcity and food insecurity. The eight design principles are also criticised for not accounting for other conditions and constraints, like market integration, globalisation and rapid economic development (Wilson et al., 2013). Furthermore, both the IAD and the eight design principles do not recognise the importance of psychological capital, which was defined broadly by Luthans et al. (2007) as the motivation of individuals through self-efficacy, optimism, hope and resilience. Psychological capital is considered critical in influencing the outcomes of CPR management, including irrigation water. Rather than focusing on any one individual facet in particular, it is expected that the combined motivational effects are broader and more impactful than any one of the constructs individually (Luthans et al., 2007). It can, therefore, be argued that positive psychological capital greatly influences human behaviour of each user and their interactions in the management of CPRs, hence its inclusion as the ninth sufficient condition in the framework.

3.2.2 Description of the study site

The study was conducted in the MRIS located in the Msinga Local Municipality, which falls under the Umzinyathi District Municipality of KwaZulu-Natal Province, South Africa (Figure 3.2).

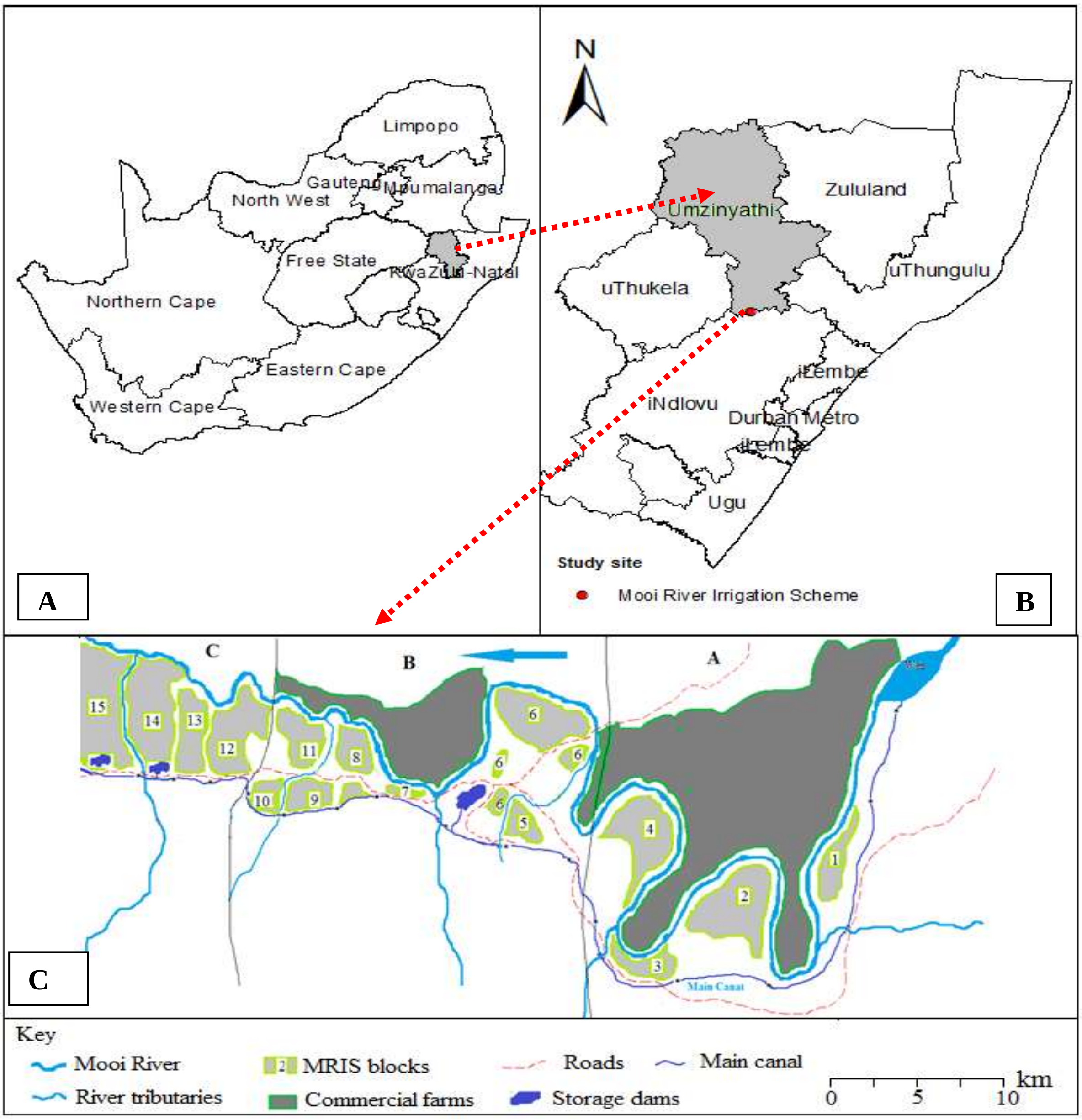

Figure 3.2. Location and sketch of study site in KwaZulu-Natal province, South Africa
Notes: A: South Africa’s provinces; **B:** Umzinyathi District municipality in KwaZulu-Natal province; **C:** Sketch of Mooi River Irrigation Scheme
Source: Adapted from Environmental Planning and Development Consultants (2007).

Msinga is a local municipality established in December 2000 (Msinga Municipality, 2009) as one of the four local municipalities constituting the Mzinyathi District Municipality in the northern part of the province of KwaZulu-Natal (Figure 3.2). According to the 2009/2010 integrated development plan, Msinga municipality is largely rural, with 69% under Traditional Authority, where land is held in trust by the Ingonyama Trust while the remaining 31% of land is commercial farm land, all of which is located to the north of Pomeroy (Msinga Municipality, 2009). It is estimated that 99% of the population in Msinga lives in traditional authority areas (Msinga Municipality, 2009). Small towns of Tugela Ferry, Keates Drift and Pomeroy are the main service centres in the area. The scheme is accessible via the R33 road, linking it with Dundee, Ladysmith, Pietermaritzburg, Kranskop and Weenen. The scheme is situated between Tugela Ferry and Greytown and approximately 124kms from Pietermaritzburg along the R33 road. The MRIS falls within a vegetation type known as Thukela Valley Bushveld (Letty, 2007). Rainfall varies throughout the district from more than 800 mm in Endumeni and Umvoti, to less than 400 mm in parts of Msinga and mean annual temperatures are high (17.1^{o}C - 22.2^{o}C), and vegetable production is only possible as a result of the availability of irrigation (Mkhabela, 2005; Letty, 2007; Msinga Municipality, 2009).

The MRIS was established by the South African government in the early 1900s and is communally owned. The main idea of establishing the scheme was to improve food security by ensuring that smallholders have the means to produce their own food in the relatively dry areas of KwaZulu-Natal (Msinga Municipality, 2009). It consists of fifteen blocks that run along the Mooi River. Across the Mooi River are larger commercial farms whose water source is the same river. A total of 824 farmers participate in the scheme, which has a total of 601 hectares. Farmers at the MRIS produce a wide range of crops under furrow irrigation, with cabbages, potatoes, tomatoes, onions and maize being the main crops. Crop production as well as marketing of produce is done individually, with minimal collective action efforts in certain activities like weeding and harvesting.

Infrastructural development was wholly funded by the South African government, through the Department of Agriculture, Forestry and Fisheries, and thereafter the government also performed some maintenance work on the infrastructure. Irrigation water is diverted from the Mooi River along a concrete-lined canal to supply downstream crop fields through gravity. The canal either feeds directly into the fields or into overnight storage dams. Farmers access water via distribution canals on specific days agreed upon by the scheme participants and block committees.

Water is diverted from a weir constructed across the Mooi River and flows by gravity along the main canal, which is about 20.8km in length. The concrete-lined canal has a top width of 2 metres and a depth of 1 metre, which is designed to convey approximately 0.36 $m^3.s^{-1}$ (Gomo et al., 2014b). The canal gradually reduces in size and capacity from the head section

(Block 1) to the tail-end section (Block 15). The main canal also feeds water into four overnight storage dams or directly to the field through infield canals. Once water is released from either the main canal or the dams, it is channelled along the smaller infield canals to the crops. Although some infield canals are concrete-lined, more than 90% are either earth built or need complete revamping due to extensive collapse and breakages.

Water allocation within the scheme is done according to a weekly roster, which is controlled by the canal attendants commonly known as canal rangers or "*phoyisa*" for police in the local Zulu language. The block committee members also assist canal attendants to enforce the implementation of the roster. The canal attendants are government employees, under the KwaZulu-Natal Department of Agriculture and Environmental Affairs (DAEA), and are responsible for opening and closing water from the main canal to the fields and storage dams. They are also responsible for monitoring unauthorised water abstractions by community and scheme members.

Selection of MRIS as a study site was informed by the size of the scheme in terms of number of participants (824 irrigators) and the land size (601ha), which could provide sufficient heterogeneity from the respondents. Furthermore, the scheme was viewed a potential site that can give a reflection of governance systems in government supported schemes, having existed pre- and post-independence in 1994. The scheme also resembles multiple governance systems, characterised by both formal and informal management structures, which had to be explored and contribute towards the performance of the smallholder irrigation sector in South Africa. The study was part of broader Water Research Commission project on smallholder values, hence the some selection criteria to meet the requirements of the sponsor was also considered, including: (1) existence of active farming in the area, (2) participation in value chains by the smallholder farmers, and (3) willingness of the farmers to voluntarily participate in research activities.

3.2.3 Sampling, data collection and analysis

In order to understand the water governance systems in the scheme, three focus group discussions were conducted across the scheme, comprising of 7, 8 and 11 irrigators, drawn from the head, middle and tail-end section of the scheme, respectively. Furthermore, a household questionnaire was administered to 71 individual farmers, randomly sampled from the three strata of the scheme, bringing the total number of respondents to 97. The IAD framework and Ostrom’s eight design principles were applied to assess the impact of various IAs on smallholder irrigation water management and access. The ninth principle on psychological capital was also assessed to establish its relevance in irrigation water management. The governance systems were grouped into themes based on the IAD framework. Qualitative synthesis and deductive evaluation of institutional performance was done to draw conclusions. Quantitative analysis of the data involved the use of descriptive statistics such as ranking, means and frequency counts to augment the qualitative analysis.

3.2.4 Contextualising water access and management system in MRIS

Smallholder farmers in MRIS face challenges of water shortage emanating from low rainfall and seasonal fluctuations of water levels in the Mooi River. The Craigie-Burn Dam, which is located at the upper part of the Mooi River and controlled by the Mvoti Catchment Management Agency (CMA) to boost water supply to downstream users, could only be accessed by registered WUAs. The WUA in MRIS was at the inception phase and not yet recognised by water management authorities as an officially registered group.

On the other hand, commercial farmers sharing the same weir with smallholder farmers were recognised as registered water-users based on their membership of the old water governing boards, currently being transformed into WUAs. As such, this group of users made official requests for the opening and closing of the feeder dam. Although smallholder farmers also benefited from the same water by virtue of sharing the same river with commercial farmers, challenges of enforcing exclusivity rights against non-registered water users complicated the approximation of quantity demanded. There have been disputes between commercial farmers and smallholders, with the former being accused by the latter of having an unfair advantage over the water resource. This was worsened by the fact that some commercial farmers use overhead irrigation systems and pump water directly from the main canal and river, upstream from the diversion point. As such, smallholders complain that commercial farmers pump too much water from the source and little water was left to flow into the MRIS supply canal.

3.3 The results and discussion

3.3.1 Application of the IAD framework to assess irrigation water management structures in MRIS

The need for communities to organise water provision, i.e. involvement in the design, construction and maintenance of infrastructure, are crucial elements that positively contribute towards irrigation water management. The characterisation of the institutional arrangements (IAs) influencing water management in MRIS was done using the IAD framework (Figure 3.1). The following sections, therefore, scrutinize the institutional arrangements by focusing on the influence of governance systems, resource systems, resource units and resource users on the water management outcomes (water access).

3.3.1.1 Irrigation organisation and water governance systems in MRIS

Water policy frameworks in South Africa (GS.1)

An important issue is how the water legislative policy in South Africa is linked to the current governance systems in irrigation schemes and how the whole system impacts provision of water to smallholder irrigation farmers. Shah (2005) defined various government agencies, international agencies, government's water policy, and water-related laws that directly or indirectly deal with water as the institutional environment (IE). The IE, closely linked to IA, was defined by Shah (2005) as humanly devised rules that govern the behaviour of water-users. Understanding the linkages between water policies and users is important because lack of user cooperation, especially due to a knowledge gap about statutory instruments between users and regulatory bodies, can hamper public allocation of resources.

With respect to the case study, 16 years after the adoption of the NWA of 1998 not all water management structures are in place. This agrees with Backeberg (2005) who noted in his theoretical analysis of the South African NWA of 1998 that the reform process may take 10–20 years for the design of appropriate institutions and implementation of the water policy. Due to non-compliance of the MRIS to the legal requirement to be registered as a water using entity with the Department of Water Affairs (DWA), the Minister of Water Affairs in South Africa, through the NWA of 1998, has the power to reallocate all or portion of the water at the Mooi River weir to other registered users, without consultation with the MRIS farmers, consequently exerting pressure on production activities in the scheme. For instance, starting 2012, water from the Mooi River weir was made available to supply domestic water to Gudwini community, about 30km from the scheme. Although domestic allocation takes precedence over all other water uses (RSA, 1998), recognition of the scheme as a water user could have influenced the quantity of water to be reallocated or even the point of abstraction could have been constructed after the weir to avoid interference with water supply for irrigation purposes. Legal recognition of the scheme is, therefore, critical to improve water security and access at local levels.

Types of organisations (GS.2)

The MRIS scheme is governed by both formal and informal management systems, which are embedded within each other. However, the problems associated with irrigation water access in most government-funded schemes in South Africa, including MRIS, arise from poor management of infrastructure, inadequate enforcement of regulations and subsidised prices. These challenges result in poor irrigation performance (Perret and Geyser, 2007). Furthermore, lack of proper business plans as per legislative requirement during formation of WUAs, poorly articulated transfer of ownership, and poor capacity building for collective management of the schemes can all be attributed to the low success rate of MRIS.

Although the informal arrangements that include the traditional norms and values, belief systems and kinship are important, they are not directly involved in securing water rights by the irrigators, especially where government agencies (Catchment Management Agencies (CMA), WUAs) and water policies are involved. The finding is critical for smallholders, including those at MRIS, where farmers misunderstand the SA water policy and perceive formation of formal structures like WUAs as a way by the government to introduce water levies on smallholder farmers, despite the anticipated benefits of securing water rights for the users. Change of mind-set and building on positive psychological capital through irrigation training and capacity building is therefore important among smallholder irrigation water users.

The registration of MRIS farmers as members of the WUA comes with its own institutional and management challenges. Firstly, there were individual farmers of the scheme who were not prepared to be part of the association but still expected to have access to the same amount of irrigation water as the members. In the case of MRIS, some farmers located at the upper section, who were perceived to be accessing more water than their counterparts located at the tail-end section, were less willing to be part of the WUA and were interested in preserving the *status quo* while the tail-end farmers, who were facing more water supply challenges, were willing to take part in the change process. The finding supported those by Bandarogoda (2005) and Madani and Dinar (2013) who concluded that head and tail-end farmers have opposing motivations when it comes to cooperating with regulatory authorities. The current design of MRIS infrastructure with no lockable off-take gates and the institutional set-up does not offer exclusive water rights to members of the WUA. As long as water is available in the canal, anyone can access the resource; hence members of the WUA do not receive any additional benefits over non-members.

Furthermore, MRIS farmers do not pay for water and their inclusion as members of the WUA means they have equal access rights with commercial farmers in the area, who pay for irrigation water. Thirdly, the nature of irrigation infrastructure used by MRIS makes it difficult to measure actual volumes of water used by individual farmers unlike the sprinkler systems used by some commercial farmers in the same area. Whilst furrow irrigation is cheaper to maintain and much easier to operate (Crosby et al., 2000), water budgeting and equitable allocation remains a challenge due to lack of measuring devices (flow meters) and uncoordinated cropping patterns among smallholder farmers in the scheme. This was worsened by non-adherence to the scheme irrigation roster and widespread unsanctioned diversions of water from the canal, which negatively affected consistency of supply and consequently crop production.

Furthermore, anticipated benefit underlying IMT through formation of WUAs includes high pay-offs if successful (Shah, 2005). Success is measured in terms of revenue collection, cost recovery mechanisms, equity and improved coordination of water users, which were not being met due to a number of factors including non-cooperation among users and resource constraints. For instance, Shah (2005) noted that IMT tended to be smooth and relatively effortless where the irrigation system is high-performing and average farm size is large enough for command area farmers to operate as agri-businesses. The scheme under study resembles a complex system, where farmers in the command area have small land holdings (0.275ha) with less productivity, making it a challenge to bring them together to negotiate. Although smallholder farmers in MRIS qualify to access government financial assistance for resource poor irrigation farmers through the WUA (DWAF, 2004b), this facility was not being utilised since the WUA was not fully operational. Furthermore, the long-term sustainability of the WUA might need to be considered, given the scepticism of smallholder farmers over the ability of the WUA, as a potential state organ, to collect irrigation maintenance fees and water levies from farmers.

Accountability system (GS.3)

Accountability systems (GS.2) are critical for effective collective management of irrigation schemes. The inclusion and subsequent participation of resource users in the monitoring and enforcement of operational rules through rotational management can be adopted as a possible strategy to improve scheme management. Through rotational management, irrigators can be subdivided into smaller groups to monitor behaviour of other users from a given canal section and reporting opportunistic user behaviour to the local irrigation management committee for sanctioning. By so doing, every member becomes accountable and irrigation water management might improve.

The informal governance procedure in MRIS stipulated that irrigation committees should be elected every five years and the local government authorities are not allowed to interfere with the selection process. The rules were not written and enforcement was weak, hence some committee members served on the committees for more than ten years without being re-elected. Some committee members felt that being members did not add any value to their daily irrigation activities and rather cost them time through attending committee meetings; hence there were no incentives to encourage them to participate. On the other hand, irrigators were often reluctant to remove a sitting member of the committee even if he/she was ineffective. Resignation or deaths have been the systems through which committee members leave office. These challenges reveal a weak governance system in the scheme, where the consequence of members overstaying in committees manifest in the form of complacency and negligence of duty. There are no incentives to join the committees, hence some potential committee members were not willing to take up responsibilities and therefore bad governance persists in the scheme.

Property rights system (GS.4)

Clearly defined property rights (GS.3) of water and land can improve ownership and accountability (GS.2) among users (Ostrom, 1990). The case study revealed that no entity had a complete bundle of rights over all or some of the components of the resource system (RS) and units (U). Irrigators in MRIS have rights to use land and water, but the access is not privately secured, hence land could be reallocated to other users by traditional authorities if it was deemed to be underutilised. Furthermore, water-use security was not guaranteed in MRIS, and the "use it or lose it" principle applies to all canal water users. Lack of clarity of the water access rights system (GS.3) negatively impacts water management due to unreliability of supply and lack of commitment by some users to invest in CPR infrastructure maintenance. Farmers were hesitant to commit financial resources to upgrade their water infrastructure due to non-exclusivity of the costs and benefits, with a potential impact of lowering resource productivity. This was consistent with Perret and Geyser (2007), who noted that smallholders in South Africa view irrigation schemes as government property, and as such maintenance and upgrading of the canal was assumed to be government's responsibility. This shows that positive psychological capital among irrigators was weak and its enhancement through capacity building workshops and training can improve farmers' attitude towards collective infrastructure maintenance.

Operational rules (GS.5)

Clarity of operational rules (GS.4) determines the success or failure of CPR management where large numbers of beneficiaries are involved (Agrawal, 2001). Although irrigation committees serve as recognised and accepted institutions to address problems of provision and sharing of irrigation water, a number of players were involved in the formulation and enforcement of water use rules in MRIS. However, some agencies operating in MRIS, like irrigation committees, traditional leadership, canal attendants and ordinary members, follow unwritten rules defined by the community together with irrigation water users. Therefore, the enforcement of the rules and the effectiveness of the agencies in managing local water-use were compromised. In order to understand the effectiveness of water management agencies operating in the scheme, farmers were asked to score the perceived effectiveness of seven water management institutions. The scoring was based on a five point Likert scale (1 = not effective to 5 = excellent) on the perceived ability of each water management institution to enforce water abstraction and canal maintenance rules in the scheme. Table 3.1 reports the average scores of the ranking process.

Table 3.1. Farmer evaluation of effectiveness of water management structures in Mooi River Irrigation Scheme, 2013 (n= 71)

	Average Score	Ranking
Canal attendants/rangers	2.5	1
Irrigation committees	2.5	1
Department of Agriculture (Extension Officers)	2.4	3
Ordinary scheme members/Irrigators	2.4	3
Department of Water Affairs (Area representative)	2.1	5
Traditional leadership	2.0	6
Water User Association (WUA)	1.3	7

Source: Survey data, 2013

The results in Table 3.1 reflect the survey respondents' perceptions on the relative importance of canal attendants and irrigation committees in the management of irrigation water. The irrigators relied on canal attendants for daily allocation of water to the different blocks according to the roster, while irrigation committees were expected to enforce compliance to the roster. However, the results might also reflect a historical perspective, especially with regard to the responsibility of the canal attendants as rule enforcement agencies. There were only two out of five canal attendants operating in the scheme as the government did not replace them after retirement or death. However, their relevance in irrigation water management was perceived to be important, and the question was whether the government must completely let go of the canal attendants as part of the IMT approach or whether they should still be maintained. Farmers perceived the role of canal attendants in the management of water as more important than ordinary members as shown by higher scores; hence there might still be a need to maintain canal attendants as part of local water management structures. The fact that farmers rank the involvement of government departments and traditional leadership in water management lowly suggests a preference for a non-coercive approach in the management of canal water. The results indicate that there is room to strengthen irrigation water management by further empowering local structures and enhancing the role of WUAs and traditional authorities to manage water resources. Although, the results reflect general perceptions of farmers on the role of various stakeholders in water management, it is quite possible that some respondents were generally unaware of the roles of some structures, and their perceptions may be biased according to the frequency with which employees of the various structures interact with members of the MRIS.

3.3.1.2 Resource system and irrigation management in MRIS

Canal water (RS.1)

A resource system represents a stock of water and irrigable land that is available for everybody in the community (Sarker, 2013). Considering the case of canal water in MRIS, users indicated through focus group discussions that it was nearly impossible to exclude individuals from the resource system. This was mainly due to weak institutional by-laws regulating water access for non-participating members. The existing scenario was such that appropriators took advantage of any improvements on the system, even without making the required contributions. Furthermore, there was a strong linkage between land access and access to canal water in MRIS.

Scarcity relative to water demand (RS.2)

The users resolve provision problems by investing in the resource system and by combining physical capital with social capital so that irrigation water is allocated fairly and efficiently by all irrigators. However, evidence from MRIS revealed that the number of irrigation beneficiaries within and outside the scheme increased over the years. This is due to population increase in the area, which led to increase in demand for irrigation land. Irrigators indicated that the capacity of the canal has never been upgraded to cope with the increasing demand of irrigation water. Furthermore, irrigators perceive the Mooi River to be discharging less water than before (i.e. more than a decade ago). There are several explanations, including climate change, increasing uses of water upstream and siltation. There is, therefore, a perceived increase in demand for irrigation water among irrigators in MRIS.

Infrastructure characteristics (RS.3)

MRIS has about 20.8 kilometres of the main irrigation canal, which feeds into four storage dams and numerous infield canals. The main canal is concrete lined, and maintenance is done by scheme members with some support from the provincial department of agriculture. The major challenge with the conveyance infrastructure is the state of collapse of the facility. Some off-takes have broken screw gates and others are rusty, making their operation a challenge. Where there are no metal screw gates, farmers use bags of sand to regulate or close water from the main conveyance. Sand bags were reported to be ineffective and result in water losses due to water leakages. Furthermore, the sand bags break and result in excessive silt deposits along the canal, which result in less volume of water flowing in the canal without spillage. Beside the use of sand bags there are instances when some farmers use stones or wooden logs to channel water to their infield canals from the main conveyance canal. These were reportedly causing the canal to break, resulting in excessive loss of water from the canal.

The challenge of water leakages was also common along infield canals, the bulk of which are either not lined or broken. Infield water leakages result in shortage of water to crops, but at the same time result in the development of water logged patches in areas where the leakages take place. There is, therefore, a need to improve water management in the MRIS by maintaining and installing new lockable off-take gates along the main canal. Effective concrete lining of both main canal and the infield canal may reduce water losses, with a potential to increase water availability among farmers and reducing the chances of water logged conditions in the fields.

Clarity of system boundaries (RS.4)

Access to irrigation water was partly influenced by owning an irrigable piece of land within the canal’s command area. However, there was no proper accountability and record keeping systems to account for actual size of land under irrigation in MRIS; hence the technical complexity of defining, with precision, the quantity of water available and demanded for crop production. This limited the capacity of local community and canal water users to manage water efficiently. The study also noted an increase in demand for irrigation land by community members, shown by pieces of irrigable land being developed outside the scheme.

The majority of the plots were allocated by traditional authorities, who did not have the technical expertise to take into account the water supply capacity of the canal. Land allocation for irrigation purposes was on a need basis, and the traditional authorities did not want to be found excluding some members of the community from accessing irrigation facilities. This comes at the back-drop of more than 30% of land lying fallow at any given time within the scheme, due to multiple factors, ranging from water constraint, inputs costs, old age of plot owners and lack of interest in farming. Although the traditional authorities had the power to reallocate idle irrigation land within the scheme to the landless community members, cases of reallocation are rare in MRIS due to close ties of families (kinship) and inheritance issues surrounding land ownership. Conflicting objectives of land access and utilisation exists between inheritance issues at household level meant to guarantee access to land by family members in the future and immediate productivity concerns. This was identified as a possible challenge impeding the productivity potential of smallholder schemes.

3.3.1.3 Resource unit in MRIS

The study considers irrigation water as the resource unit that requires community or user management. The challenge of managing irrigation water stems from its attributes, which include high mobility, highly subtractable and having an economic value born from the cost of infrastructure maintenance (Sarker, 2013). The MRIS draws water from the Mooi River at no direct cost, and it is diverted into a gravity fed canal that supplies the whole scheme. When the water enters the MRIS canal, it changes from a public good to a common pool resource (CPR). The case of MRIS is that due to high subtractability, when water is available in the canal, the motivation for users is to abstract it. Furthermore, water savings made by an individual and ‘left’ (stored) in the storage reservoir or canal may at a later stage, be used by another operator deemed to have a higher priority of use at that time. Lecler (2004) referred to this outcome as the ‘use it or lose it’ mind-set. This phenomenon is inherent in the common property resource (CPR) and consequently diminishes the farmers’ incentive to save water in MRIS. Apart from the potential for recurrent conflicts, the major problem affecting effective water conservation and demand management strategies on canal water, as in the MRIS, is lack of rule enforcement and compliance among water users. This might be because individual users have very limited or no control over water abstraction by other beneficiaries.

Focus group discussions (FGDs) with irrigation committee members developed an understanding of farmers' perceptions of reasons behind water management challenges in MRIS. Evaluation was based on what farmers perceived to be the major issues affecting the resource unit (U) in the scheme. Ranking of eight variables affecting water access and management in MRIS was done. The ranking allowed farmers to choose in order of priority and based on personal experiences the variables that greatly influenced water access and management in the scheme (score 1) and the variables with the least effect (scored 8) in chronological order. Results of the ranking process are presented in Table 3.2.

Table 3.2. Farmers' perceptions of challenges associated with water management in Mooi River Irrigation Scheme, 2013 (n=26)

Variable	**Block1-5 (Head) (n =7)**	**Block 6-10 (Middle) (n = 8)**	**Block11-15 (Tail-end) n = 11)**
Water supplied not adequate	4	5	3
Conveyance structure leakages	**1**	**1**	5
Unsanctioned water access by non-scheme members	5	6	4
Unsanctioned water access by scheme members	7	4	**1**
Absence of regulatory policies	6	3	6
Weak regulatory framework	8	**2**	**2**
Increase in water users	**2**	8	7
Increase in area under irrigation	3	6	8

Source: Survey data, 2013

Results in Table 3.2 indicate that head-end farmers perceived technical challenges, including leakages along conveyance structures, as greatly affecting availability of the resource unit in MRIS. Irrigators cited cracked canals and debris along the canal as the major causes of leakages. In contrast, tail-end farmers (Blocks 11-15) indicated that water being supplied along the canal was not enough to meet their irrigation requirements, although previous research indicated that the design capacity of the canal for MRIS was adequate to meet the water demand (Gomo et al., 2014b). The high ranking of unsanctioned water access by scheme and non-members points to poor water management systems resulting in unequal water distribution. The sentiments were also echoed by the farmers, who believe that the existing irrigation programme was not adhered to and weak regulatory mechanisms negatively affect water supply in the tail-end blocks and water management in the scheme.

With respect to temporal distribution of water, the procedures regarding water access in MRIS were organised by irrigation committees, with the help of government-paid canal attendants. As such, the study identified two different settings for the process of withdrawing water from the canal at any given time, including:

i. unlimited or uncontrolled withdrawal of water in situations where water supply was abundant in the whole canal system, and
ii. if there was a water supply constraint, the order of withdrawal was unknown to the farmers. In addition, the amount of water for a single farmer was not restricted but was based on mutual understanding among farmers sharing the same distribution canal.

The first scenario was usually applied in the rain season or after heavy rains and irrigation of crops was not considered critical. The second scenario was the one that occurred most often in MRIS, and there was a general agreement not to withdraw water outside the farmer's irrigation roster. Although the appropriation rules were attached to the provision rules and the local conditions, the study found that under either regime, all appropriators act according to their rational self-interest and attempt to maximise their own utility from the resource with no consideration for the impacts on other users and the community. When water level was low in both the Mooi River and the supply canal, demand for irrigation water in the scheme exceeded supply, posing a challenge on the sharing of the limited supplies of water. Rule violation among scheme members became dominant, especially as farmers access water outside their roster, with no appropriate sanctions enforced. This practice violated design principles 4 and 5. Irrigation management in MRIS was, therefore, found to be under-performing due to poor enforcement of institutional design principles.

3.3.1.4 Resource users and the decision making process in irrigation water management

The effectiveness of water governance structures could be assessed on how diversity of interests is considered during the decision-making process. In this context, Wilson et al. (2013) emphasize two elements in the process of balancing interests: getting everybody truly represented in the decision-making process and facilitating the negotiation process by the timely distribution of credible, easy-to-access and understandable information, and by ensuring that all stakeholders' problems and interests were catered for. It is important to note that user-based allocation of water is undertaken through collective management of water sources. However, low level of cooperation hamper infrastructure maintenance in MRIS, resulting in poor allocation of water among users. Failure to identify and develop positive psychological capital among farmers was one of the factors leading to poor cooperation among farmers.

The transaction cost of managing a large group size was the other institutional factor negatively affecting participation in collective activities at MRIS. Moreover, lack of clearly defined water distribution rules and mechanisms and non-compliance to appropriation rules by irrigators was resulting in low water allocation efficiency and poor performance of the irrigation scheme.

3.4 Applying institutional design principles on irrigation management in MRIS

According to Sarker (2013), design principles 1, 2, 3 and 7 (see section 3.2.1) serve to deal with appropriation and provision problems while principles 4, 5, 6, and 8 serve as sufficient conditions for fair allocation of the resource. As such, some principles are discussed together (for example, 3 and 7 for collective action arrangements and the need to self-organise, respectively, as well as principles 5 and 6 for graduated sanctions and the need to establish dispute-resolution mechanisms, respectively). In addition, positive psychological capital was also discussed as an additional sufficient condition for the management of CPRs.

3.4.1 Clearly defined boundaries

Boundaries of a CPR are defined with respect to users and the resource systems (Wilson et al., 2013). This means individuals or households with rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself. The 601 ha scheme at MRIS was being serviced by one main canal that supplied irrigation water to the scheme. Farmers owned multiple plots, depending on family size and leasing arrangements, and the farmland was fragmented into 0.1 ha plots to accommodate more beneficiaries in the scheme. Boundaries were, therefore, defined in terms of three aspects; that is, land ownership within the scheme, irrigation water access from the canal, and whether an individual qualifies to use the canal water by virtue of being a community member or allocated a plot in the scheme (irrigators).

Although the system had clearly defined boundaries in terms of space or area to be irrigated, enforcement and maintenance of the boundaries posed a serious threat to the management of water in the scheme. Irrigation land was continuously being accessed outside the scheme boundaries, through traditional and self-allocation by community members. This was done without due consideration of the capacity of the canal. Use of portable pumps that draw water directly from the canal or the extension of distributional canals was also being done by the irrigators to supply water to additional plots located outside the scheme boundaries. These activities compromised water access by other members, thereby negatively affecting their productivity. Weak enforcement of land boundaries in MRIS to counteract its negative impact on water resources management was a big challenge, which might turn the canal from being a CPR to an open access resource if not regulated. This could be averted by either excluding irrigators outside the scheme boundaries from accessing canal water or by upgrading the capacity of the canal to meet the increasing demand. In the immediate future, the focus has to be on enforcing resource withdrawal rules to ensure excludability at local level.

Furthermore, there was no clear demarcation between authorised and un-authorised users of canal water in MRIS. As such, canal water was used for unintended uses like livestock watering and non-agricultural purposes like house construction and brick making by community members. Despite the fact that canal water was exclusively meant for crop production purposes, no exclusivity rules exist to all other uses. This has a bearing on the day-to-day management of water resources, through potential non-cooperation by some user groups in violation of design principle 3. For instance, livestock farmers and brick makers utilising the canal water were not represented in the WUA that was formed, despite the impact they might have on irrigation water access. However, it can be highlighted that due to the diversified nature of rural livelihoods, some irrigators also owned livestock and also benefited from non-agricultural activities like brick making and laundry, thereby posing a challenge to enforce exclusive rights to canal water for irrigators. Recognising the multiple uses of canal water was paramount and further incorporating such users in the local water management structures might improve the management of canal water. Furthermore, if other users were to be accommodated, the canal capacity required a capacity upgrade or livestock farmers and brick makers have to get access to other water sources. Such alternative arrangements have to be collectively negotiated so that efforts to enhance the wellbeing of irrigators do not happen at the expense of others.

3.4.2 Clarity on proportional sharing of benefits and costs

Proportional sharing of benefits and costs form a major pillar for an effective incentive system in CPR management. The challenge in MRIS was the large number of beneficiaries, and where rule enforcement mechanisms are weak and fairness or equity are not guaranteed, the incentive was for users to free-ride. Quantity of water allocated to either paying or non-paying members was not guaranteed at MRIS. The same applies to the contribution of members towards infrastructure maintenance, i.e. labour contribution, financial contribution, decision making and policing roles. As such, improving the clarity of benefits and costs as well as realigning the IAs was necessary to improve resource sharing.

3.4.3 Collective arrangements, monitoring and self-organisation (principles 3 and 7).

The case of canal water access in MRIS was such that entry was easy and exclusion was difficult or not attempted due to kinship and lack of clarity of appropriation rules. Principle 1 and 6 were essential to ensure effective application of principle 3 in MRIS. Maintenance of irrigation infrastructure also requires full implementation of design principle 3 for facilitating collective choice actions among canal water users. However, farmers expressed their concerns pertaining to the scale and multiple users of the canal water, whose numbers were too large to be effectively managed by the elected committee members. Previously, there were many canal attendants to ensure effective monitoring of the canal. However, these were no longer being employed or replaced after retirement or death as the government slowly implement IMT policies. The farmers argued that this stance was causing water sharing problems in the scheme, and their assertion was supported by the collective action theory, which indicates that smaller CPR groups were easier to manage than larger groups (Agrawal, 2001; Gadzikwa, 2008). Learning from other experiences in Africa, the disappearance of canal guards and replacement by water user associations in the Gezira scheme in Sudan led to a chaotic situation in water distribution after transfer (Van der Zaag and Rap, 2012). This study, therefore, identified the need for great caution in fully transferring smallholder schemes without considering the long term implications on the management of the schemes.

MRIS has a large number of participants, and the case exposes a situation where a common-pool resource is highly subtractable and unequal allocation of water led to shortages due to management problems. In contrast, Ostrom (1991) noted that if irrigators or CPR users are strongly involved in the decisions and the establishment of rules, they must have the capacity to modify operational rules to suit the group size at minimal cost. In MRIS, farmers compete for water and by so doing compromise the potential benefits of collective sharing of the resource. The right of appropriators to devise their own institutions (design principle 7) was therefore lacking. In MRIS there were no governmental rules governing the irrigation process, except with respect to access of support services like extension services and tractors. The irrigators were completely responsible for the collective management of the system. However, rule violation negatively impacted the management process, with little consequence to the perpetrators.

3.4.4 Congruence between resource appropriation and provision rules

According to design principle 8, appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities around irrigation water in MRIS were organised in multiple layers of nested enterprises (that encompass individuals as well as organisations) at local, regional and national level. At the local level there were the irrigators and the irrigation committees, with the CMA operating at a regional level. The national level was another layer, but with little importance because decisions made at this level were not directly impacting the direct day-to-day running of irrigation activities. Only the local and regional layers respond through compliance and enforcement of the policies.

Although the appropriation rules were attached to the provision rules and the local conditions, the study found that under either regime all appropriators act according to their rational self-interest and attempt to maximise their own utility from the resource with no consideration for the impacts on other users and the community. Low water levels in the Mooi River or the MRIS canal constrained the supply; hence demand for irrigation water in the scheme increased. This posed a challenge on the sharing of the limited supplies of water. The violation of water sharing rules among scheme members became dominant, characterised by farmers accessing water outside their roster, with no appropriate sanctions enforced. The failure to enforce sanctions on those that do not follow water sharing rules and violated design principles 4 and 5, could be an indicator of under-performance among committee members and weak institutional structures in the MRIS.

3.4.5 Graduated sanctions and establishment of conflict-resolution mechanisms

Appropriators of canal water in MRIS had access to low-cost local arenas to resolve conflicts among themselves. These include irrigation committees and the traditional leadership structures that preside over the village courts. However, despite access to these arbitration mechanisms, rule breaking was common and it was causing irrigation management challenges in MRIS, where offenders were not even recorded. A penalty of R200 is payable to the village headman if a water user flouts water access rules including irrigating outside the roster (stealing water), wasting water and not participating in canal maintenance activities. The fine was not payable to the irrigation committees, hence the money was put to personal use and not used to upgrade or repair irrigation infrastructure. In some instances, committee members were charged the same fee if irrigators in their respective areas flouted irrigation rules. While the rationale was to instil commitment to monitor water-use among committee members, one chairperson of the committee who paid the fine to the headman indicated dissatisfaction with the penalty system. The offense was committed by one of the irrigators in her area when she was away, but she was still made to pay the fine.

In exploring the penalty issue to enforce compliance in an irrigation context, Wilson et al. (2013) assert that when irrigators lose the ability to feel morally committed to value and respect the rules, the power of the regulatory authority over the regulated agents diminishes, thereby increasing chances of non-compliance by the latter. Specific roles of traditional leaders in irrigation water management in MRIS are not clearly defined, but their role in conflict resolution among community members gave them the right to implement the same even in irrigation matters. Proper incorporation of the traditional leaders into the water management structures like WUA and CMA might need to be considered, with the hope of improving collective management of resources at local levels. This strategy might be effective in MRIS where the culture, norms and belief systems of surrounding communities place more respect to the traditional leadership than the modern governance systems.

The case of MRIS revealed a reliance on informal rules and governance systems supported by formal governance structures, which were weak and failed to clearly define the property rights and water security systems at scheme level. The importance of recognising the polycentric nature of governance mechanisms and the need to relate to each institution for effective irrigation water management was noted. In summary, the IAs for water management in MRIS needs to be redesigned.

3.4.6 Importance of positive psychological capital in CPR management

According to Luthans et al. (2007), the major components of psychological capital allow resource users to have confidence (self-efficacy), make positive contributions (optimism), persevere toward goals (hope) and build a sustaining effort, allowing them to bounce back to attain success when faced with obstacles and adversity (resilience). The element of positive psychological capital was missing among farmers in MRIS. The notion that smallholders in most communally-managed schemes that were/are still being funded by the government regard the infrastructure as belonging to government (Perret, 2002), can be changed through a mind-set shift, defined in the context of psychological capital. Self-efficacy, hope and resilience were missing among farmers in MRIS, evidenced by farmers quitting farming and infrastructure deterioration as farmers fail to participate in collective activities like irrigation maintenance.

Other indicators of low positive psychological capital among MRIS farmers include: the slow pace at which irrigators were willing to join and participate in the local WUA for fear of being charged water fees, poor chances of farmers volunteering to serve as committee members leading to the prolonged stay of existing members, prevalence of free-riding and rule violation at the expense of other irrigators, and the prevalence of fallow plots across the scheme. Abandonment of plots by farmers citing water distribution challenges was viewed as a lack of resilience and hope. Farmers might tap into positive psychological capital to address water challenges instead of quitting or underutilising land. As such, the positive thinking processes brought along with psychological capital ensure effectiveness and success in the collective management of CPRs. A broader focus and adoption of strategies to enhance psychological capital among irrigators might improve irrigation performance. It can be argued that technical skills training and the redesigning of irrigation policies without supporting the psychological component might yield minimum results in the long-run.

3.5 Alternative water governance mechanisms in MRIS

There was a polycentric water governance system of canal water in MRIS, made up of local irrigation committees, traditional leaders, and officials from the Department of Agriculture, Forestry, and Fisheries (DAFF), CMA, WUA and crop production cooperatives. The multiple organisations present a complex set of both formal and informal governance structures. However, clarity of organisational roles and relevance in water management was critical. Through focus group discussions, water users ranked the preferred management structures to avert the water management challenges in the scheme. Although focus could have been put on improvement of operational rules, these may fail to yield positive results if the enforcement agencies are weak and not supported by the users. Farmers ranked the preferred institutional arrangements on a five-point Likert scale, and average scores were allocated for each arrangement. The scores ranged from the least preferred (score 1) to the most preferred (score 5) and the results are presented in Table 3.3.

Table 3.3. Farmers' perceptions of various strategies to improve water management in the Mooi River Irrigation Scheme, 2013 (n=71)

Intervention strategy	Average Score	Ranking
Training farmers on water management	**3.2**	**1**
Empowering local irrigation/block committees	**3.2**	**1**
More involvement of Department of Agriculture extension officials	3.1	3
More involvement of Department of Water Affairs representatives	3.1	3
WUA membership of all irrigators	2.9	5
Involvement of traditional leadership	2.7	6
Involvement of political leadership (councilors)	2.5	7

Source: Survey data, 2013

Irrigation water users ranked the need for training of farmers and empowerment of irrigation committees top as possible intervention strategies towards improving water management. This comes on the back-drop of minimal farmer training on irrigation management, including scheduling and drainage by water users in MRIS. Furthermore, this has to be complemented by effective irrigation committees that can enforce operational rules for the benefit of the entire scheme. The effectiveness of irrigation committees can improve if the majority of users have the know-how of the best practices in irrigation management, which can be acquired through training. A combination of irrigator training and effective irrigation committees can ensure effective cooperation in water management and collective action activities, as stipulated in Ostrom’s third institutional design principle. The study, however, found that irrigators were willing to improve irrigation management. As such, involvement of government authorities was ranked slightly lower than training of irrigators and committee involvement (Table 3.3). This showed that irrigators were keen to cooperate among each other rather than having government authorities involved in the crafting and enforcement of local water management rules. Similarly, irrigators have shown their dissatisfaction with the involvement of political leadership in the management of irrigation water.

3.6 Summary

The study sought to understand the governance and institutional arrangements around smallholder water management at MRIS. Given the qualitative and investigative nature of the research design, there was no test to identify which arrangement was superior to achieve good irrigation management. The chapter concluded that rule-violations were common, yet sanctioning was rare among smallholder irrigators. The study, therefore, asserts that CPR users relied more on deep rooted social capital of kinship and trust to monitor each other’s actions, providing room for rule violation. Under such circumstances, associated with non-cohesive rule enforcement, Olson (1965) indicated that rational group members always free-ride to maximise their utility against the wishes of other group members. Traditional leadership was also found to have strong linkages with the socio-cultural aspects of rural irrigators, whose role in resolving internal problems around water sharing, sharing of benefits and costs as well as compliance with operational rules was critical. Furthermore, institutional mechanisms and incentives to ensure that additional benefits accrue to those who cooperate and comply with membership rules of user associations were missing and need to be developed at scheme level. Institutional by-laws clarifying ownership and access rights for water users need to be strengthened. Rotational management of canal water by all irrigators might have to be explored to ensure equity, accountability and effective behaviour monitoring.

While technical interventions like provision of lockable water supply infrastructure to ensure easy control of unsanctioned withdrawal of water, upgrading of supply capacity and water measurement devices can be pursued at scheme level, focus on improving the institutional arrangements, management capacity and the governance systems can achieve better water allocation and minimize supply uncertainties. Without investing in building effective local institutions, promoting user cooperation and building positive psychological capital among users, engineering interventions for CPR management are often subject to vandalism and infrastructure decay.

CHAPTER 4

IMPLICATIONS OF INSTITUTIONAL ARRANGEMENTS ON PERCEIVED AGRICULTURAL WATER-USE SECURITY[2]

4.1 Introduction

This chapter examines farmers' perceived water-use security at farm level. The study applied principal component analysis (PCA) to group the major determinants of water-use security among smallholder irrigators in MRIS. The PCA was applied taking into account the broad definition of water-use security. As such, the multiple components defining water-use security, that include physical availability of the resource, quality, pricing and distribution issues, were scored by irrigators and indices were generated to measure water-use security in relative terms. Socio-economic and institutional factors affecting water use security were regressed against the water-use security indices. The proceeding sections include the research methodology, wherein the conceptual framework and the empirical models are explained, followed by the results and discussion sections and, lastly, by the summary of the chapter.

4.2 Research methodology

4.2.1 Sampling and data collection

Multistage sampling was used to draw a sample of 307 respondents from 824 scheme members. The sampled comprised of 246 scheme members, i.e., 29.7% of the total number of irrigators in the scheme, plus 61 respondents of an indeterminate population of non-members who irrigate from the MRIS. Pre-survey discussions with community leaders indicated that farmers were allocated plots in blocks closer to their homesteads, except in situations where plots were not easily available, thus forcing the farmers to take up plots in more distant blocks. Therefore, to ensure that a representative sample is drawn, the scheme was stratified into three segments (upper, middle, and tail-end) based on positions of individual farmers' irrigation plots along the main conveyance canal. The upper segment of the MRIS comprises of members farming in blocks 1 to 5, the middle segment comprises of members farming in

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[2] This chapter gave rise to the following manuscript: Muchara B, Ortmann GF, Mudhara M and Wale E. Implications of institutional arrangements on agricultural water-use security: evidence from Mooi River Irrigation Scheme in KwaZulu-Natal, South Africa. (Under review: *Water SA*)

blocks 6 to 11, and the tail-end segment constitutes blocks 12 to 15. Respondents were proportionally selected from each of the three sections based on the number of farmers in each segment of the scheme. A household questionnaire was used to extract data from the sampled farmers. Interviewees were contacted at farmers' homesteads to ensure easy tracing of the farmers by using homestead numbers and mobile telephone numbers.

4.2.2 Conceptual framework

Measurement and conceptualisation of irrigation water-use security is complex because water is not homogenous, and has many dimensions besides just quantity, which include: (a) location; (b) timing; (c) quality; and (d) variability/uncertainty (Hanemann, 2006). To a user, one litre of water is not necessarily the same as another litre of water if it is available at a different location, at a different point in time, with a different quality, or with a different probability of occurrence (Young, 1986:2-29). The water-use security concept refers to the satisfactory provision of all the above attributes of water to meet the demand of the consumer/irrigator. As such Hanemann (2006) proposed two ways to incorporate the multi-faceted nature of water in a formal economic analysis. The first approach defines different types of water as different commodities. For example, the consumption of water in January is represented by X_l, that in February is represented by X_2, that in March by X_3, etc. The consumer is then assumed to have a utility function defined over monthly consumption throughout the year and also over other commodities whose consumption is denoted by z, leading to the formulation:

$$U = U(X_1, X_2, ..., X_{12}, z) \qquad [4.1]$$

Therefore, each month would have separate demand function, indicating the water-use security of an irrigator vary over time (Hanemann, 2006). Economically, this means the demand for water in the i^{th} month will be a function of the price of water in that month, the prices of water in the other months (which may or may not be different), and the price of z, as well as the consumer's income,
$Xi = h^i (P_l, P_2 ,..., P_N ,P_z, Y)$. The differences between one month's demand function and that of another will reflect the different ways in which the two monthly consumptions enter the underlying utility function (4.1) (Hanemann, 2006). While this approach can easily be

applied to drinking water or where water markets exist, it poses a challenge in smallholder irrigation set-up, where water is neither measured nor priced.

The second alternative framework for analysing differentiated commodities, known as the characteristics approach to consumer demand was provided by Lancaster (1966) and Maler (1971). The Lancaster-Maler model extends the utility model (4.1) by offering an explicit account *X's*, based on their specific characteristics (Maler, 1971). Suppose there are K relevant characteristics (attributes), and q_{ik} denote the amount or level of the k_{th} characteristic associated with one unit of consumption of commodity i. The characteristics of each commodity are taken as given by the consumer who is free to vary only the quantity of the commodity, Xi. Thus, if the consumer wishes for more of the *kth* characteristic, he/she accomplishes this by consuming more quantity of the commodity, because the desired characteristic cannot be detached or provided separately from the product; quality variation is accomplished through quantity variation (Hanemann, 2006). This dilemma that affect common pool irrigation water, is that quality of water supplied, reliability of supply without and quantity of water available for irrigation is inseparable, and therefore need to be assessed concurrently.

If these attributes could be separated, then water could be regarded as N separate differentiated commodities together with undifferentiated consumption, z. The utility function therefore takes the form:

$$U = U(X_1, X_2, , X_N, q_1, q_2, , q_N, z) \qquad [4.2]$$

where $qi = (qi_1, ..., q_{ik})$.

Since irrigation water-use security is multi-faceted with respect to consumer choice, the second approach provides a better framework for analysing the demand for attributes and can be give a better approximation of water-use security. In addition to providing a framework for conceptualizing the demand for certain attributes of irrigation water, the Lancaster-Maler model also provides a framework for the economic valuation of the attributes (Maler, 1971), hence can also be used to measure water users' willingness to pay (WTP) for better availability of water, more reliable water supply, or more generally water of one type versus another (groundwater versus surface water), or availability of water at one location versus another (Hanemann, 2006).

The attributes that describe irrigation water is not limited to the type of physical characteristics such as location, timing, quality, and reliability, but also include other aspects, such as how the water is provided, and the users' preferences, fairness in allocation or payment (Lancaster, 1966). The Lancaster-Maler formulation also permits one to incorporate psychological or sociological attitudes within an economic model of the demand for water, so that one can analyse how these attitudes might generate a different water-use security status obtained from a particular source (Maler, 1971).

Based on the definition of water-use security (Komnenic et al., 2009), the various attributes of water-use security such as reliability of water supply, adequacy of water supply, price of water, quality of water, compliance to regulatory frameworks, conflict resolution mechanisms; have been measured and used as indicators of water-use security. At farm level, irrigation water-use security can be measured in relative and not in absolute terms; hence the need to encompass as many dimensions of water-use security as possible. Positive feedback from the respective attributes might be an indicator of good or satisfactory access/security, while negative responses reveal poor performance with respect to water use security. Improved water access in terms of volumes and the regulatory environment is expected to increase water use security, and consequently agricultural productivity (yields, incomes).

4.2.3 Empirical models

The study adopted two statistical tools to understand the relationship between institutional arrangements in irrigation management and water-use security at farm level. As noted before, the definition of water use security poses a measurement challenge, hence the need for more robust methods to analyse water-use security at farm level. First, PCA was used to generate the water-use security indices and group them into three main dimensions. Secondly, the PCs were regressed against a number of institutional variables to determine their effect on water-use security. Detailed description of the analytical techniques used is presented in the proceeding sections.

Principal Component Analysis

Principal Component Analysis (PCA) is a multivariate data analysis technique, to reduce the dimensionality of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set (Jolliffe, 2002:1-9). According to Jolliffe (2002:1-9), the reduction is achieved by transforming to a new set of variables, the principal components, which are uncorrelated, and which are ordered so that the first few retained components explain the variation present in all of the original variables. This can be expressed in mathematical terms following Vyas and Kumaranayake (2006:459-468);

$$\mathrm{PC}_1 = a_{11}X_1 + a_{12}X_2 + \ldots\ldots\ldots\ldots\ldots\ldots + a_{1n}X_n \qquad [4.3]$$

$$\mathrm{PC}_m = a_{m1}X_1 + a_{m2}X_2 + \ldots\ldots\ldots\ldots\ldots\ldots + a_{mn}X_n \qquad [4.4]$$

Where a_{mn} represents the weight for the m^{th} principal component and the nth variable.

Application of the PCA is wide including the construction of poverty index, food-security index, household asset index and wealth index (Filmer and Pritchett, 2001), social capital index (Mabuza et al., 2012) and recently has also been applied to calculate water security index (Sinyolo et al., 2014b). Similarly the study applied the PCA to reduce a large number of dependent variables that could be used as proxies for agricultural water-use security. A total of nine variables relating to agricultural water-use security were ranked by respondents based on their personal experiences to determine individual water-use security status. Respondents ranked on a 5 point Likert scale, the level of water use security by indicating whether they strongly disagree, disagree, neutral, agree or strongly agree to the hypothesised water related scenarios. The values increased from 1 if the respondent strongly disagrees to 5 if he/she strongly agrees with the statement. For instance, water users ranked their situation as to whether water supply is adequate in terms of volume supplied, whether the user has the capacity to pay for water infrastructure maintenance, whether the user regularly participate in decision making processes regarding water allocation; and the variables are presented in Table 4.1. Some statements were asked to proxy for certain water security indicators defined by (Komnenic et al., 2009) and Hanemann (2006). For instance, farmers in the study area are currently not paying for water but are paying for infrastructure maintenance. Therefore, the ability to pay for infrastructure maintenance was used as a proxy for farmers' ability to pay for water. Some variables like quality of water were deliberately left due to lack of heterogeneity emanating from a single source of water. Key informants and focus discussions in the same area also indicated satisfaction with the quality of water for irrigation purposes.

Table 4.1. Description of variables used to identify water use security in Mooi River Irrigation Scheme, 2013 (n=307)

Variable	label	Scale
Water sharing at farm level is fair	W_DISTR	1-5
Water is supplied in adequate quantities	W_ADEQ	1-5
Water supply to my plot is reliable	RELWAT	1-5
Conflict resolution mechanisms are effective	INV_CONF	1-5
The penalty system is effective	EF_PENLT	1-5
I have the capacity to pay for infrastructure maintenance	CAPAY	1-5
I often participate in infrastructure maintenance	M_PARTIC	1-5
Reliability of communication networks for water issues	RELCOM	1-5
I participate fully in decision making relating to water allocation in the scheme	WAT-CONS	1-5

Source: Survey data, 2013

Note: Strongly disagree=1, disagree=2, neutral=3, agree=4, strongly agree=5

The dimensions of water use security were extracted from the variables in Table 4.1. The coefficients are computed such that the first principal component (PC_1) to the last principal component, explain the largest to the smallest variation of the original variables, respectively (Jolliffe, 2002:1-9). By applying the Kaiser criterion, three PCs with eigenvalues greater than 1 were retained, and were used as dependant variables in an Ordinary Least Squares regression model to determine the factors affecting agricultural water use security.

Ordinary Least Squares Regression Model

Water use security is a relative term, and the use of a single index to define water use security might not offer sufficient dimensions especially among heterogeneous groups. As such, three regression models were estimated, whose dependent variables were derived from the PCA and represent the dimensions of water use security among respondents. According to Cook and Bakker (2012), a water user is considered to have better water use security if water supply is guaranteed, has capacity to pay for the water, enforcement mechanisms are satisfactory and farmer actively participate in decision making processes concerning irrigation water in the scheme. Following Gujarati (2004), the OLS regression model is specified as:

$$Y_i = \beta_0 + \beta_i X_i + \mu_i \qquad [4.5]$$

Where Y_i is the agricultural water use security index (PC_1, PC_2 and PC_3) for farmer *i;* X_i is a vector of socio-economic and institutional factors affecting water use security; β_0 is the intercept; β_i are the coefficients to be estimated and μ_i is the error term.

4.2.4 Dependent and independent variables

4.2.4.1 Dependent variables:

PCs that identified the different dimensions of water security were used as dependent variables in the OLS regression model. Similar studies in food security and other wealth indicators have often placed the PCA derived indices into two or more categories (Filmer and Pritchett, 2001; Sinyolo et al., 2014b), defined as severe, fair or good. The cut-off points and the methods of categorisation are critiqued for relying on arbitrary and subjective percentages, with minimum scientific backing (Vyas and Kumaranayake, 2006:459-468). For instance, Filmer and Pritchett (2001) used cut-off points to group households into broad socio-economic categories based on an asset index, with the lowest 40% representing the poor while the upper 20% represented the rich. The assumption there was that the socio-economic status is uniformly distributed, which might not be substantiated and therefore was not adopted in this study. Gwatkin et al. (2000) also assumed uniformity of the socio-economic index and used quintiles to group households into distinct socio-economic groups. In this study, applying arbitrary cut-off points, such as the 40‑40‑20 split as in Filmer and Pritchett (2001), was not feasible and would have disaggregated the distribution, but it would not reflect the exact nature of the underlying data, hence the use of continuous measures of water-use security. Besides, agricultural water-use security among users is always measured in relative and not in absolute terms; hence, this would not justify the placing of irrigators into distinct groups based on the computed index.

4.2.4.2 Independent variables

Socio-economic attributes

The literature on agricultural water-use security at farm level is limited and does not clearly depict its relationship with household socio-economic attributes. However, Sinyolo et al. (2014b) argued that demographic attributes that include age, gender and farm experience are critical determinants of water-use security. Furthermore, a number of studies, e.g. Van der Zaag and Rap (2012) and FAO (2012), identified significant relationships between water access and access to credit, gender, education level and age. With reference to gender issues around water access, Van der Zaag and Rap (2012) and FAO (2012) indicated that masculinity played a major role in the performance of water sharing schemes. It can, therefore, be argued that demographic attributes are critical in determining water-use security at farm level, where the elderly and women are postulated to be associated with agricultural water insecurity, while an increase in farming experience might improve water-use security among irrigators. Based on the assumption that capacity to pay for infrastructure maintenance is influenced by the household’s income levels, it was hypothesised that the level of income from irrigation activities is an incentive for households to participate in irrigation farming, hence has a positive effect on water-use security.

Institutional variables

Shah et al. (2004) postulated that the IAs governing irrigation schemes influence the performance of the latter and consequently water-use security. Since there are sequential linkages and synergies among institutional components, performance of communal irrigation schemes are likely to be better with well-defined IAs than without (Shah et al., 2004),

In an environment like the smallholder agricultural sector in South Africa, where water markets are non-existent and informal IAs dominate, an analysis of the influence of arrangements that are necessary to support water-access is critical. As such, formal and informal IAs that are hypothesized to directly or indirectly impact on irrigation water access and consequently water-use security status include membership in specific groups such as WUAs, cooperatives or an irrigation scheme. In South Africa, the informal IAs include village committees, water committees and social ties among users, which are reinforced by formal and legal requirements for farmers to form WUAs as enshrined in the 1998 National Water Act (RSA, 1998).

The study also assessed variations in the perception-based information of water users on institutions governing water resources, including irrigation committees, application of water governing rules, resource sharing, and cost sharing in the scheme. Although perception-based information may be subjective due to factors such as bias and expectations, it offers an overall indication of how water users perceive the local institutions and governance systems, and thus their willingness or otherwise to cooperate with the system. Variations in perceptions can be interpreted as an indicator of uncertainty about the features of water institutions and their performance impacts (McKay and Keremane, 2006). At a local level, individual perceptions about irrigation management can also be considered as a measure of institutional effectiveness, hence their inclusion in the analysis. Since the main function of institutions is to reduce uncertainty and make human behaviour predictable, the extent of uncertainty or ambiguity evaluated in specific cases can also provide comparative insights into the relative efficacy and performance of water institutions in different contexts (Shah, 2005).

4.3 The results and discussions

4.3.1 Descriptive analysis of socio-economic and institutional variables

Based on a sample size of 307 respondents, the characteristics of the respondents are presented on Table 4.2 and 4.3. The average age of the respondents was 56.9 years, ranging between 20 and 93 years. Generally, the farmers are relatively old, with an average farming experience of 21.9 years, ranging between 1 and 60 years. The high number of years of farming experience might signify that there were few entrants into farming, especially the youth. On average, the farmers' homesteads are located 1.34km from their irrigation plots, with the furthest located 4km away. Distance is not a major threat to water access, given that the literature has presented farmers who walk much longer distances to access irrigation services.

Table 4.2. Descriptive analysis of continuous variables for sample farmers, Mooi River Irrigation Scheme, 2013 (n=307)

Description	Variables	Mean	Std. Dev	Min	Max
Age of household in years	AGE	56.99	13.18	20	93
Farming experience in years	F_EXPER	21.94	13.95	1	60
Income from irrigation farming (Rands per annum)	IRGINCO	3807.00 (R13843.63/ha)	5672.27	0	33500
Average annual contribution by a water user towards irrigation maintenance (Rands)	AV_CONT	100.35	109.12	0	600
Average distance of homestead from the canal (km)	HMSDIST	1.34	1.22	0	4
Irrigated area per farmer (ha)	IRRSCH_HA	0.275	0.013	0.1	1.5

Source: Survey data, 2013

The returns from irrigation farming are fairly low, with an average of R3807 per annum. Average irrigated land per household was 0.275ha, and therefore, returns from irrigation was approximately R13 843/ha per household per annum. This figure is less but close to the R15000/ha per annum reported by Sinyolo et al., (2014a) as the revenue from irrigation farming per household in the Msinga area of KwaZulu-Natal Province. However, most farmers in MRIS did not plant in winter (May-August) due to low irrigation water supply. This reduced farm incomes for the farmers in MRIS. However, although returns are low and expansion of land under irrigation does not seem feasible, there is room to improve returns through intensification of the production systems. Improved water provision in winter, fencing of fields, institutional support to promote collective maintenance of irrigation infrastructure may all be explored to improve yields in MRIS.

A summary of the categorical variables are presented in Table 4.3. It is important to note the high number of female headed households (72.6%) in the area, who also happen to be the most active in irrigation farming. The less number of males taking part in irrigation agriculture might also be due to culture. Irrigation farming is considered to be a female activity in the area, while male concentrate on cattle rearing (Sinyolo et al., 2014b). While canal water is meant for irrigation, lack of clarity on who the beneficiaries should be is indicated by the factor that about 20% of the respondents are actually irrigating plots located outside the scheme boundaries.

Table 4.3 shows that a small percentage of respondents (8.5%) are actually members of the WUA in the area, and only 36% have received some form of training in irrigation. This shows a gap in terms of institutional support, especially with regard to government departments. Extension services need to be improved to ensure more access to irrigation training. Furthermore, more capacity building workshops are required to ensure that farmers comply with the National Water Act of 1998, by registering as water users.

Table 4.3. Descriptive analysis of categorical variables of sample farmers, Mooi River Irrigation Scheme, 2013 (n=307)

Description	Variable	Units	Freq.	Percent (%)
Gender of household head	GENDER	1=Male	84	27.4
		0=Female	223	72.6
Membership to the irrigation scheme	SCH_MEB	0= No	61	19.9
		1= Yes	246	80.1
Training in irrigation water management	TRAWAT	1=Yes	111	36.2
		0=No	196	63.8
Whether an individual irrigator is a member of a Water User Association	WUA_MEB	1=Yes	26	8.5
		0=No	281	91.5
Whether a water user is a member of any group that is involved in water use.	GRP_WAT	1=Yes	75	24.4
		0=No	232	75.6
Position of farmer's plot along the main canal	BPOSITN1	Upper (dummy)	62	20.2
	BPOSITN2	Middle(dummy)	112	36.5
	BPOSITN3	Tail-end (dummy)	133	43.3
Perceived effectiveness of the committee members	COMIT_EF	1=Effective	188	61.2
		0=Not effective	153	49.8
Perceived condition of irrigation infrastructure	INFRASCO	0= Bad	259	84.4
		1= Good	48	15.6
Whether appropriation rules are clearly defined and known to all water users	APRULS	0 = Bad	243	79.2
		1= Good	64	20.8
Whether there is equitable sharing of water resources	RESHAR	0 = Bad	202	65.8
		1 = Good	105	34.2
Whether there is equitable sharing of maintenance	COSTSHAR	0 = Bad	194	63.2
		1 = Good	113	36.8

Source: Survey data, 2013

Statistics reveal that infrastructure condition, resource sharing and compliance to appropriation rules are all poor, indicating institutional failure. In view of the challenges highlighted, the dimensions of water use security among irrigators were assessed.

4.3.2 Proxies of agricultural water-use security

The societal challenge of achieving and sustaining agricultural water-use security is determined by many factors. Grey and Sadoff (2007) identified three main determinants of water security at national and global level, namely (1) the hydrologic environment, (2) the socio-economic environment, and (3) changes in the future environment. The hydrologic environment refers to the absolute level of water resource availability and its spatial distribution, while the socio-economic environment refers to the structure of the economy and the behaviour of its actors. The future environment refers to the influence of climate change on the water situations. Furthermore, there is considerable and growing evidence that climate change also plays a major part in determining water security at a global scale. These factors play important roles in determining the institutions and the types and scales of infrastructure needed to achieve water security.

Agricultural water-use security at a smallholder level is influenced by a range of local conditions. As such, the PCA was applied using a correlation matrix to group dominant determinants of water-use security in MRIS. The PCA can perform a compression function of the available information only if the null hypothesis is rejected. The Bartlett’s sphericity test was applied to check if the observed correlation matrix diverges significantly from the identity matrix (theoretical matrix under H_0: the variables are orthogonal). For this study, the Bartlett’s test was significant ($P < 0.001$) and therefore rejects the null hypothesis that variables are not inter-correlated, hence a PCA can be performed efficiently on the dataset. However, Dunteman (1989) cautioned on the drawback of the Bartlett’s test that tends to be statistically significant when the sample (n) increases. Therefore, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was also applied and a value 0.67, which is greater than 0.5, indicates that the PCA could be applied to the dataset. Table 4.4 presents the PCs of the major determinants of water-use security among smallholder farmers and appendix 4 presents the descriptive statistics of the variables used in the construction of the indices..

Table 4.4. Principal component analysis of the determinants of agricultural water security in Mooi River Irrigation Scheme, 2013 (n=307)

Variable	**Principal Components**		
	PC_{WS1} Water availability	**PC_{WS2}** Rule enforcement	**PC_{WS3}** Involvement in decision making
W_DISTR	**0.4511**	0.3322	-0.3158
W_ADEQ	**0.4967**	-0.0197	-0.0970
RELWAT	**0.5403**	0.1301	-0.2053
EF_PENLT	-0.0443	**0.6414**	0.1043
INV_CONF	-0.1109	**0.5468**	**0.4430**
RELCOM	0.2316	-0.2427	**0.5397**
WAT-CONS	0.1828	-0.0278	**0.4537**
CAPAY	0.3286	-0.2828	0.2686
M_PARTIC	-0.2202	-0.1494	-0.2687
eigenvalue	2.48	1.34	1.11
Variance explained	28%	15%	12%
Cumulative % of variance explained	28%	43%	55%
Keiser-Meyer-Olkin (KMO) Measure of sampling adequacy	0.675		
Bartlett test of sphericity	Chi-square = 447.48 Degrees of freedom = 36 p = 0.001		

Notes: Component loadings greater than |0.40| are highlighted in bold print
Source: Survey data (2013).

Applying the Kaiser criterion that PCs with eigenvalues greater that one may be retained, three PCs were therefore considered. The three PCs were named based on the dominant variables and explained 55% of the total variation in the data. The first component (PC_{WS1}) explained 28% of the variation and was found to be closely related to the level of physical availability of water among irrigators. The dominant indicators of water access are reliability and consistency of supply (RELWAT), infield water sharing or distribution among farmers (W_DISTR) and supply of water in adequate quantities (W_ADEQ).

The second component (PC_{WS2}) explained 15% of the variation and represented rule enforcement mechanisms around irrigation water management among users. The canal in MRIS is a CPR and as such is governed by both informal and formal rules that are known to the users. However, rule enforcement is always viewed as the major challenge leading to the collapse of infrastructure and inequitable sharing of CPRs (Ostrom, 2007). Rule enforcement was, therefore, measured in the context of conflict resolution mechanisms (INV_CONF) and effectiveness of the penalty systems (EF_PENLT) that are used to minimise rule breaking by CPR users. The indicators of rule enforcement show that CPR users can effectively monitor usage of water if strong conflict resolution mechanisms and penalty systems are enforceable, which are also positively associated with equitable sharing of water among irrigators.

Irrigator involvement in the decision making process around water management is reflected in the third component (PC_{WS3}). The indicators suggest that adequate consultation of water users (WAT-CONS) by management authorities is positively associated with reliability of communication networks for water related issues (RELCOM) and effectiveness of conflict resolution mechanisms (INV_CONF) around water access. These indicators are, therefore, positively associated with water-use security among small-scale irrigators.

4.3.3 Factors affecting smallholder farmers' water-use security

The results of the PCA shows that water use security can be defined with respect to three dominant pillars; that is, water availability, rule enforcement mechanisms and the involvement of users in decision making process concerning irrigation water. The eigenvalues (variance) for each principal component indicates the percentage of variation in the total data explained. Following Vyas and Kumaranayake (2006:459-468), the percentage variations for individual PCs are not high, and this could reflect the number of variables included in the analysis or the complexity of correlations between variables, hence each included variable may have its own determinants (Vyas and Kumaranayake, 2006:459-468). As such, in order to capture the various factors affecting the water use security at farm level, OLS regression model was estimated using the three PCs as dependent variables, being explained by a range of socio-economic and institutional factors (Table 4.4). Adopting one index of water-use security would mean losing valuable information explained by the second and third PCs.

Model diagnostics tests were performed to test the fitness of the OLS model to the data. First, the variance inflation factors (VIF) were estimated to test for multicollinearity among variables. The VIFs were less than the critical value of 10 (Greene, 2003), indicating that multicollinearity was not a serious problem in the data set. Furthermore, heteroscedasticity was accounted for by estimating robust standard errors. Results of the OLS regression model are presented in Table 4.5.

Table 4.5. Regression results of factors affecting dimensions of water use security in Mooi River Irrigation Scheme, 2013 (n=307)

Variables	**Water Availability (PC_{WS1})**		**Enforcement of rules (PC_{WS2})**		**Involvement in Decision making (PC_{WS3})**		V.I.F
	Coef.	Rob Std. Err	Coef.	Rob Std. Err	Coef.	Rob Std. Err	
Socio-economic factors							
GENDER	-0.0344	0.1315	0.0859	0.1554	-0.0037	0.1310	1.14
F_XPER	0.0036	0.0046	-0.0092*	0.0047	-0.0145***	0.0047	1.46
IRGINCOM	0.0001***	0.0000	0.0001	0.0000	0.0001	0.0000	1.36
AV_CONT	-0.0007	0.0006	-0.0018***	0.0008	0.0014***	0.0005	1.35
HMSDIST	-0.1006**	0.0451	0.0414	0.0608	-0.0698	0.0473	1.17
Institutional variables							
SCH_MEB	-1.6830***	0.1849	-0.4733**	0.2311	0.2839**	0.1463	1.21
WUA_MEB	-0.1904	0.1892	0.0271	0.1660	0.2953	0.2045	1.09
TRAWAT	0.1084**	0.0480	-0.0214	0.0559	-0.0537	0.0460	1.45
COMIT_EF	0.1532***	0.0523	-0.0537	0.0674	0.0239	0.0503	1.21
GRP_WAT	-0.1350	0.1233	0.1600	0.1228	0.3440**	0.1367	1.24
APRULS	0.3313*	0.1996	0.1174	0.1921	0.3303*	0.1755	1.65
INFRASCO	0.1191	0.1454	-0.2915*	0.1557	-0.4056***	0.1431	1.5
COSTSHAR	-0.0078	0.0778	-0.0226	0.0818	-0.2088***	0.0755	1.13
BPOSITN1	0.8598***	0.1699	0.3022*	0.1728	0.2887**	0.1207	1.88
BPOSITN3	-1.8255***	0.1613	-0.1296	0.1882	-0.6171***	0.1366	2.09
_cons	1.9550	0.2718	0.9949	0.3166	0.561374	0.2187	
Model summary	F-Stat =35.44 R-square =0.576 P = 0.001		F-Stat =3.17 R-square =0.102 P = 0.001		F-Stat =7.52 R-square =0.229 P = 0.001		

Notes: ***, **, and * mean significance at the 1%, 5 %, and 10% levels of probability, respectively
Source: Survey data, 2013

The regression results indicate a relationship between the perceived water-use security and a number of explanatory variables. The results have been discussed according to the different dimensions of water use security, namely physical on-farm availability of water, rule enforcement, and farmer involvement in decision making processes.

Physical on-farm availability of water in MRIS

The results in Table 4.5 indicate that water availability is influenced by socio-economic and institutional arrangements related to water access. Irrigation income (IRGINCOM) is perceived to be positively related to water availability. Higher returns from irrigation activities, in terms of income, ensure that farmers have the capacity to pay for irrigation maintenance activities. Similarly, farmers with greater perceived water availability are more likely to invest in irrigation agriculture; hence they will tend to earn more from irrigation agriculture, *ceteris paribus.* This is a critical finding in the light of the current focus on IMT that seeks to transfer ownership of community irrigation schemes from government to local communities. By improving availability of irrigation water, farmers become relatively water secure and are, therefore, expected to improve their productivity. The challenge is that farmers are failing to internalise their expenditure in irrigation management; hence irrigation maintenance benefits all MRIS members/water users and the marginal benefit that accrues to a funder (paying farmer) of irrigation maintenance is probably small. This might be the cause of the perceived prevalence of free-riding in MRIS.

The results also indicate that water users that belong to groups (formal and informal) are perceived to be more water insecure, especially regarding physical access. This was highlighted by the negative coefficient for members of the scheme (SCH_MEB), members of the water user association (WUA_MEB) and members of cooperatives (GRP_WAT). The groups or associations were meant to improve irrigation water access. It was, however, noted that non-group members flouted water appropriation rules at the expense of group members. For instance, non-scheme members had the opportunity to choose sites outside the scheme boundaries and strategically establish their plots in areas on the upper sections of the canal where there was better access to water compared to scheme members. This was identified as a major challenge affecting water-use security among farmers in the scheme.

The WUA comprised mainly of members of the scheme, and the members perceived water availability to be inadequate. The water allocation system in the area did not give special treatment for water access to scheme members or members of the WUAs, because it was based on a “use-it or lose-it principle”, thereby putting non-compliant irrigators at an advantage. In South Africa, water access by members of WUAs is well defined and secured in the water policies and the regulatory framework of the National Water Act (NWA) of

1998. However, MRIS illustrates the informal nature of the water sector at smallholder level, which was characterised by weak implementation of statutes, thereby delaying the formalisation of the collective management of irrigation water. This might also have undesirable effect on the water management transfer to use groups in South Africa. Ensuring that incentives are put in place and water-use rights and exclusivity rights are protected for formal groups can improve the formalisation of collective water management, with the hope of also improving water-use security at scheme level.

Institutional arrangements governing appropriation were weak and had no capacity to protect users; hence location of plots at the tail-end (BPOSITN3) of the supply infrastructure was negatively associated with water availability among farmers, while belonging to the head section (BPOSITN1) was positively associated with water availability. The results were consistent with Gomo et al. (2014a) and Sinyolo et al. (2014a), where tail-end water users were identified as more vulnerable to water insecurity. This was also a major challenge among farmers sharing the Kat River in Eastern Cape Province of South Africa (Mbatha and Antrobus, 2008).

Perceptions were also sought on the effectiveness of irrigation committees (COMIT_EF), and their capacity to ensure water-use security at farm level. Respondents who perceive the committee to be effective also tend to perceive that they have greater water availability. Furthermore, the causality is more likely to reflect that respondents who perceive to have have greater water availability are more likely to be satisfied with the performance of the irrigation committees and will tend to perceive them to be efficient. Weak committees signify inefficient institutions, often lacking the will and capacity to enforce appropriation rules that ensure equal sharing of water resources and costs (Niasse, 2011).

The estimated coefficients for the clarity of appropriation rules (APRULS) and access to irrigation training (TRAWAT) were statistically significant at the 10% and 5% level, respectively. The signs of the coefficients are both positive and conform to *a priori* information that the variables have a positive influence on perceived water availability at farm level. Access to irrigation training by farmers is perceived to improve efficient water utilisation at farm level, while well-defined appropriation rules is perceived to minimise free-riding, hence improvement in water-use security among users. However, distance from the canal (HHSDST) is perceived to negatively affect water access by farmers. Farmers staying closer to the canal can monitor the flow and respond by channelling the water to their fields unlike those whose homestead are far away from the conveyance structures.

Rule enforcement among water users in MRIS

It is noted that rule enforcement is measured as the respondents' perception that rules are being enforced, and not the actual level of enforcement of the rules (Table 4.5). The negative relationship between SCH_MEB and rule enforcement may be explained by the negative relationship between SCH_MEB and water access. The irrigators who are members of the group prove not to have reliable access to water; hence they may have the perception that the rules are not enforced.

However, rule enforcement was perceived to be associated with farming experience (F_EXPER), average financial contributions towards scheme maintenance (AV_CONT), the condition of irrigation infrastructure (INFRASCO) and block position along the main conveyance canal (BPOSITN1). The condition of infrastructure in MRIS is poor and cause water leakages. Respondents who perceive that the condition of infrastructure is bad also perceive that rule enforcement is the main challenge. The condition of lockable gates is bad and in most cases not functional, hence monitoring and allocation of water to individual plots is perceived to be a challenge. Sharing of water is at two stages; first at scheme level among the head and the tail-end farmers, and secondly at plot level among farmers sharing the same distribution canal. However, farmers in the head section of the scheme (BPOSITN1) perceive that rules are being enforced. This might be due to the perceived reliability of water access by farmers located in the dead section compared to tail-end farmers. Down-stream farmers were perceived to be water constrained due to limited availability of the resource and enforcement of rules might be one way to improve water-use security among them.

Farmer involvement in decision making process in MRIS

The management of small-scale irrigation schemes in South Africa is being transferred from state control to the users, in line with PIM and IMT. The inclusion of farmers in decision making processes is important to improve water access and hence water-use security. In line with expectations, farming experience (F_EXPER) and average contribution towards irrigation activities (AVE_CONT) were perceived to influence farmers' involvement in decision making processes. The positive relationship between average contributions and decision making could mean that farmers who contribute money towards irrigation activities may want accountability for the use of resources (Table 4.5). Furthermore, members of the scheme (SCH_MEB) and members of informal groups (GRP_WAT) were perceived to be more likely to participate in decision making processes around water use. This finding was in line with *a priori* expectation that group members were more likely to participate in decision making than non-members. However, membership of a WUA (WUA_MEB) was statistically insignificant, contrary to expectations. This might be because the WUA in the area was still in its inception phase and most decisions regarding water use in the scheme were still being controlled by the irrigation committees and canal attendants and not by the WUA. While the irrigation literature on IMT emphasizes the importance of farmer participation in the promotion of successful WUAs (Huang et al., 2010), in MRIS, there was little participation by farmers in the WUA. Rigorous persuasions by the officials from the Department of Water Affairs (DWA) and the local Department of Agriculture and Environmental Affairs (DAEA) led to few members joining the WUA. However, attendance of WUA meetings was poor, feedbacks from meeting outcomes were poor and farmers seem not to know how to participate in aspects of water management through the WUA.

The results also indicate that irrigators were less likely to participate in decision making when they perceive that appropriation rules were not clear (APRULS) and that the condition of the irrigation infrastructure (INFRASCO) is bad. This was an indication of a reactive nature of the governance system in the scheme, where irrigators were called to attend meetings to address specific challenges like canal breakages and non-compliance to the roster. However, farmers who perceive distribution of irrigation maintenance costs (COSTSHAR) as unfair were less likely to be involved in decision making processes at scheme level.

There was positive relationship between involvement in decision making and location of the farmers’ plots at the head section of the scheme (BPOSITN1) and a negative relationship with location at the tail-end section (BPOSITN3). The results reveal that farmers at the tail-end section of the scheme (Bpost3) were less likely cooperate in decision making because they perceive that their water access is more constrained than their counterparts in the dead section. In MRIS, farmers in the tail-end were always in short supply of water and often frustrated with the water allocation system. There might be need to improve their water access situation to motivate them participate more in decision making processes in the scheme.

4.4 Summary

By applying PCA and an OLS regression model, the study managed to identify the major dimensions of water-use security among smallholder irrigation farmers, as well as examining the factors affecting agricultural water use security at among common pool irrigation users. The dimensions of agricultural water-use security at farm level include physical access to water, rule enforcement mechanisms at farm level, and involvement of water users in decision making processes pertaining to water access. Consequently, a combination of socio-economic factors, institutional arrangements and governance systems affect the relative water-use security status of irrigators. The findings reveal that formal associations including WUAs, scheme membership and membership of cooperatives are currently not offering adequate incentives to water users at a local level. The perceived violations of rules by some water users was more likely depriving members of groups of the anticipated improvement in water access at local level. Regarding enforcement mechanisms, conflict management and decision making, the existing structures were perceived to be too weak to ensure reasonable compliance to both formal and informal rules, manifesting in unequal sharing of common pool resources and costs among water users. The study concludes that water-use security among communal irrigators is multidimensional. Both technical and institutional support that ensure improved availability of water, promote the participation of farmers in decision making and effective conflict management mechanisms might ensure improvement in water-use security at farm level.

CHAPTER 5
FARMER PARTICIPATION IN COLLECTIVE IRRIGATION WATER MANAGEMENT[3]

5.1 Introduction

The chapter seeks to understand the various ways in which respondents participate in collective management of irrigation water. This is further expanded by identifying the determinants of farmer participation in the collective activities as a basis to inform smallholder irrigation management policy. This chapter draws its data from the survey instruments described in chapter 4 and this detail is, therefore, not repeated here. The following section presents the methodological framework, followed by the empirical results and discussions in section 5.3. The last section presents the summary of the results.

5.2 Research methodology

5.2.1 Theoretical and conceptual framework

The importance of collective action in the management of common pool resources like irrigation schemes is vital and cannot be overemphasised. Weirich (2008) argued that failure to monitor group or organizational activities involving several people may lead to the group degenerating into chaos and anarchy. The assumption underlying this view is that individuals involved in group activities invariably make decisions based on self-interest rather than the common good if their actions are not monitored and action taken if individual decisions result in collective loss or tragedy. This assumption finds justification in rational choice theory, which predicts that individuals will act in ways that maximize their personal utility without any regard of the common good. Although MRIS is a common pool resource (CPR), lack of rule enforcement and institutional failures to exclude non-irrigators, such as livestock owners and brick makers, from accessing canal water, led to the resource being open access. Hardin (1968) explained this scenario in the “Tragedy of the Commons”, wherein individuals with access to a common resource over-exploit it in their pursuit of personal gain, and thus end up

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[3] This chapter gave rise to the following publication: Muchara B, Ortmann GF, Wale, E and Mudhara M (2014). Collective action and participation in irrigation water management: a case study of Mooi River Irrigation Scheme in KwaZulu-Natal Province, South Africa. *Water SA* **40**(4): 699-708.

depleting the resource completely, resulting in a tragedy common to all. In the current study, the tragedy can manifest itself in the form of infrastructure decay, water shortages and poor yields. On the other hand, Ostrom (2007) argued that given the right conditions, individuals and groups behave rationally and can work towards the common good even if it means foregoing personal gains. However, individual utility maximisation is regarded as a necessary condition of rationality, subject to constraints on the goals (Weirich, 2008). Figure 5.1 illustrates the postulated relationship among factors influencing individual behaviour towards collective activities, the various ways through which individuals contribute, and the possible outcomes of such behaviours.

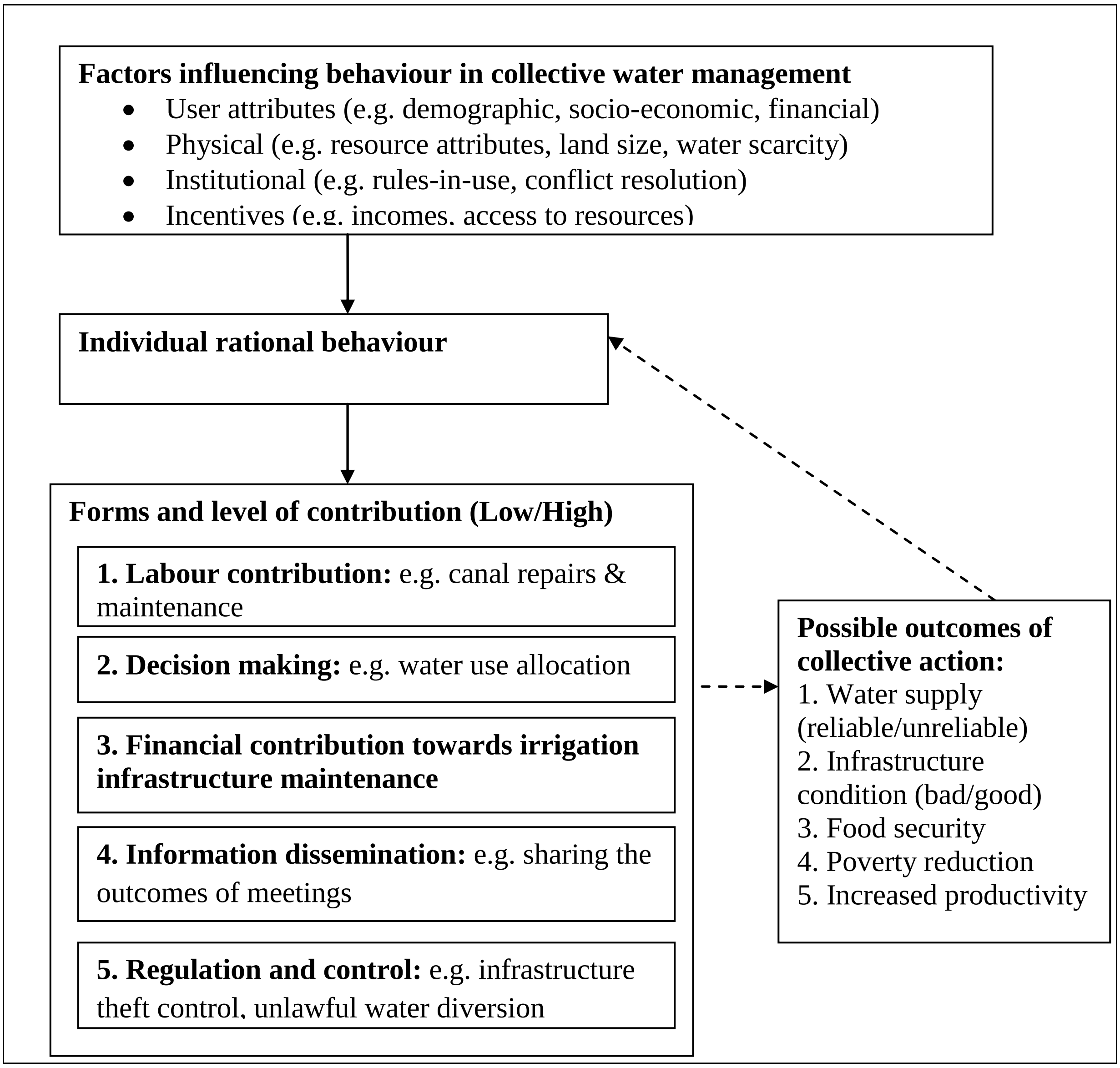

Figure 5.1. Framework for analysing collective irrigation water management
Source: Adapted from Ostrom (1994) and Sabatier (2007)

The collective action theory finds relevance in the present era of IMT, where a group of farmers sharing water resources are supposed to cooperate in order to maximise benefits from the resource. Based on Ostrom (2010), the three underlying assumptions of collective action are that: participants have common knowledge about the structure of payoffs to be received by all individuals under the combination of collective actions; decisions are made independently and simultaneously; and no external actor or central authority is present to enforce agreements among participants.

The nature and intensity of individual participation in collective activities is influenced by personal attributes, resource attributes, institutional setting and the incentive systems (Fischer and Qaim, 2014), and these have been summarised in Figure 5.1. Members participate in collective activities through contributing labour, finance, decision making, information dissemination as well as regulation and control (Van der Zaag and Rap, 2012). However, the levels of contribution vary across members of the group depending on individual decisions and resource constraints. This gave rise to the need to measure individual intensity of participation in irrigation scheme management. The analytical framework considers the outcomes as important measures of collective action. The outcomes, that include reliability in water supply, infrastructure condition, food security, poverty reduction and incomes, may impact directly or indirectly on the way members perform collective activities. Undesirable outcomes hinder collective action activities, while positive outcomes can potentially motivate member participation in collective activities.

5.2.2 Empirical methods of data analysis

Reference is made to sampling design and data collection methods presented in the previous chapter. The study employed three main data analysis techniques: Principal Component Analysis (PCA) specified in equations 4.3 and 4.4, was used for dimension reduction. The Tobit regression was applied to assess the determinants of participation, and lastly the ordered Probit regression was used to measure individual intensity of participation in irrigation water management.

Other studies mostly in collective marketing (Fischer and Qaim, 2012) have considered participation as a choice and step-wise decision, where respondents either participate or not. Under such circumstances, binary choice models are applied to analyse the determinants.

This study could not consider the binary option due to the multidimensional nature of activities involved in water management. A respondent might be participating in one activity and not in others, as such it is logical to generate a composite index that captures the most possible collective activities that farmers are expected to engage in. Participation in water management activities within the MRIS is mandatory for all members, although compliance and cooperation seems to be a challenge. More so, participation in canal water management in the MRIS is multi-dimensional; hence, PCA was used to generate a composite index of participation. The variables representing the various forms of farmers' participation in collective action are not orthogonal, hence PCA reduce dimensionality of variables (Manyong et al., 2006) and decompose variations in the variables included in the analysis into orthogonal components, each having a characteristic unique from the others (Dunteman, 1989; Fujiie et al., 2005).

Respondents ranked their participation level in a wide range of irrigation management activities. A total of 15 activities were identified, which were grouped into five main themes (Figure 5.1), namely (1) labour-based participation: canal cleaning, canal repairs and pump repairs; (2) financial-based participation: contributing finance towards infrastructure repairs and towards the running of the WUA; (3) participation in decision making: attending meetings, lobbying, and contributing ideas in water related issues; (4) information dissemination activities: distributing water related information in the area: and (5) participation in regulation and control: reporting unlawful diversion of water, reporting theft of irrigation infrastructure, and reporting damages and water leakages along the major irrigation infrastructure. Participation in activities was ranked using a five-point Likert scale from zero (0) if a farmer is not involved in a given activity, to four (4) if he/she is highly involved. The rankings were then used to compute the participation index (PI) using PCA for individual farmers in water-related activities.

Explicitly, the forms of participation in collective activities by farmers are assumed to have equal weights. This may be queried where smallholder farmers value the forms of contribution differently; for example, one farmer might value labour contribution more than financial contribution or attending meetings. Differences in value allocation might be emanating from different socio-economic status of respondents or the characteristics of the resource. The complexity of allocating specific values to the various forms of participation resulted in the current implicit assumption about equal weights. The PI was therefore used as a proxy to measure farmers' involvement in collective action.

The PCA was also used to generate an incentive index based on benefits accrued from participating in collective water management activities. Water users ranked a total of seven perceived benefits of participating in water management on a five-point Likert scale from 0 (poor) to 4 (excellent). Some of the perceived benefits include reliability of water supply for agricultural needs, improvement in government support, improved capacity to lobby by water users, increased feeling of responsibility, reliability of water supply for non-agricultural activities, and improved access to canal water. The incentive index was then used as an independent variable to explain farmers' participation in collective action. The study hypothesised that incentives have a positive influence on the intensity of participation in collective action.

Following previous studies, e.g., Manyong et al. (2006) and Wang et al. (1997), a censored Tobit regression model was applied to estimate the factors influencing behaviour in collective water management (*Z*) i.e. user attributes, physical or resource attributes, institutional attributes and incentives on the forms and level of participation (participation index) (Figure 5.1). The PCA derived composite index of participation (σ) is the dependent variable. Given the right- and left-censoring at minimum ($\sigma_{\min}$) and maximum ($\sigma_{\max}$) score, respectively, the two-limit Tobit model (Maddala, 1983:261); Wang et al., 1997) is specified as follows:

$$\sigma_i^* = \beta'(Z_i) + \varepsilon_i \qquad [5.1]$$

Where σ_i^* is an unobservable latent response variable, Z_i is an observable vector of explanatory variables, β is a vector of parameters to be estimated, and ε_i is a vector of independently and normally distributed residuals with a common variance θ. Then the actual model can be represented as follows:

$$\begin{aligned} \sigma_i &= \sigma_{\min} \text{ if } \sigma_i^* \le \sigma_{\min} \\ &= \beta'(Z_i) + \varepsilon_i \text{ if } \sigma_{\min} \le \sigma_i^* \le \sigma_{\max} \\ &= \sigma_{\max} \text{ if } \sigma_i^* \ge \sigma_{\max} \end{aligned} \qquad [5.2]$$

With this specification, parameters of participation variables, the model can be estimated by maximizing the following corresponding log-likelihood function (Maddala, 1983:261):

$$L(\beta,\theta)=\prod_{\sigma_i=\sigma_{\min}}\Phi\left(\frac{\sigma_{\min}-\beta' Z_i}{\theta}\right)\prod_{\sigma_i=\sigma_i^*}\frac{1}{\theta}\phi\left(\frac{\sigma_i-\beta' Z_i}{\theta}\right)\times\prod_{\sigma_i=\sigma_{\max}}\left[1-\Phi\left(\frac{\sigma_{\max}-\beta' Z_i}{\theta}\right)\right] \quad [5.3]$$

where Φ and Ø are the standard normal density and distribution functions, respectively.

Ordered Probit regression was then applied to assess the determinants of participation intensity in common pool water resource management by smallholder farmers. Based on individual rationality, which is influenced by resource, socio-economic, incentives and institutional attributes (Figure 5.1), respondents indicated that they either participate or not participate in collective activities. For those that participate, their level of participation varies. Respondents' observed preference to take collective responsibilities was regarded as a key measure of participation intensity. As such, the intensity of participation in irrigation water management is an ordered dependent variable and categorically measured as:

Category 0 = User not participating at all (none)
Category 1 = Willing to participate but not participating (poor)
Category 2 = Participating as an ordinary member (good);
Category 3 = Participating as a committee management member (very good)
Category 4 = Participating as a chairperson (Excellent)

Due to a limited number of respondents, categories 3 and 4 were merged to improve the estimation of the model. According to Greene and Hensher (2008:6-7), the ordered Probit model (OPM) takes into account the order value of the dependent variable, hence its adoption in this study. Intensity of participation in irrigation water management depends on certain measurable factors (X_i) and certain unobservable factors (ε_i). The ordered Probit model was therefore estimated for the polychotomous dependent variable with four categories.

Following Wooldridge (2002:540-5), the ordered Probit model for Y (conditional on explanatory variables X_i) can be derived from a latent variable model as follows:

$Y_i^* = \beta' X_i + \varepsilon_i$, where $i = 1,..., N$, and [5.4]

Y* is unobserved, but what are observed are threshold values of Y (Wooldridge, 2002:540-5), which in the present case would be:

$Y = 0 \quad \text{if } Y^* \leq 0$

$Y = 1 \quad \text{if } 0 < Y^* \leq 1$

$Y = 2 \quad \text{if } 1 < Y^* \leq 2$

$Y = 3 \quad \text{if } Y^* \geq 3$ [5.5]

The vector of independent parameter estimates are embedded in the coefficient vector β (Wooldridge, 2002:540-5), consisting of demographic, institutional and socio-economic factors (Tables 5.1, 5.2 and 5.3). The model adjusts better to a probability curve by using a normal distribution function to estimate the probability of a certain ranking (Greene and Hensher, 2008).

5.3 The results and discussions

5.3.1 Descriptive statistics of variables used in the models

An understanding of the household characteristics (Table 5.1) is important to contextualize farmers' behaviour in irrigation management. The average number of household members who are economically active and have indicated that they actually participate in agricultural activities is two people per household. Farming households utilize both family labour and hired labour to carry out their agricultural activities.

Table 5.1. Description of continuous variables, Mooi River Irrigation Scheme, 2013

Variable	Total sample (n=307)	Scheme members (n=246)	Non-scheme members (n=61)
Average age of household head in years (AGE)	56.99	56.50	58.80
Average number of household members who do agricultural work (FARMLAB)	2.29	2.30	2.25
Average number of years in formal education (YRSEDUC)	2.52	2.30	3.38
Average annual income from irrigation agriculture in Rands. (IRGINCOM) (April 2012 –April 2013)	5694	5878.00	3807.00
Average irrigation area (ha) per household (IRIG_HA)	0.275	0.306	0.148
Average area per household (ha) (irrigated plus dry land) (TOT_HA)	0.405	0.424	0.347
Average amount farmers are willing and able to contribute for irrigation maintenance per year in Rands (AVE_AMT) (April 2012-April 2013)	100.35	112.55	51.14
Average household's non-farm income in Rands (NON_FARM)	17425.18	16956.54	19315.08
Number of days without consistent supply of water per week (NOWAT)	3.11	3.11	3.13

Source: Survey data, 2013

The average size of irrigation land accessed per household is 0.275ha. This area increases to 0.405ha per household after adding both irrigated and dry land fields that a household has use rights outside the scheme. With regards to willingness to contribute finances towards canal maintenance, those who irrigate within the scheme (scheme-members) have a higher willingness to pay (R112.55/farmer/year) than those who irrigate plots located outside the scheme boundaries (non-scheme members) (R51.14). The difference between the two groups lies in the fact that the land being irrigated by the latter group was not part of the original infrastructure design of the irrigation scheme; this poses a possible water constraint to the land originally meant to be irrigated from the canal. However, irrigation of plots outside the scheme is necessitated by shortage of irrigation land within the scheme. Although, agricultural income levels are higher for scheme members (R5878.00 per/year) than non-scheme members (R3807 per year), like other schemes, they are generally lower than expected (Cousins, 2013; Sinyolo et al., 2014a). However, the income differences between the groups cannot entirely be attributed to water access alone because some sources of variation like farmer training, access to land and institutional aspects could not be controlled. A detailed summary of the categorical variables is presented in Tables 5.2 and 5.3 for the response and explanatory variables respectively.

Table 5.2. Description of categorical variables, Mooi River Irrigation Scheme, 2013 (n=307)

Response variable (Ordered categorical)		**Total**	**Percentage (%)**
Farmers' intensity of participation in common water management (LPARTIC)	0= not participating at all (none)	54	17.6
	1= not participating fully (poor);	145	47.2
	2= participating as an ordinary member (good);	92	30.0
	3= participating as a committee management member (very good)	16	5.2

Source: Survey data, 2013

Table 5.3. Description of categorical variables, Mooi River Irrigation Scheme, 2013 (n=307)

Explanatory Variables	Units	Total sample	Percentage (%)
Gender of household head (GENDER)	1=Male	84	27.4
	0=Female	223	72.6
Training in irrigation water management (TRAWAT)	1=Yes	111	36.2
	0=No	196	63.8
Membership of individual irrigators to a Water User Association (WUA_MEB)	1=Yes	26	8.5
	0=No	281	91.5
Member has been involved in water-related conflict in the past year (CONFLC)	1=Involved	210	68.4
	0 =Not	97	31.6
Membership to a group/cooperative that uses water (GRP_MEB)	1=Yes	75	24.4
	0=No	232	75.6
Mode of water supply (IRRTYP)	1=Gravity	228	74.3
	0=(Pump)	79	25.7
Position of block along the main canal (BPOSITN) dummies	BPOSITN1(Upper)	62	20.2
	BPOSITN2 (Middle)	112	36.5
	BPOSITN3(Tail-end)	133	43.3
Whether user often draws water directly from the Mooi River (DIR_RIV)	1=Yes	129	42.0
	0=No	178	58.0
Whether there is need for water measurement devices in the area (WAT_MST)	1=Yes	136	44.3
	0=No	171	55.7
Perception of irrigation water adequacy (ADEQCY)	1=Adequate	64	20.8
	0= Inadequate	243	79.2
Perceived effectiveness of the committee members (COMIT_EF)	1=Effective	188	61.2
	0=Not effective	153	49.8
Frequency of attending water related meetings (FREQM).	1= Regular attendance	198	64.5
	0= less regular or not at all	109	35.5
Whether the respondent is a full-time farmer or not (OCCUP)	1=Full-time farmer	174	56.7
	0=Part-time/has other full time income generating occupation	133	43.3
Perception of infield water distribution (WAT_PERC)	1=fair	105	34.2
	0=Unfair	202	65.8

Source: Survey data, 2013

The majority of the respondents were women (72.6%), indicating active involvement of women in smallholder irrigation crop farming and 56.7% of the respondents were full-time farmers. The general perception among farmers was that irrigation water supply was inadequate and unfairly distributed as reported by 79.2% and 65.8% of the irrigators respectively. Furthermore, a significant number of respondents (68.4%) have also been involved in water-related conflicts in the area. The identified challenges might have a negative effect on farmer participation in collective management of irrigation. Both the continuous and the categorical variables in Tables 5.1, 5.2 and 5.3 have been used as explanatory variables to estimate the Tobit and the ordered Probit regression models. The descriptive statistics of the variables used to construct the indices are presented in appendix 5.

5.3.2 Measures of participation in collective activities

Seven principal components were extracted using Pearson correlations. By applying the Kaiser criterion, three components that had Eigen values greater than one were retained. Table 5.4 presents the PCA results. The first principal component (PC_{CP1}) has a higher explanatory power and explains 58.67% of the variation in farmer participation in collective activities, with PC_{CP2} and PC_{CP3} explaining 21.56% and 18.05%, respectively. The three PCs explained 98.28% of the variation in the data. The PC vector of the first component is economically meaningful because, unlike the other components' vectors, none of its coefficients is negative. Since each of the variables represents participation in each different activity of scheme management, the positive weights for all the variables in the first component vector can be taken as evidence that PC_{CP1} represents the aggregate variations due to the differing degrees of participation; hence PC_{CP1} was retained and then used to generate the participation index. The first retained component accounts for such a large percentage of the variance in the variables that it can be used alone without much loss in information (Manyong et al., 2006).

Table 5.4. Collective participation index generation using PCA, Mooi River Irrigation Scheme, 2013 (n=307)

	Principal Component (PC)		
	PC_{CP1}	**PC_{CP2}**	**PC_{CP3}**
Eigenvalues	4.55	1.67	1.40
% of variance explained	58.67	21.56	18.05
Cumulative % of variance explained	58.67	80.23	98.28
Variables	**Factor loadings**		
Providing labour for main canal cleaning (CANCLEN)	**0.5095**	**-0.4289**	0.2288
Canal repairs (RPCANAL)	**0.7016**	0.2364	0.0517
Repair of infield distribution canals (INFILDCA)	**0.5924**	-0.3814	0.3153
Pump repairs (REP_PUMP)	0.1285	**0.4917**	**0.5918**
Contribute funds for pump repairs (FUNDPUM)	0.1149	0.3301	**0.6908**
Contribute towards Water User Association (FUNDWUA)	**0.4579**	0.3540	0.1204
Attend water-related meetings (ATTMEET)	**0.5720**	**-0.4129**	0.1925
Attend irrigation training (ATRAING)	**0.5834**	0.2172	-0.0578
Participating in meetings (IDEAS_IN)	**0.6791**	-0.0745	-0.0039
Engage water authorities (ENGAGE)	**0.6004**	0.1742	-0.2319
Disseminate water-related information (INFODISTR)	**0.5202**	**-0.4912**	0.0811
Informally train others on water management (TRAINWAT)	**0.6233**	0.2104	0.0130
Report unlawful use of water (RPT_UNLAW)	**0.5983**	0.2815	-0.3415
Report equipment theft (RPT_EQUP)	**0.6005**	0.3289	**-0.4057**
Report damages and leakages (RPT_LKGS)	**0.5860**	-0.2913	-0.1487

Notes: Five-point Likert scale values are: 0 = never been involved; 1 = low involvement; 2 = Average; 3 = High; 4 = Very high
Source: Survey data (2013)

This first component (Table 5.4) is dominated by farmers' involvement in canal repairs as well as participation in decision making activities. This indicates that the farmers who participate in water management are more involved in labour-based activities like canal repairs and maintenance. Such farmers are also involved in complementary activities like decision making through participating in meetings, reporting infrastructure theft as well as engaging authorities to resolve water-related challenges in the scheme. Since most of the activities in management of communal irrigation schemes are complementary in nature (Fujiie et al., 2005), they should therefore be viewed wholly, and water users must be encouraged to participate equally in all activities because failure or success of a particular activity affect the performance of the others. This can be an effective approach to ensure sustainable management of communal smallholder irrigation schemes.

It is also important to note the high factor loading of irrigation training as a complementary activity in scheme management. Most of the training is informal and mainly “farmer to farmer” through irrigation information sharing. Informal training is very critical at smallholder level where access to extension services is at times a constraint (Cousins, 2013). Possible strategies to improve informal learning include short courses in crop production, irrigation management and farmers’ days that can also facilitate information diffusion among irrigators at scheme level.

5.3.3 Determinants of collective participation in irrigation water management

Following Manyong et al., (2006) a PCA generated index was used as a dependent variable to estimate a two-limit Tobit regression. The index of farmer participation (PC_{CP1}) in collective water management activities was the dependent variable in the Tobit regression model. To ensure that the Tobit regression is correctly specified, post-estimation tests were conducted. The test for multicollinearity among the explanatory variables was assessed using Variance Inflation Factors (VIF), which were all below 10, with an average of 1.41. The robust standard errors were also estimated to correct for heteroskedasticity. The importance of testing that the disturbance term is normally distributed comes from the fact that the standard tobit estimator is not consistent if the disturbance term is not normally distributed. Violation of the normality assumption results in biased and inconsistent estimates. The Jarque-Bera test for normality of the residuals was therefore performed. The results of the Tobit model are presented in Table 5.5.

Combinations of socio-economic, institutional and resource related variables influence farmer participation in collective activities. The results indicate that location of plot (BPOSITN), income contribution towards infrastructure maintenance (AVE_AMT), income from irrigation farming (IRGINCOM), total household land ownership (TOT_HA), frequency of attending irrigation management meetings (FREQM), training in irrigation management (TRAWAT), whether farmer has been involved in water related conflicts with the farming 2012/13 season (CONFLC), farmer perception on the adequacy of irrigation water (ADEQCY), perception of committee effectiveness (COMIT_EF), amount of labour per household (FARMLAB) and years of formal education (YRSEDUC) significantly affect farmer participation in collective activities (Table 5.5).

Table 5.5. Determinants of collective participation (Tobit results), Mooi River Irrigation Scheme, 2013 (n=307)

	Tobit regression		
Variables	**Coef.**	**Rob Std. Err**	**VIF**
AGE	-0.0032	0.0044	1.35
SCH_MEM	0.2355*	0.1251	1.19
IRRTYP	-0.1318	0.1393	1.89
BPOSITN1	-0.0269	0.1185	1.56
BPOSITN3	0.2721*	0.1586	2.73
AVE_CONT	0.0014***	0.0005	1.29
IRGINCOM	0.0001***	0.0001	1.29
TOT_HA	0.2739***	0.0847	1.09
WUA_MEB	0.2066	0.1795	1.06
TRAWAT	0.3832***	0.0957	1.23
NOWAT	0.0521	0.0637	1.63
INCE~X	0.0397	0.0827	2.32
CONFLC	0.1175***	0.0455	1.12
ADEQCY	0.0706	0.0546	2.10
COMIT_EF	0.1565***	0.0423	1.22
NON_FARM	0.0001	0.0001	1.24
GENDER	0.1650*	0.0975	1.10
YRSEDUC	-0.0436***	0.0143	1.33
_cons	-0.9590	0.3716	
sigma	0.7712	0.0297	
F(18,288)	10.55		
Prob>F	0.000***		
Pseudo R^2	0.1657		
Uncensored observations	299		
Left censored observations	6 (Minimum ≤ -2.38)		
Right censored observations	1 (Maximum ≥2 .03)		

Notes: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.
Source: Survey data (2013).

The results indicate that participation in collective activities more likely influenced by farmers' plot location within the scheme. Irrigators located at the tail-end (BPOSITN3) are more likely to participate in collective activities than their counterparts in the head section. This can be due to unequal distribution of water among head and tail-end farmers, with the latter experiencing more water stress and hence lower incentive to participate than their head counterpart. This is consistent with the finding by Mbatha and Antrobus (2008), whose study noted that physical location of farmers along a watercourse, where water resources are diverted individually, contributes to economic inefficiencies due to resource misallocations, *ceteris paribus*. This suggest the need to focus on localised institutional arrangements to address distribution of water among head and tail-end farmers, which might improve participation in collective activities. This must also be accompanied by improving the amount of irrigation water available to the farmers.

The coefficients for the income a farmer receives from irrigation farming and the amount an individual farmer contributes annually towards water management activities are statistically significant at the 1% level. This makes economic sense that farmers who receive more income from irrigation farming are more willing to participate in collective activities than those that receive less. Income generated in irrigation farming can be an indicator of the incentives available for farmers to participate in irrigation activities. Furthermore, irrigation training (TRAWAT) has an influence on farmer participation. Farmers with some form of training in water/irrigation scheme management participate more in scheme management activities. This highlights the importance of farmer training as being key to improving collective water/ irrigation scheme management.

The total household irrigation land (TOT_HA) is more likely to affect farmers' participation in water management activities. As the size of irrigation land increases, demand for reliable water supply increases, and hence more effort is required by the farmer to achieve this. In the MRIS, irrigation water is not allocated according to land size per farmer or type of crops planted, but is based on a roster that allocates specific number of irrigation days per block. Once the water gets to the block, it is then accessed on a "first-come first-take" basis, with a possibility of depriving water to irrigators who start irrigating late or are at the tail-end of the fields or canal. This is a possible indicator of both technical and institutional failure in the scheme. The system should have been designed with proper water measurement devices to regulate flow allocation per farmer, enforceable at field level. Water meant for late irrigators or those not available to irrigate should rather be stored in the balancing dams /reservoirs for future use, instead of being used by a few farmers.

The conditions for successful collective action suggest that the establishment of the right institutions can create incentives that would make cooperation the rational choice. It has however been observed that, while these conditions are common to many successful collective action efforts (Agrawal, 2001), there may be other factors that influence the behaviour of people. As such, some of the institutional determinants of participation in collective activities include membership to the scheme, perceived effectiveness of the scheme and block committees and the perceived occurrence of water related conflicts in the scheme. Water users who are members of the scheme (SCH_MEM) and those who perceive the existing scheme committee to be effective in managing irrigation water resources are more likely to participate in collective activities. Rule enforcement is important to minimise water related conflicts, as such farmers who perceive water related conflicts to be less, also participate more in collective activities. Furthermore, farmers with lower levels of education are less likely to participate in collective activities than those with better formal education. Since early 2012, the Department of Water Affairs (DWA) has been offering capacity-building workshops to WUA committee members in the MRIS, in which some aspects of collective management of water are covered. Through attending water management meetings, non-members of the WUA can benefit from those that are currently attending the capacity building workshops. The need for functional support institutions at local level is therefore noted, the absence of which might result in lack of cooperation by members. Intensity of participation of individual respondents in collective water activities was analysed, and the findings are presented in the following section.

5.3.4 Participation intensity in irrigation water management

The study expanded on the commonly used concept of participation, mostly measured as a binary choice variable, which is often critiqued for losing valuable information about intermediate-level collective action. The level of participation was based on the individual participation status as observed during the time of data collection. Respondents indicated their level of involvement in water management at local level and were grouped into four groups, as presented in Table 5.2. Participation intensity increases from not participating at all to high levels of participation as committee members. An ordered Probit model was used to identify the determinants of participation intensity by the respondents, and results are presented in Table 5.6.

Table 5.6. The determinants of participation intensity in managing small-scale irrigation, Mooi River Irrigation Scheme, 2013 (n=307)

Variables	Estimated Coefficients	Marginal effects (dy/dx) when LPARTIC equals			
		0	1	2	3
AGE	0.0003	0.0001	-0.0001	0.0001	0.0000
SCH_MEB	0.2021	-0.0454	-0.0264	0.0637	0.0081
IRRTYP	-0.2544	0.0535	0.0395	-0.0815	-0.0115
BPOSITN1	-0.0381	0.0081	0.0058	-0.0122	-0.0017
BPOSITN3	-0.1882	0.0401	0.0283	-0.0600	-0.0084
AVE_CONT	0.0031***	-0.0006***	-0.0005***	0.0010***	0.0001***
IRIGINCOM	0.0000	0.0000	0.0000	0.0000	0.0000
TOT_HA	0.2750**	-0.0578**	-0.0427**	0.0881**	0.0125*
WUA_MEB	1.8426***	-0.1622***	-0.4526	0.2825***	0.3322***
TRAWAT	-0.0394	0.0083	0.0060	-0.0126	-0.0018
NOWAT	0.2051**	-0.0431**	-0.0319**	0.0657**	0.0093*
INCE~X	0.1003	-0.0211	-0.0156	0.0321	0.0045
ADEQCY	-0.2393	0.0543	0.0303	-0.0752	-0.0094
COMIT_EF	-0.1166	0.0249	0.0175	-0.0372	-0.0051
NON_FARM	0.0000	0.0000	0.0000	0.0000	0.0000
GENDER	0.1806	-0.0362	-0.0308	0.0581	0.0089
YRSEDUC	0.0495**	-0.0104**	-0.0077**	0.0159**	0.0022*
/cut1	-0.5040				
/cut2	1.0459				
/cut3	2.7138				
Number of observations	= 306		Brant test for parallel line assumption		
Wald Chi-square (17)	= 93.71		Chi-square	= 24.12	
Prob > Chi-square	= 0.000		D.F	= 38	
Pseudo R2	= 0.1455		P >Chi-square	= 0.867	
Log pseudo likelihood	= -307.22				

Notes: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.
Source: Survey data, 2013

Before interpreting the results of the full model, tests for model fitness were done. The ordered Probit model has a good fit to the data, as shown by a strong probability of the Chi-square (p=0.000). The parallel line assumption of proportional odds was also tested using the Brant test. The results fail to reject the null hypothesis that the model without predictors is as good as the model with the predictors. Since the model did not violate the parallel line assumption, its use in this study was justified.

The results of the ordered Probit model indicated that irrigation type (IRRTYP), average contributions towards water management (AVE_AMT), total irrigation area (TOT_HA), membership to a water user association (WUA_MEB), frequency of days without consistent supply of water (NOWAT) per week and years of education (YRSEDUC) have a statistically significant influence on participation intensity. As such, those respondents whose water supply is wholly supported by gravity are likely to participate more in water/irrigation scheme management than those with an additional system (pump system). During discussions with users, farmers highlighted that managing a pump is more complex, especially when mobilising participants to contribute money towards purchasing fuel. Water users would rather participate more as committee members in a gravity-only system that they perceive to be less challenging than the pump system. This finding point to the fact that furrow irrigation systems, relying on gravity, are easy to manage compared to sprinkler and furrow systems powered by diesel pumps. This is consistent with findings by Crosby et al. (2000) that smallholder gravity-fed short furrow irrigation systems are better managed and more efficient for smallholder farmers in South Africa. Turral et al. (2010) also noted that irrigation technology must be appropriate to meet the agricultural, managerial, financial and economic needs and capacity of system operators and farmers. This is an important decision making tool that can be of use in the current IMT and rehabilitation of smallholder irrigation schemes (RESIS) in South Africa. A focus on revitalising gravity fed furrow irrigation systems, which farmers are willing and able to manage might be a better policy option for smallholders in South Africa.

Farmers who contribute finances are likely to participate at higher levels including being committee members than non-contributors. The marginal effects indicate a negative influence of financial contributions to participation at lower level categories as ordinary members (category 0 and 1) and a positive influence of participation at higher levels as committee members (categories 2 and 3). This can be attributed to financial accountability. Irrigators who contribute finances want to ensure that their finances are used appropriately; hence such farmers participate more, even in irrigation scheme meetings, either as ordinary or committee members.

Total irrigation area (TOT_HA) and membership of a WUA (WUA_MEB) are significant predictors of participation intensity. During the time of conducting the study, there seemed to be a very low understanding of how formal institutions like WUA operate, with some respondents not even knowing what it is. Water users who are current members of the WUA participate more in water management activities than non-members. There is a 31.3% and 35.2% chance of WUA members to participate regularly in collective activities as ordinary members (category 2) and as committee members (category 3). Some WUA members in the MRIS have attended capacity building workshops (“cum-training”) offered by the Department of Water Affairs (DWA) on the importance of being active participants in water management through the local WUA. This could be the reason for a statistically significant influence of WUA membership on intensity of participation in water management. However, the detailed discourse of water institutions and their effect on water management and access at farm level are beyond the scope of this study.

Theory predicts that users’ demand for and dependence on a resource influences their participation in the collective management of that resource (Sserunkuuma et al., 2009). The increase in demand for water, represented by number of days per week without irrigation water (NOWAT) may result in irrigators putting more effort in order to access the resource. However, this might be true among the persistent irrigators who anticipate higher returns from irrigation farming, but at the same time, severe water scarcity might result in some irrigators to quit farming. This suggests that farmers recognise the role of participation in water management activities to improve their level of water supply. However, it was anticipated that a negative coefficient would have meant that a high frequency of days without water discourages participation, and eventually users would cease irrigation farming in the long-run. The fact that it has a positive influence might represent a short-run effect of water scarcity on farmer participation. In the long-run, if the problem of water persists, farmers might quit farming as revealed by negative marginal effects for lower level participants.

Intensity of participation is also influenced by the education level of the farmer. An increase in formal education increases intensity of participation in water/scheme management. Education level is a very critical aspect in making objective judgements on the importance of participation in group activities. However, farmers in the MRIS have low levels of formal education (2.5 years); hence there is a need to focus on literacy level development and irrigation training among irrigation water users as a strategy for improving collective management of the scheme.

5.4 Summary

Understanding the factors affecting farmer participation in irrigation water management is crucial for formulating sustainable smallholder irrigation policies. This is relevant given the high rate of failure of smallholder schemes following withdrawal of government funding and the step-by-step transfer of management and ownership to the users. A range of socio-economic, institutional and resource-based attributes greatly influence farmer participation in collective management of schemes. The fact that irrigators who joined the local Water User Association revealed higher participation intensity compared to non-members suggests a need to increase farmer participation in formalised institutions that also expose them to water management training, through capacity building programmes presented by the government and other initiatives.

Technical interventions in the management of communal schemes, such as infrastructure refurbishments and upgrading of scheme capacity, need to be complemented by institutional interventions. This can be a positive step towards deepening the irrigation management transfer process, and building the capacity of water users through targeted training. Institutional arrangements in irrigation scheme management must also be tailor-made to take into account the low literacy levels among smallholders.

CHAPTER 6

EXPLAINING VARIATION IN SMALLHOLDER IRRIGATION WATER VALUES: A RESIDUAL VALUE APPROACH[4]

6.1 Introduction

The chapter aims to estimate irrigation water values using the residual value method as a basis to explain variation in irrigation water-use at smallholder level. Factors influencing variation were identified. The chapter is presented as follows: the next section presents the methodology. The results and discussion are presented in section 6.3, followed by the summary of the results in section 6.4.

6.2 Methodology

6.2.1 Conceptual framework

Valuation of irrigation water can be explained from the neoclassical theory of the firm. Although the behaviour of the firm may be characterised in a number of ways, focus of this study shall be on profit maximisation. A profit-maximising firm, operating in a competitive environment, uses an input to the point where marginal revenue gained from an additional unit of a specific input equals the marginal cost of obtaining the input (Gardner and Young, 1983; Young, 2005). By adapting the product exhaustion theorem for residual valuation, economic value of a single un-priced good such as water entails isolating that portion contributed by water to the total value of the product from the contribution of all other inputs that go into the production process (Young, 2005). The theorem postulates that under competitive equilibrium, the total value of the product can be divided into shares, so that each resource is paid according to its value of marginal product and the total value of the product will be exactly exhausted by the distributive shares (Scheierling et al., 2004). In the case of smallholder farmers in South Africa, some markets are either absent or dysfunctional, while others operate at expected levels. The study, therefore, applies the residual valuation method

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[4] This chapter gave rise to the following manuscript: Muchara B, Ortmann GF, Mudhara M and Wale E. Valuation and management of smallholder irrigation water in the Mooi River Irrigation Scheme of KwaZulu-Natal Province: A residual value approach. (Accepted pending corrections: *Agricultural Water Management*)

to impute returns left to water, in an environment where no market for water exists. In this case, the residual value method assumes that if all markets are competitive, except for water, the total value of production equals the opportunity costs of all inputs (Scheierling et al., 2004). Thus, in using the residual method, after attributing the values of all the resources except water to the respective inputs, the rest can be attributed to water.

Reliable estimates of water values can be an important decision making instrument in the water sector. According to Hussain et al. (2007), water values can help in: investment decisions in water resources rehabilitation and for cost-benefit analysis of water-based projects, policy decisions on water allocations and re-allocations among users, assessing the socio-economic impacts of water management decisions, designing water pricing policies, and comparing performance of irrigation schemes.

6.2.2 Study area, sampling design and data collection

This was a follow-up study, which came after the realisation that data collected during the initial survey of 307 farmers could not accurately quantify individual input usage and yields due to reliance on recall information. A sample of 60 smallholders was, therefore, drawn from the initial survey of 307 farmers that had been interviewed during the first survey. To ensure that a representative sample was drawn, the scheme was stratified into three segments (upper, middle, and tail-end) based on positions of individual farmer's irrigation plots along the 20.8km main conveyance canal. The stratification was also consistent with the scheme's weekly water allocation roster, where farmers in the upper, middle or tail-end sections access water on specific days of the week. Proportional sampling across the scheme also ensured variability and reasonable inference of the data at scheme level. Selection of the farmers was also based on: (1) willingness to participate in the data collection process for the entire crop cycle, (2) whether the farmer was full-time and actively involved in irrigation farming in the scheme, and (3) whether the farmer was targeting to maximise returns from the farming activities to meet marketing and home consumption needs. A data collection form (Appendix 3) was used to extract data from the sampled farmers. The form contained all possible farming activities that farmers engaged in, including land preparation, planting, weeding, fertiliser application, irrigation, and marketing activities like grading and packaging. Interviews were conducted at farmers' fields on a weekly basis to ensure easy tracing of activities by reducing the recall period. In cases where some farmers were not in the fields on the scheduled day of interview, follow-up interviews were done at homesteads or through phone calls to document the activities of the week.

The input-output data requirements for application of the RVM led to the adoption of a more intensive weekly data collection procedure from land preparation to harvesting of the crop. The labour demand and complexity of monitoring and collecting weekly data from farmers also influenced the size of the sample. The sampling and the data collection procedure aimed to reduce the shortcoming of the RVM in underestimating or overestimating water values depending on the accuracy of the data used during the analysis (Young, 2005); hence the initial once-off survey data could not be used in the water valuation model (i.e.,RVM).

6.2.3 Valuation of smallholder irrigation water

Several water valuation techniques are available depending on the specific use of the water and the purpose for which the information is required. Al-Karablieh et al. (2012) noted three groups of water valuation methods, namely (1) methods that infer water value from information based on water-related markets and benefits where value is derived from rentals and sales of water rights; (2) methods relying on the use of derived demand for water as an intermediate good, where water is assessed from the producers' point of view; and (3) methods that estimate water values from direct consumer demand as in the case of agricultural and industrial use.

Some of the methods that are widely applied in water valuation where water markets are non-existent or dysfunctional include the production function method, RVM, change in net income approach (CNI), conjoint analysis, cost-based approaches, optimisation methods using mathematical programming, and the value-added method derived from computable general equilibrium (CGE) (Young, 2005). The economic valuation of water can also adopt environmental approaches like hedonic pricing and contingent valuation method (CVM). Each technique has its challenges, with optimisation techniques being criticised for over-estimating water values (Young, 2005; Al-Karablieh et al., 2012), while CGE specification requires aggregation which may not be sufficient for local conditions (Al-Karablieh et al., 2012).

The major challenge in deriving economic values of agricultural water in the absence of markets is separating the returns of water from those that should be allocated to other inputs like labour, agrochemicals and land (Hussain et al., 2009). Although the most scientifically accepted methods of water valuation are those based on market behaviour (Hussain et al., 2007; Speelman et al., 2008; Speelman et al., 2011), these are not well suited to smallholder farmers in the study area because of non-existence of water markets, which is provided free by the government.

By assuming competitive markets for all production inputs except for water, the total value of production equals the opportunity cost of all the inputs (Young, 2005; Lange and Hassan, 2006; Berbel et al., 2011). This view suggests that the residual value of water can be estimated even if water is a scarce resource and crops are irrigated with deficit or supplementary irrigation because a water value is assigned once the remaining inputs get allocated their market costs (Berbel et al., 2011).

The mathematical expression of output (Y) with respect to a vector of inputs (X) is shown in equation [6.1].

$$Y = f\ (X_{m}, X_{h}, X_{f}, X_{l}, X_{w}, X_{e} X_{ld}) \qquad [6.1]$$

Where Y = Output (Yield/ha)

X_m = Machinery/ha

X_h, = All agrochemicals except fertilisers (herbicides, pesticides etc.) /ha

X_f = Fertilisers/ha

X_l, = labour/ha

X_w, = Water/ha

X_e =Transport/ha

X_{ld} =Land (ha)

Expressing the function in terms of total value of production, equation [6.1] is written as:

$$(Y*P_y) = [(VMP_{mc}*X_m) + (VMP_{hc}*X_h) + (VMP_{fc}*X_f) + (VMP_l*X_l) + (VMP_w+X_w) + (VMP_e*X_e) + (VMP_{ld}*X_{ld})] \qquad [6.2]$$

VMP is the value of marginal product of each input (X_i). In order to operationalize equation [6.2], Young (2005) posited three assumptions, namely: the value of the product be assigned to each input according to the marginal productivity except the input under investigation (water); the opportunity cost of non-water inputs are given by their market prices; and that profit maximising behaviour occurs at farm level.

$$(Y*P_y) = [(P_m*X_m) + (P_h*X_h)+(P_f*X_f)+(P_l*X_l)+(P_w+X_w)+(P_e*X_e))+(P_{ld}*X_{ld})] \quad [6.3]$$

Where $(Y*P_y)$ represents the value of product (Y) computed for a unit surface (hectare) equated to the total cost of all inputs. The residual value of water (RV_w) is calculated as the difference between the total value of output$(Y*P_y)$ and the costs of all non-water inputs.

$$RV_w = (Y*P_y)-[(P_m*X_m) + (P_h*X_h)+(P_f*X_f)+(P_l*X_l)+(P_w+X_w)+(P_e*X_e)+(P_{ld}*X_{ld})]/X_w) \quad [6.4]$$

Hence;

$$RV_w = \frac{TVP - \sum P_i X_i}{X_w} \quad [6.5]$$

Although the RVM can derive meaningful results, Scheierling et al. (2004) and Young (2005) highlighted the possibility of over- or under-estimation of the value of water. Over-estimation occurs when returns that should be allocated to other inputs are allocated to water (Young, 2005). This could also happen when any input (variable or fixed) is left out due to data constraints. Similarly, misallocations of returns from water to non-water inputs result in under-estimation of the value of water (Haab and McConnell, 2002; Lange and Hassan, 2006). The RVM is sensitive to variable omissions and use of inaccurate prices (Speelman et al., 2008; Al-Karablieh et al., 2012). The other challenges of RVM can emanate from the specification of the production function, assigning prices to inputs and outputs, measuring and pricing inputs and output and the case of measuring labour and human effort (Hussain et al., 2009). In order to improve data precision and reduce the estimation errors, the present study used data collected on a weekly basis by field assistants from selected farmers and plots over a full cropping season. However, the inputs captured were not exhaustive, hence a possibility of over-estimation. For instance, farm management could not be captured due to the non-separability of family labour and operational cost of management at smallholder level.

The study also aimed to analyse how different factors (age as a proxy for farming experience, area planted, location of the farmers' plot within the scheme, frequency of irrigation and number of crops grown) influence variability of water values at smallholder level. It is argued here that the possible over-estimation of water mentioned above does not affect the distribution of the response variable (water values) as the variable left is for all sampled plots.

Analysis of variance using the General Linear Model (GLM) procedure in IBM SPSS statistics 21 was used to identify factors that influence variation in water values. The magnitude of the effects was determined by computing Partial Eta squares. The value of the measure of association (partial eta squared) is interpreted as the proportion of variance in the dependent variable that is attributable to each effect (Pierce et al., 2004). The use of Type III sums of squares option tests the unique contribution of each independent variable by removing effects of all other independent variables (McCullagh and Nelder, 1989; Pierce et al., 2004). Furthermore, Type III sums of squares of the GLM ensures that both continuous and categorical variables from either balanced or unbalanced samples are not problematic (Green and Wind, 1973), hence its adoption in this analysis. The process of quantifying factors influencing variation enhances an understanding of the challenges of water allocation at a local level and influences water management decision making processes at a local and national level (Hussain et al., 2007; Speelman et al., 2011).

6.2.4 Description of variables

Production and marketing data were collected between June and December 2013, which according to scheme participants was the peak irrigation period, with minimum rainfall. Weekly record sheets were compiled for irrigation potato farmers, and used to quantify and value costs used in production and marketing of potatoes as specified in equation 1. Some of the costs include; land preparation, agrochemicals, labour, harvesting and marketing. Based on the 2013 observed prices, farmers in the study area faced land preparation costs of ZAR1 495/ha. Farmers relied on hired-in tractors from government bodies, either the local office of the Department of Agriculture and Environmental Affairs or the local municipality. Conventional chemical fertilizers were used by most farmers, both as basal dressing and as a top dressing at an average market price of ZAR350/50kg bag. There was limited use of conventional crop protection chemicals among potato farmers in the area. A large number of farmers in the MRIS started potato production in 2011, and by 2013 there were still few or no severe cases of potato pest and disease outbreaks in the scheme. This has greatly influenced the low use of conventional pesticides, fungicides and insecticides by farmers in the scheme.

A combination of family and hired labour is commonly used by farmers in MRIS. Payment for hired labour was in cash. Where labour is hired in to assist harvesting by farmers, the same labour performs packaging and grading to prepare the produce for the market. As such, there was no additional labour hired for marketing of produce. The price of farm labour in South Africa is regulated by the government. The minister of labour has the power to review and increase minimum wages annually and is often linked to the consumer price index (CPI) (RSA, 2013). However, this only applies to minimum wages and not actual wages. Parties are still at liberty to negotiate for better increases, using the minimum as a floor. As at December 2013, the minimum farm wage was ZAR105/day (RSA, 2013). Lange and Hassan (2006) noted that the minimum wages in developing economies may be substantially higher than the marginal value of unskilled and semi-skilled labour especially at smallholder level. This poses a challenge for valuing labour in the MRIS. Following Lange and Hassan (2006), labour cost was therefore adjusted by using the observed wages being paid to hired labour in the scheme, which was ZAR30/day as at December 2013. While farmers in the MRIS tend to hire labour for some operations, irrigation was mainly done using family labour. This is due to uncertainties in water supply to the plots. More often, some farmers in the middle and tail-end section of the scheme resort to night irrigation to improve irrigation water access, making it difficult to rely on hired labour for irrigation purposes. Additional costs include packaging material, which was valued at ZAR1,74/10kg pocket and market research cost valued at ZAR60,00 per farmer per crop cycle. The average producer price of potatoes in the study area was ZAR35,02/10kg bag. Crop revenue was therefore calculated by multiplying quantity harvested by the average farm-gate price.

In addition to water, land is one of the main production inputs without a market value within the study area and its monetary value could not be attached. This is because land is communally owned and allocated to community members by traditional leaders without financial payment for the resource. Some members also inherit land from their elders, posing a potential challenge to attach a market value to land as a production input. Furthermore, another challenge emanates from the fact that value of land is also based on water access rights; hence, the value must incorporate value of water, whose financial value could not be ascertained due to absence of water markets in the area.

There are no water measurement devices in the scheme under study; hence, more intensive methods to estimate quantity of water were applied. Firstly, SAPWAT 3, which is a computer based programme, was used to estimate seasonal irrigation water requirements. The estimation is based on statistical methods and biophysical models that govern water uptake and use, with the advantage of producing accurate estimates once it has been calibrated for a specific area (Heerden et al., 2009). Secondly, field research assistants were hired to measure quantity of water applied to the crop using a Global Water Flow Probe. The Global Water Flow Probe relies on the velocity-area method, which involves measuring mean velocity of water at various cross-sections along a channel (Gomo et al., 2014b). Velocity-area method is recommended for temporary flow measurements such as research studies and in the absence of hydraulic structures (Yoder, 1999; Martin, 2009; Gomo et al., 2014b). Selection of the velocity area method was based on availability of the required instruments to the researchers and the ease of computing the outputs. The approach was also regarded as less costly because no new installations or construction are required along the canal, yet it still manages to give good estimates of water flow (Yoder, 1999; Forero and Fulton, 2013).

The main focus of the study was infield water application; hence, measurement was done along infield canals that feed directly to individual crops. The discharge (Q) of a canal is the product of its cross-sectional area and the mean velocity of the water passing a given section (Forero and Fulton, 2013), which is determined by the following equation:

$$Q = V \text{ x } A \qquad [6.6]$$

where Q = discharge [$m^3.s^{-1}$], V = average velocity [$m.s^{-1}$], and A = flow area [m^2].
The Global Water Flow Probe directly gives velocity readings (m/s^{-1}). The canals in the MRIS are parabolic in shape and hence flow area was calculated as follows, following (Gomo, 2012):

$$A = 2/3\ (TY) \qquad [6.7]$$

where A is the area (m^2), T is the top width of flow, and Y is flow depth; all measured in metres.

The quantity of water applied was estimated by multiplying discharge (Q) by the duration of the cycle (hours) and the number of cycles from planting to harvesting of the crop. Average quantity of water applied by a farmer per cycle was used, acknowledging the challenges of keeping track of recording multiple fluctuations in flow per each time period (0.5hr or hourly) during the irrigation process. Such precision could not be attained during the study due to time constraints and the cost associated with the data collection procedures required to monitor such fluctuations as recommended by Forero and Fulton (2013). However, following the study by Schuster (1970) which noted that in many irrigation systems, water measurements are made only once a day, or only when some mechanical change in supply or delivery has been made. Although it was beyond the scope of this study, the use of automated permanently fixed water measuring devices along the canal instead of the potable Global Water Flow Probe could have enabled monitoring the fluctuations of the flow more precisely.

6.3 The results and discussion

6.3.1 Descriptive analysis of production and marketing activities in MRIS

The average size of land under potatoes was 0.2ha per farmer, with a minimum of 0.1ha and a maximum of 0.4ha. All the 60 sampled farmers planted the Mondial potato variety. Labour and input utilisation for potato production in the MRIS varies across the sampled farmers with averages presented in Table 6.1.

Table 6.1. Labour use and tradable inputs in irrigated potatoes, Mooi River Irrigation Scheme, 2013 (n = 60)

Cost breakdown	**Average cost (ZAR/ha)**
Labour:	
Clearing	556
Weeding	1091
Irrigation labour	775
Chemicals/Crop protection*	284
Harvesting	938
Total labour costs	**3644**
Tradable inputs:	
Land preparation/Tractor hire	1495
Seed cost	6655
Irrigation cost (contributions to buy repair material)	524
Fertiliser cost	2182
Packaging cost	1233
Transport cost	1997
Marketing	262
Total tradable inputs	**14347**
Average variable cost (ZAR/ha)	**17991**

Notes: Exchange rate was US$1:ZAR10.91 as at December 2013
Source: Survey data, 2013

Based on the individual cost structure in Table 6.1, gross margins (GM) were calculated by subtracting costs from gross returns. The gross margins shown here do not include a share of fixed or overhead costs, such as canal maintenance, repair or replacement of tools and equipment. Gross margins, both positive and negative, for the 60 farmers in the sample are summarised in Table 6.2.

Table 6.2. Profitability of potato production in Mooi River Irrigation Scheme, 2013 (n = 60)

Plot location	No. of sampled farmers per section	Growers with negative gross margins n (%)	Growers with positive gross margins n (%)	Gross margin range (ZAR/ha)	Average positive gross margins (ZAR/ha)	Average negative gross margins (ZAR/ha)
Upper	12	3 (25%)	9 (75%)	-12765 – 22987	13256	7441
Middle	25	10 (40%)	15 (60%)	-28213 – 28486	9754	7964
Tail-end	23	15 (65%)	8 (35%)	-29522 – 16092	6317	9219
Total	**60**	**28 (47%)**	**32 (53%)**	**-29522 – 28486**	**10092**	**8575**

Source: Survey data, 2013

The gross margin (GM) represents the amount of total sales revenue that the farm enterprise retains after incurring the direct costs associated with production of the commodity. Caution in interpreting the GM results is required, considering that GM does not produce the profit (or loss) generated by the enterprise, as it does not take into account the fixed costs (overheads) that may be attributable to the overall business.

The study showed that GM decreases from the head section of the scheme towards the tail-end section of the scheme. The majority of farmers, 75% and 60%, in the upper and middle section respectively, managed to achieve positive gross margins, compared to 35% in tail-end section of the scheme. The gross margin per grower ranged from -ZAR29 522/ha to ZAR28 486/ha (Table 6.2). Among those who had positive returns, the average GM was ZAR10 092/ha per farmer. Farmers in the MRIS grow two crop cycles per year, and an average farmer has a potential to double the current GMs, if they can manage to do two crop cycles. However, such income cannot be met by the majority of the farmers, whose land access is restricted to an average of 0.2ha per farmer, unless extra land is rented from friends and relatives whose plots are not fully utilised. Furthermore, variation in water access across the scheme also causes a decrease in GM from the head section to the tail-section. This is also compounded by the fact that tail-end farmers incur more costs in pumping water to supplement canal water, thereby lowering their GM.

6.3.2 Economic estimation of residual water values for irrigated crops in MRIS

The residual imputation method was applied to estimate water values for commonly grown crops in the Mooi River Irrigation Scheme. This was done using two different data sets. The first estimation was done using secondary data for eight crops grown in the MRIS and ssecond estimates were based on primary data for actual water applied to a potato crop measured against the actual crop margins recorded for each sampled farmer.

Irrigation water requirements for the various crops were estimated using the SAPWAT 3 model, which was developed and tested with WRC funding, and is the accepted model for use in the calculation of irrigation requirements for registration and licensing purposes by the Department of Water Affairs and Forestry (van Heerden et al., 2009). Yield levels used in the study are based on 2012/13 “Combud” estimates (DAEA, 2012) for furrow irrigated crops, hence the SAPWAT 3 derived water requirements are also based on furrow irrigation, which is the irrigation system used by farmers in the study area. The production and revenue figures from Combud are commonly used by the Provincial Department of Agriculture for planning and budgeting purposes. A scrutiny of the enterprise budgets revealed lack of proper quantification of water being used in the budgeting process. This is due to either less or more quantities of water being reflected in the budgets compared to area specific irrigation water requirements as estimated by programs like SAPWAT 3. This can be attributed to lack of better water estimates for each crop, grown in specific geographic locations. The SAPWAT 3 estimated water requirements were, therefore, used to impute residual water values for the different crops grown in the MRIS by applying equation [6.5] of the model. The results are presented in Table 6.3.

Table 6.3. Irrigation water values based on 2013 crop prices and SAPWAT 3 water estimates, Mooi River Irrigation Scheme

Crop	[5]**Est. Irrigation Water Requirements (IWR) (m^3/ha)**	[6]**Est. Total revenue (ZAR/ha)**	[6]**Est. Costs (ZAR/ha)**	[6]**Est. gross margins (ZAR/ha)**	**Water Values (ZAR/m^3)**
Spinach	6920	62 002	30 908	31 083	4.47
Potato	4480	74 995	62 994	12 001	2.73
Cabbage	5240	86 396	59 307	27 090	5.13
Tomatoes	7030	227 495	144 634	82 872	11.78
Maize	5170	20 500	13 834	6 666	1.31
Sweet Potato	5680	89 004	45 931	43 073	7.53
Dry Beans	4940	17 500	12 088	5 411	1.09

Notes: Exchange rate was US$1:ZAR10.91 as at December 2013.
Source: Own calculation, 2014

It is important to note that the estimated average water values are short run values under the assumption that fixed costs are sunk and are not considered in annual cropping decisions. The estimated water values range from ZAR1.09/m^3 in dry beans production to ZAR11.78/m^3 in tomato production. The estimated water values for some crops compare well with some studies while others do not. For example, Speelman et al. (2011) reported marginally lower values of ZAR3.93/m^3 for cabbages, ZAR2.51/m^3 for tomatoes and a much higher water value of ZAR9.16/m^3 for dry beans, against imputed values of ZAR5.13/m^3, ZAR11.78/m^3 and ZAR1.09/m^3 for this study respectively. Similar studies, for example, Yokwe (2009) reported a lower value of ZAR3.60/m^3 for tomatoes and Hussain et al. (2009) reported lower values of US$0.01/$m^3$ (equivalence of ZAR0.11/ m^3 in current terms) for smallholder irrigated maize in Pakistan. In this study, maize and dry beans production generated the lowest residual value of water at ZAR1.31/m^3 and ZAR1.09/m^3 respectively. The results show that high water values are associated with crops that have higher margins. This makes

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[5] Estimates for irrigation water requirements (IWR) in Tables 6.3 and 6.4 are based on SAPWAT 3 model.

[6] Estimated revenue, cost and gross margins per hectare are based on KwaZulu-Natal Department of Agriculture and Environmental Affairs enterprise budgets (Combud) for 2012/2013 (IDAEA, 2012)

water valuation results an important decision making tool, especially regarding crop choice at farm level. In the context of water scarcity, the water values can help ensure efficient allocation of water by minimising use on low value crops and redirecting the resource to alternative high value crops.

It is evident considering the variations reported by various authors that water values vary spatially and temporally. The reasons of variation in water values remain a key aspect. According to Hussain et al. (2007), possible causes of variation could be due to different irrigation management styles and a wide range of institutional arrangements governing water resource management, household demographics as well as different approaches in costing of production and marketing activities. Some of the factors affecting water values for a communally managed scheme are explained in the next section.

6.3.3 Residual water values for potatoes grown in MRIS

Water applied to potatoes was calculated as a function of number of cycles per week, total irrigation hours and the flow rate during the time of irrigation, aggregated from establishment to harvesting in cubic metres (m^3). Total water applied to the crop was also based on the location of the plots along the scheme (upper section, middle section and tail-end section), and was compared against the irrigation water requirements for potatoes, estimated using the SAPWAT 3 model. This was done to show possible variability of water values within a scheme, with the assumption that locational differences along the main conveyance canal have influence on water access and consequently on water values. Such information would help to reflect water allocation challenges among farmers within the same scheme. Table 6.4 presents actual water applied by farmers in the MRIS compared to estimated (SAPWAT 3) irrigation water requirements (IWR).

Table 6.4. Comparison of irrigation water requirements and actual water applied to potato crop, Mooi River Irrigation Scheme, 2013 (n=60)

Plot location along the main canal.	Est. crop water requirement (IWR) (m^3/ha)	Actual water applied (m^3/ha)	Irrigation performance (Actual Applied/IWR)	Performance Range (%)
Upper section	4480	4119	91.9%	32% - 174%
Middle Section	4480	2780	62.1%	20% - 135%
Tail-end section	4480	2001	44.7%	14% - 118%
Scheme Average/ha	4480	2749	61.4%	14% - 174%

Source: Survey data, 2013

The water applied to crops in the study is based on actual water accessed during the entire production cycle. Due to relatively dry conditions in the area, farmers did not indicate any deliberate cut on irrigation water applied to crops. The results show that actual water applied to the crop gradually decreases from the head/upper section to the tail-end section (Table 6.4). However, it is important to note that the overall water application is 61.4% of the estimated crop water requirement, distributed as 91.9%, 62.1% and 44.7% from upper, middle and tail-end sections, respectively. Although the literature has noted water distribution disparities among head and tail-end farmers sharing a water course (Mbatha and Antrobus, 2008), quantification of the magnitude of variation is limited especially among smallholder farmers where water use is not measured. Qualitative measures based on farmers' perception have always been used to describe the uneven water distribution among farmers where water is not scientifically measured. Some authors, for example, Hassan and Mungatana (2006), relied on farmers' estimates, which might not be accurate given their unfamiliarity of water measurement techniques and the low literacy levels among smallholder farmers in most developing countries. Furthermore, smallholder crop water values from other researchers (Speelman et al., 2008; Yokwe, 2009) are aggregated without taking into account variation within the individual schemes. A breakdown of water values based on farmer location with respect to water source helps to identify embedded multi-user institutional and management issues in water allocation at a local level. Quantification of such a disparity is important since it may have an influence on how farmers react to water regulation and enforcement agencies, especially local Water User Associations (WUAs). Lack of cooperation by farmers or water users with the local water governing bodies is mostly affected by existing water management challenges as well as incentives. In this instance, water shortages and unequal distribution in the MRIS might have a negative effect on farmer cooperation with such associations.

The irrigation water values for potatoes were estimated by dividing the net gross margins of the crop by the actual water applied. The gross margins were calculated by subtracting variable costs from gross revenues, at market prices. Water values were calculated for the three sections of the scheme (Table 6.5).

Table 6.5. Return to water for smallholder irrigated potato, Mooi River Irrigation Scheme, 2013 (n=60)

Description	**Variability for farmers with positive gross margins**				**Variability for all sampled farmers**			
	Upper n=9	**Middle n=15**	**Tail-end n=8**	**Mean n=32**	**Upper n=12**	**Middle n=25**	**Tail-end n=23**	**Mean n=60**
TR (ZAR/ha)	34 803	24 504	22 802	26 980	29 108	20 118	11 565	18 634
TVC (ZAR/ha)	20 805	14 750	16 485	16 889	20 478	17 445	15 372	17 260
GM (ZAR/ha)	13 998	9 754	6 317	10 092	8 641	2 673	-3 819	1 375
Water (m^3/ha)	4 324	3 263	2 759	3 388	4 119	2 780	2 001	2 749
Water values range								
Min (ZAR/m^3)	0.33	0.33	0.11	0.11	-4.04	-10.91	-17.57	-17.57
Max (ZAR/m^3)	5.02	12.66	8.95	12.66	5.89	12.66	6.98	12.66
Average water values (ZAR/m^3)	3.24	2.99	2.29	2.98	2.10	0.96	-1.91	0.50

Note: Exchange rate was US$1:ZAR10.91 as at December 2013.
Source: Survey data, 2013

Yokwe (2009) imputed a residual value of ZAR0.65/m^3 for a potato crop in Zanyokwe irrigation farmers in the Eastern Cape Province of South Africa, which was lower than the average of ZAR2.98/m^3 imputed in this study for MRIS farmers with positive gross margins for irrigated potato (Table 6.5). However, the value over all farmers, including those with negative gross margins was ZAR0.50/m^3, which was similar to Yokwe's estimate. As such, water values derived from reliable secondary sources based on optimal conditions may be used to infer water values for similar irrigation schemes, especially at national level, where individual water use data may not be available. Although the variation in water values within the scheme seem to have a narrow spread, the water values declined after including negative gross margins in the imputation method (Table 6.5). Since average water value is a good indicator of performance (Hussain et al., 2007), it is apparent from the high proportion of farmers (47%) with negative gross margins and consequently negative water values, that smallholder farmers in the MRIS are underperforming. Furthermore, water values may show intrinsic challenges of water allocation and management at a local level, evidenced by negative values by tail-end water users in the scheme (Table 6.5).

The water value estimates from the RVM are accurate to a certain degree, and omission of some variables like land might increase the estimates. Although this might be the case in this study, such omission exert an equal influence on the final water value figures for all sampled farmers and does not affect the variability of water values across the different users. There is need for intervention, especially to improve farmers' capacity to manage water, schedule irrigation and application of best irrigation practices among farmers who have water values close to zero or negative. However, since most smallholder farmers do not pay for water in South Africa, negative water values might also be an indicator of the extent of underperformance of government supported schemes. Of concern are farmers who applied above scheme average ($\geq$ 3380m^3/ha), but still managed negative gross margins. These farmers represented 7% of the sample and qualitative reasons for the negative gross margins were sought. Some of the reasons include crop damage by livestock at flowering stages while potato blight was reported by one farmer as the main reason she lost her crop after applying so much water. After the blight attack, the farmer continued to irrigate with the hope of harvesting a meaningful yield. However, such a decision could have been different if the farmer was paying for irrigation water, whose cost could have deterred her from continual application of water to a failing crop. To ensure maximum returns to water, irrigation management must always be supported by other scheme management and agronomic practices like fencing as well as pest and disease control which minimises crop damage. Extension support might also help to improve production decisions.

Furthermore, comparing SAPWAT 3 derived irrigation water requirements with actual water applied to a potato crop in the MRIS revealed lower irrigation performance and failure to meet the desired water application rate at smallholder level. Due to water constraints emanating from weak water management systems, farmers at the MRIS are on average applying 61.4% of the estimated irrigation water requirements. The amount applied varied among farmers, signalling the importance of more localised institutional arrangements surrounding irrigation water management at smallholder level.

In the scheme under study, water allocation among farmers was unfairly distributed, as shown by variations in volume of water applied from the head section to the tail-end sections. There was a need for mechanisms to be developed to improve the water distribution system. The relevant question for policy is how smallholder irrigation farmers can improve water management in order to raise water values and at the same time optimally allocate scarce irrigation water resources among themselves across a wide range of crops. Raising water values means an increase in water use efficiency. The current irrigation scheme revitalisation programme in South Africa might need to focus on redressing water management challenges among farmers in communally owned schemes. Improvement of system design might need to take into account the difficulties of excluding farmers who do not comply with the scheme irrigation roster from accessing or drawing water outside the agreed schedule. Whilst the MRIS revealed a case of under-application of water, over-application can happen in irrigation schemes where water supply is not a major constraint.

The residual values vary with time and location of farmers (Hassan and Mungatana, 2006), depending on the commodity being produced and market conditions, both for the inputs and outputs. The precision of data might also play a role in the imputation of water values, for instance, the value of land and management labour could not be correctly estimated in this study, which might lead to an over-estimation of water values. There is, however, an opportunity to improve the quality of the valuation results by monitoring the actual water applied to several crops over many years to establish common trends in water use at smallholder level. This also presents the need to analyse some of the factors affecting variability in water values at scheme level.

6.3.4 Irrigation water distribution and access

Water is in short supply and one day of irrigation per week has proved to be insufficient for farmers in the MRIS. Most farmers grow more than one crop in each season, with an average of two crops per farmer. During the single day of irrigation per week, a farmer has to make critical decisions on which crop to irrigate depending on the amount of water available and the condition of the crop. Some crops end up being water-stressed due to water inadequacy. According to key informants and observation of activities, some irrigation challenges in the MRIS are associated with leakages along conveyance structures, non-compliance with irrigation schedules and lack of enforcement of rules governing water use. Whilst leakages are visible along the entire canal from Block 1 to 15, tail end blocks (11, 12, 13, 14 & 15) are the worst affected. Farmers engage in unregulated irrigation practices to improve water access. These include continuous irrigation outside their scheduled days, irrigating plots outside the scheme and night irrigation. All the mentioned practices increase demand for water and deprive tail-end block members of irrigation water. Although continuous irrigation was cited as a common problem among head section members in blocks 1, 2, 3 and 4, the irrigation of plots outside the scheme boundaries is prevalent across the whole scheme.

In light of a possible increase in area under irrigation and a rise in population in the area, a detailed evaluation of whether the scheme infrastructure is still adequate to meet current peak crop-water demand might be necessary for a possible upgrade. Of concern is the failure by scheme management structures to address the water distributional challenges. However, the short term and more sustainable strategies must target to improve water management by redesigning water allocation systems and ensuring compliance among farmers in the MRIS. It is evident that the current reliance on block committees to management water is not achieving equitable distribution of the resource among scheme members. By shifting the focus from committee members, to ensure that more individuals directly take part in the management of water resources through rotational management based on weekly or monthly roster is suggested. Rotational management together with irrigation management training for farmers ensures that farmers become accountable to their actions and can therefore take part in correcting the water management challenges in MRIS.

6.3.5 Factors affecting variation in irrigation water values (Effect Size)

Identifying factors influencing variation of water values enhances an understanding of the challenges of water management at a local level, and influences allocation policies at a local and national level (Hussain et al., 2007). This is particularly important where farmers share water from a single source or channel. Local level factors affecting water values are grouped into resource-related and production-related (Hussain et al., 2007). Resource-based factors include reliability and availability of water. As such, the number of irrigation cycles (IRRIG_CYS) was used as a proxy to measure resource-related factors. However, some resource-based aspects like water quality could not be captured due to the homogeneous nature of the sample, drawing water from the same source. Production-related factors include irrigation technology, crops grown (NUM_CRPS) at farm level, land size (HA_PLT), input usage as well as water management institutions (Hussain et al., 2007; Speelman et al., 2011). Number of crops grown at farm level was therefore used as proxy for diversification and hence a mechanism to increase farm returns among smallholders, who are viewed as risk averse and participate in agriculture to meet multiple household objectives (Bembridge, 2000).

Due to challenges of water distribution across the scheme, emanating from institutional and management failures, location of the plots along the main canal (FARM_LOC) was used as a proxy of the institutional and resource management issues around water allocation in the MRIS. Due to unavailability of more detailed biophysical data for individual plots, aspects such as soil fertility, slope and drainage could not be incorporated in the model. In order to ensure maximum utilisation of water, some socio-economic factors like age and education level (EDUC) were used as proxies for farming experience and decision making capabilities, respectively.

In the General Linear Model (GLM) regression procedures, there are two ways to assess the size effect of an individual predictor (Turner, 2008). The first is based on the estimated regression coefficient and gives a measure of how much the dependent variable is a function of a change in an independent variable; i.e. the estimated regression coefficient provides the change in the dependent variable per unit change in the independent variable (Greene, 2003). This approach can also derive meaning from the standardized regression coefficients to assess the response. The standardized regression coefficient is the coefficient from a regression in which all variables are standardized (i.e., have a mean of 0 and a standard deviation of 1.0); hence, all units are expressed as "standard deviation units" (Turner, 2008).

The second way to measure the size effect of an independent variable is in terms of the variance explained by that variable (Turner, 2008), and this was adopted for this study. This was informed by the objective of the study that sought to explain the underlying factors leading to variation in water values among irrigators. This measures the proportion of variance in the dependent variable explained by the independent variable controlling for all the other independent variables (Turner, 2008). An F-test was used to determine the fitness of the GLM model, and it was accepted at the 5% significance level (p=0.016). Variance Inflation factors (VIF) were computed for the variables included in the model and the results indicated that multicollinearity was not a serious problem (VIF<10). The GLM results are presented in Table 6.6.

Table 6.6. Factors affecting variation in water values, Mooi River Irrigation Scheme, 2013 (n=60)

	Type III Sum of Squares	**DF**	**F**	**Sig. p-value**	**Partial Eta Squared**
Corrected Model	551.810	7	2.772**	0.016	0.272
Intercept	119.423	1	4.201**	0.045	0.075
AGE	11.553	1	0.406	0.527	0.008
EDUC	92.694	1	3.261*	0.077	0.059
HA_PLT	10.333	1	0.363	0.549	0.007
NUM_CRPS	0.081	1	0.003	0.958	0.000
IRIG_CYS	90.967	1	3.199*	0.08	0.058
FARM_LOC	211.484	2	3.718**	0.031	0.125
Error	1478.730	52			
Total	2074.968	60			
Corrected Total	2030.540	59			

Notes: ** and * mean statistically significant at the 5% and 10% levels, respectively.
Source: Survey data, 2013

Variation in water values across a scheme is mainly influenced by farmers' education level, frequency of irrigation and farm location with respect to the main water source. The F-Value for education (EDUC) is statistically significant at the 10% level and explains 5.9% of the variation in water values. This is consistent with *a priori* expectations that level of education would influence water utilisation. Education has an influence on farmer decision making processes. Most farmers in the MRIS grow multiple crops at each given time; hence, they always make critical decisions pertaining to water allocation across the different crops. The more the crops a farmer grows at a time, the more the constraints s/he faces in supplying adequate water to the crops. This might be attributed to the restricted access to water in the MRIS, where a farmer is allocated water one day per week. Assuming that farmers are rational, it can be argued that they allocate the water to what the farmer would regard as strategic crops for the household. This can either be based on potential revenue or household food security demands. Expectedly, such allocation has an impact on the variability of water values per crop and decision making processes have been shown to be positively influenced by farmers' education level.

Water allocation in the MRIS varies across the different sections of the scheme and among the farmers within the blocks. The major challenge affecting farmers is water access. Farmers in the upper section of the scheme receive more water than those on the middle and the tail-end sections (Table 6.4). Analysis of variance (Table 6.6) shows that 12.5% of the variation in water value is explained by farm/plot location (FARM_LOC). Plot location was used as a proxy to explain institutional challenges around water allocation and how farmers whose plots are located at different positions along the main canal have unequal water access. The statistically significant F-value explains how location further from the water source affects variation in water values (Table 6.5). This is also revealed by statistically significant F-values for irrigation frequency (IRRIG_CYS), which vary from the upper section to tail end section of the scheme (Figure 6.1). Similarly, Speelman et al. (2011) reported that coefficients for scheme location and farmers' age influenced water variability at the 5%levels of probability, while crops grown were significant at 10% level. Consequently, irrigation cycles explain 5.8% of the variation in water values. This calls for improvement in local water management systems and fair allocation of irrigation water resources.

6.4 Summary

Based on the variation in quantity of water applied, gross margins and in water values across farmers within the same scheme, the study can conclude that farmers in MRIS are underperforming. The study attributes inequitable water distribution to ineffective water management systems and institutional failures in the scheme. Negative water values could also imply the existence of negative externalities emanating from upstream users withdrawing extra water, reducing the quantity for downstream users. This provides important insights into the potential benefits of collective management of irrigation water as a common pool resource. Undoubtedly, a policy shift towards a more aggressive cost recovery strategy might fail due to the unprofitable levels of smallholder irrigation farming in South Africa. However, participative approaches make farmers accountable and more pro-active in water resource management instead of relying on external intervention, which is mainly from government.

CHAPTER 7

CONCLUSIONS, RECOMMENDATIONS AND FUTURE RESEARCH

7.1 Recapping the purpose of the research

Agricultural crop production in South Africa ranges from being purely subsistence, where production is only for household food consumption, to sophisticated irrigation systems, which are commercially oriented. However, development of the smallholder irrigation sector in most Sub-Saharan African countries has faced many challenges. This is despite the considerable potential for smallholder irrigation farming to contribute towards household food security and rural livelihoods. A review of the literature on smallholder irrigation schemes in South Africa revealed that most of them are facing operational challenges and some have ceased operation. Besides the generic challenges of input constraints, poor market access, poor access to credit and lack of technical skills, the collapse of irrigation schemes in South Africa is mainly attributed to poorly coordinated irrigation support structures. The democratic South African government initiated strategies to improve irrigation management since 1994, including irrigation management and transfer, introduction of water-user associations, scheme revitalisation and rehabilitation programmes, and finance for poor resource farmers, but little success has been achieved. Smallholder irrigation schemes in South Africa continue to face challenges due to poor governance systems, water-use insecurity, poor participation of farmers in the management of schemes, and unequal distribution of water that lead to low water productivity and values.

While irrigation farming is one of the major users of stored fresh water, availability of water is becoming constrained in South Africa. This is worsened by recurring droughts, which presents strong motivation for continuous improvement in water management in the irrigation sector. In order to ensure long-term viability of irrigated agriculture, insights into the performance of the various water management and irrigation systems are needed, together with the adoption of best management practices at scheme and national levels. There is limited research on the identification of local irrigation management challenges from an institutional perspective.

The specific objectives of this study, focused on the Mooi River Irrigation Scheme (MRIS) in KwaZulu-Natal Province in South Africa, have been to: (i) assess the water governance systems and their effect on irrigation water management; (ii) assess the implications of institutional arrangements on water-use security; (iii) assess the level of farmer participation in collective irrigation management and the factors affecting their participation; and (iv) explain the factors affecting variability in water values at farm level and implications for irrigation water management. The theoretical underpinning of the study was the New Institutional Economics, and therefore the different conceptual and empirical models are informed by this school of thought.

Firstly, the IAD framework together with Ostrom's eight institutional design principles, were applied in Chapter 3 to assess the overall performance of governance systems in smallholder irrigation farming. The challenges of poor cooperation, ambiguously-defined resource boundaries and weak complementary linkages between formal and informal institutions negatively affect irrigation management. This exposed farmers to varying degrees of water-use insecurity associated with poor sharing of irrigation water. Secondly, the extent of water-use security among irrigators was analysed in Chapter 4. A combination of Principal Component Analysis (PCA) to generate an index of water-use security and Ordinary Least Squares (OLS) to determine the institutional factors affecting it were applied on 307 randomly selected farmers. Thirdly, based on the literature, it was imperative to examine collective action issues in smallholder irrigation as a major driver towards scheme sustainability. As such, the third empirical chapter applied the collective action theory to determine the extent of participation in irrigation water management by the 307 sampled farmers. After generating an index of participation in irrigation water management, a Tobit regression model was used to identify factors affecting participation, and the ordered Probit Model was applied to explain factors affecting intensity of participation in irrigation activities. The fourth empirical chapter (Chapter 6) explained the variation in water values. The residual value method was applied to estimate water values from both secondary and primary data. The SAPWAT 3 model was used to derive irrigation water requirements based on the long-term weather data of the study site. The SAPWAT 3 estimates were compared with estimated provincial gross margin budget estimates, known as Combud (2012/13). Primary data were collected from 60 irrigators, whose plots were monitored over the entire production cycle of June to December of 2013, and input-output data were captured. The data were used to estimate average water values and the generalised linear model was used to identify factors explaining variability among irrigators within the same scheme.

The remainder of this chapter presents the conclusions (Section 7.2), followed by policy recommendations (Section 7.3). Section 7.4 describes the limitations of the study, and, finally, future research directions are presented in section 7.5.

7.2 Conclusions

This study sought to understand the governance and institutional arrangements around smallholder water management at MRIS by applying the IAD framework and Ostrom's institutional design principles. Given the research design that focused on empirical investigation of the institutional linkages between the resource system and the governance system, it has emerged that exogenous variables, including the government's non-coercive cooperation and the surrounding environment, affected resource units and resource users at MRIS. Actions of irrigation participants on a set of activities like conflict resolution, maintenance activities, negotiations and water allocation were assessed. The qualitative analysis helped to determine the interaction of variables, which were relevant to understand the outcomes in smallholder irrigation management at MRIS. Some of the findings are that despite rule violations being pervasive, rule monitoring and sanctioning of rule violation activities are perceived to be uncommon and inadequate. Furthermore, despite the fact that irrigators attempt to resolve appropriation and provision problems to avert the 'tragedy of the commons', the state does not deal with various internal problematic issues around water sharing, such as sharing of benefits and costs as well as compliance with operational rules.

Institutional and economic categories of laws clarifying ownership, access rights and specific incentives for common property resources (CPRs) need to be strengthened, to avoid the degeneration of CPRs into open access, with a possibility of further complicating irrigation water management. To ensure equity in localised water allocation, it is important to assess how the diversity of interests is considered in the decision-making process. This can be achieved through stakeholder meetings by the public institutions, which can help to reduce tensions among different users and establish fair systems of water distribution. This can be coupled with rotational management of canal water by all irrigators to ensure accountability.

The findings on the analysis of water-use security revealed that formal associations including water user associations (WUAs), scheme membership and membership of cooperatives were not offering adequate incentives to water users at smallholder level. The study noted that rule violations by some water users deprived members of formal associations of the anticipated improvement in water access at local level. Regarding enforcement mechanisms, conflict management and decision-making, the existing water governance structures were weak and did not ensure reasonable compliance with both formal and informal rules, which manifested in unequal sharing of water and maintenance costs among water users. The overall effect is water-use insecurity among smallholder irrigators, which translates into reduced agricultural production. The development of local water management systems by synchronising the informal and formal institutional arrangements, promoting the participation of farmers in decision making, and effective conflict management mechanisms can ensure improvement in water-use security at farm level.

Farmer participation in irrigation water management is crucial for the sustainability of smallholder irrigation schemes, which are currently associated with high rates of failure. By applying the collective action theory and econometric models, the study investigated the management and equitable resource sharing of water resources in MRIS. A case study approach was adopted to gain insights on user participation in the collective management of smallholder irrigation scheme. In cases where water supply is not adequate and is unreliable to meet scheme demand, technical interventions in the management of communal schemes, such as the infrastructure refurbishments and upgrading of scheme capacity, need to be complemented with institutional interventions, which can lead to improved financial contributions towards infrastructure maintenance by water users. This can be a positive step towards deepening the IMT process, and building the capacity of water users through targeted training.

Institutional arrangements in irrigation scheme management must also be tailor-made to take into account the low literacy levels among smallholder farmers. The fact that irrigators who joined the local WUA revealed higher participation intensity compared to non-members, suggests a need to increase farmer participation in formalised institutions that also expose them to water management training, through capacity building programmes run by the government and other initiatives. However, water-use security was not guaranteed to members of both formal and informal groups, hence a need to strengthen exclusivity rights to cooperating members and promote collective irrigation management.

Regarding the factors that affect the variability of water values, the results showed that variations in average water values was influenced by crop types grown by farmers, although this could not be an indicator of individual importance of each crop to the welfare of farming households. Furthermore, the results revealed that crops with higher gross margins (e.g., tomatoes and spinach) are also associated with higher water values, while those with lower margins (e.g., dry beans and maize) have lower water values. Nevertheless, caution is required in interpreting water values across crops because some crops with the lowest returns to water are often the most important in terms of household food security, since smallholder farmers diversify crop enterprises for a variety of reasons. An example is the lower water value in maize, which is a staple crop in South Africa. The impact of maize production on household food security might need to be further explored in view of the low financial returns and low average water values.

The negative GM attained by 47% of the farmers, raises doubts on the feasibility of implementing cost recovery measures among South Africa’s smallholder farmers, as specified by the National Water Act 36 of 1998. On the other hand, if the assumption that smallholder farmers have the capacity to conduct farming as a business holds, then cost recovery fees might be a suitable stimulant to encourage efficient management of water and other resources at farm level. However, this has implications for the current water policy where smallholder farmers in South Africa are not paying for water, regardless of the inefficiencies in management and utilisation of the resource at farm and scheme level.

Based on the variation in quantity of water applied, gross margins and in water values across farmers within the same scheme, the study can conclude that where water measurement does not take place, water distribution is not equitable. The study attributes inequitable water distribution to ineffective water management systems and institutional failures in the scheme. To reinforce the monitoring mechanisms, there is need to invest in both engineering approaches of installing water measurement devices and institutional approaches through human capacity development. This might ensure that water measurement be done in each scheme at a manageable cost that farmers are willing and able to pay, with a potential to improve collective management of water.

7.3 Recommendations for policy

Based on the findings of the study, a number of policy recommendations could be drawn. Firstly, the descriptive statistics revealed low literacy levels among irrigators, hence tailor-made training and capacity-building approaches are required to improve farmers’ skills. Such an approach may enhance decision-making and consequently farmer productivity in the medium to long-term.

Traditional leadership institutions were found to have a strong influence on the behaviour and socio-cultural aspects of rural irrigators. There is a need to capitalise on social standing and respect afforded to traditional leaders at local level by incorporating them into the formal water management structures. This may be important to improve water management in smallholder irrigation communities of South Africa. The anticipated benefits of such an action are to enhance community participation in collective activities and the possibility of enhancing revenue collection mechanisms, which form the basis for cost recovery objectives of the IMT and PIM.

Negative average gross margins and water values indicate that many smallholders are performing poorly, making cost recovery strategies a challenge. Therefore, it is recommended that partial support in the form of employing more water controllers be continued at scheme level to ensure accountability and improvement in water allocation. Irrigators considered their water access situation to be better when there were more water controllers who are operational, than fewer and less empowered to act against offenders due to IMT. The water controllers can be incorporated as working staff of the water-user association, whose salary obligation is met by the government. This is in view of the poor financial performance, poor coordination and failure of most WUAs to fully operate after several years of existence. The number of hired staff may increase in correlation with the size of the irrigation system. However, despite the increase in hired staff, the process of bureaucratisation (staff organized within a hierarchy) can be decreased where the manager or supervisor of the water controller is the irrigator and not an officer outside the scheme. Such an approach would ensure effective decentralisation of scheme management, at the same time maintaining effective accountability systems through full-time employees in the form of water controllers.

7.4 Recommendations for water managers

Technical interventions like provision of lockable water supply infrastructure to ensure easy control of unsanctioned withdrawal of water, upgrading of supply capacity and water measurement can be pursued at scheme level. These measures have to be complemented with an improvement in the institutional arrangements, management capacity of users and the governance systems in order to achieve better water allocation and minimize supply uncertainties. Without effective local institutional support, user cooperation and investment in psychological capital, engineering interventions for smallholder irrigation management may continue to be subjected to vandalism and infrastructure decay.

Mechanisms to ensure that additional benefits/incentives accrue to those who cooperate and those who comply with membership of WUAs are missing at smallholder level and need to be developed during scheme design level and during revitalisation processes. This can be explored by thoroughly analysing the interaction of technological improvement, management system and governance systems in irrigation water management at scheme level. These three systems have to complement each other to ensure improved resource availability and utilisation.

The challenges of irrigation water governance highlight the importance of a community’s social capital in management of irrigation water. A key to the construction and success of social capital is the extent of relevant linkages in a community, as these are what facilitate information exchange and successful water management organizations in a community. One concern is whether all members of the community are included in the relevant social capital networks of their communities. In particular, the governance systems need to acknowledge the importance of women’s participation in the management of their water systems, not only on the basis of equity but also because access to irrigation water affects the welfare of women and households. This is based on the realisation that women constitute the majority of rural irrigators in the study area and South Africa in general.

7.5 Directions for future research

Time and funding constraints prevented the additional research. The study relied on cross-sectional data collected from a single irrigation scheme. As such, more research insights could have been gathered if the study had covered a number of irrigation schemes across the country. Furthermore, the use of panel data collected over several years may have improved an understanding of the dynamics of smallholder irrigation farming. More seasonal data could have improved the water valuation process by taking into account seasonal water variations. Furthermore, since policy changes influence irrigation farming, an analysis over a longer period could have enabled a detailed explanation of the impact of structural changes on the performance of irrigation schemes.

These limitations provide possibilities for further research in this field. Research on the impact of psychological capital and social capital in the management of communal irrigation schemes is recommended. This is informed by the literature, which points to the fact that smallholder irrigators view scheme infrastructure as government property, hence they have shown little commitment to maintaining the infrastructure. Furthermore, the use of panel data might improve the reliability of water valuation results. As such, use of marginal instead of average water values require more data precision, hence the recommendation to adopt more intensive data collection methods. The study could not control for water use inefficiencies by farmers, hence the study recommends the use of frontier estimation techniques to examine inefficiency in irrigation water utilisation (under or overvaluing). This allows for an identification and adoption of efficient production systems from randomly distributed farm-level observations.

The possibility of integrating traditional leadership structures into the formal water user associations, and defining their possible roles in such an integration process need further investigation. This approach might be plausible since most of the traditional leaders are already involved in water management through their own parallel structures that concentrate on conflict resolution. They are familiar to farmers and likely to receive the least resistance. This study concluded that many smallholder irrigation farmers were under-performing and generated negative gross margins, hence they are less likely to pay for water management services. However, further investigation is required and more cases need to be considered in order to inform the irrigation cost recovery policy at national level with more certainty. This may be coupled to investigating the farmers’ willingness to pay for irrigation water in view of the negative water values, and whether this would impact positively on farmers’ average water values. Furthermore, exploring water-use security against the water rights systems among smallholder farmers may provide insights into improving water access and productivity among irrigators.

The majority of participants in community irrigation schemes are women. This justifies the need for future research to investigate the implications of water governance systems, water insecurity and collective action issues on the empowerment of women and household welfare. It can be hypothesised that good governance systems, improved water security and good collective action practices positively contribute towards economic empowerment of women. Furthermore, the importance of social networks in water governance systems, water-use security and collective action also require further investigation.

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LIST OF APPENDICES

Appendix 1: Household survey questionnaire on collective action and water-use security, MRIS, 2013

UNIVERSITY OF KWAZULU-NATAL
School of Agricultural, Earth and Environmental Sciences
Discipline of Agricultural Economics

Note: The information captured in this questionnaire is strictly confidential and will be used for research purposes by staff and students at the University of KwaZulu-Natal, Institute of Natural Resources and Water Research Commission. Participation in the survey is not compulsory but voluntary and no financial or non-financial benefits are paid during or after participation. The respondent should be the (actual) household head or any one 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: ....

Homestead Number		Interviewee Name	
Contact Details		Interviewer:	
Date		Village Name	
Are you a scheme member?		*1= Yes, 0 =No*	
Block Number where plot is located			

A. SOCIO-ECONOMIC VARIABLES:

Question	**Response**
A1. Gender of household head: *1 = Male; 0= Female*	
A2. Indicate the marital status of the household head	
A3. Age of the household head (years)	
A4. Household Size (Total number of household members)	
A5. Number of household members who work in the field/rear livestock (actual	
A6. Level of education of the household head (years attended school, including	
A7. Occupation of household head (what the household head does for a living)	
A8.How many years have you been involved in crop farming (years)	

A9. Do you consider the following to be important sources of household income?

Source of income	Ranking (level of importance) 1.Not involved 2.Involved but not important 3.Important 4.Very important	Average income per month (Rands)	How many times do you receive this income per year? e.g 3 times, 4 times per year, etc.
Irrigation Crop farming			
Rain-fed crop farming			
Livestock farming			
Family remittances			
Social Grants			
Pension			
Formal employment			
Informal employment			

Household asset endowments: Indicate agricultural production assets that you have access to:

A10. Indicate production Assets you have access to.	A11. Do you own the assets: *1. Yes 2. No*	A12. Quantity/ Number of items owned
1: Hand Hoes		
2: Shovels/spades		
3: Ox-drawn plough		
4: Wheelbarrow		
5: Trailer		
6: Tractor		
7. Tractor drawn plough		
8: Vehicle		
9. Cattle		
10. Goats		
A13. Do you consider the production assets you have to be adequate for your Agricultural Activities: *1= Yes ; 0=No*		

Give details of your household land ownership and utilisation?

A14. Land type	A15. Type of land ownership: 1: Traditional allocation 2. Rented-in. 3. Other (specify)................	A16. Total Area (Ha)	A17. Area under use (ha)
1: Homestead garden			
2: Dry-land fields			
3: Irrigation plots inside the scheme			
4: Irrigation plots outside the scheme			
Total			

A18: If land is not fully utilised, give reasons:

……………………………………………………………………………………………………

…………………………………………………………………………………………………….

A19: What crops have you grown under irrigation between April 2012 and April 2013?

a. Winter crop (April 2012-September 2012)			**b. Summer crops (2012 October-April 2013)**		
Crop	**Area (ha)**	**Yield(specify units)**	**Crop**	**Area (ha)**	**Yield(specify units)**
1.			1.		
2.			2		
3.			3		

B: FARMERS’ INCENTIVES TO PARTICIPATE AND LEVEL OF PARTICIPATION IN IRRIGATION WATER MANAGEMENT

B1: Do you benefit (including your livestock) from canal water?*1= Yes; 0=. No*

B2: Do you know of any Water User Association that represents you in your area? *1= Yes 0 = No*

B3: Are you a member of the Association? *1= Yes; 0 = No*

B4. What is your current level of participation in water management structures in the scheme? (Circle one appropriate answer).

0. Not participating and not willing to do so.
1. Willing to participate but not participating.
2. Participating as an ordinary member.
3. Participating as a committee member
4. Participating as a chairperson of the committee.

B5. If Not participating, give your reasons?

…………………………………………………………………………………………………….

B6. Due to current water leakages from the canal, which result in irrigation water shortages in some blocks, there might be need to improve the condition of the canal. If you are requested to contribute cash towards repairing the canal, how much money would you contribute per year before you can consider it unsustainable? (Tip: *Tip: Enumerator to use the bidding game technique): R …………………………per year.*).

B7: If No OR R0 for question B11, explain your reasons? ……………………………….

B8: If a contribution would ensure reliable supply of water during the peak demand periods of your agricultural activities, how much would you be willing to contribute? (*Tip: Enumerator to use the bidding game technique): R …………………………..*

B9: Explain your value:……………………………………………………………………

B10: If No OR R0 in B13, explain your answer:

………………………………………………………….

B11: What is your level of involvement in the following activities for the year (April 2012 – April 2013): *0. None (never involved) 1. low 2. Average 3. High 4. Very high (always involved)*

Activities	**Rank**
Labour based participation	
B12: Canal cleaning (removing debris, overgrown grass, etc.)	
B13: Repairing broken main canals	
B14: Repairing infield canal	
B15: Repairing pump	
Financial based participation	
B16: Contributing finance towards irrigation pump maintenance	
B17: Contributing finance towards irrigation maintenance (buying material, paying the maintenance people, etc.)	
B18: Contributing finances towards the Water Users' Association (WUA)	
Participation in decision making processes	
B19: Attending irrigation meetings	
B20: Attending irrigation/water related training	
B21: Giving ideas pertaining to water use and allocation in meetings	
B22: Engaging authorities regarding water issues in the area	
Information dissemination	
B23: Distributing information about water issues (written or verbal)	
B24: Helping other farmers to manage/conserve water	
Other(specify)	
Participation in regulation and control	
B25: Reporting unlawful diversion or use of water from the main canal	
B26: Reporting theft/damage of water management devices (canal gates, flow meters or pumps)	
B27: Reporting leakages along the canal for repairs	

B28. How often do you attend water related meetings (e.g. weekly, monthly, none, etc.): ……………………………………………………………………….

Please answer the questions below.

Questions	**Response**
B29: Do you have any training in irrigation water management? *1= Received training, 0= Otherwise*	
B30: How do you perceive water distribution among scheme members (within same block)? *1= Fair distribution , 0= Unfair*	
B31: Is water supply adequate to meet your irrigation demands? *0. Poor. (not adequate at all) 1. Fair 2. Average 3. Good 4. Excellent (adequate)*	
B32: Do you perceive existing committees as effective to ensure compliance to regulations on water users? *0. Don't know 1. Not effective; 2. Neutral; 3. Effective 4. Very effective*	
B33: Do you belong to any group/cooperative that deals with irrigation water management issues in the scheme? *Member = 1, Not a member =0*	
B34. Is water supply reliable to meet your irrigation needs in the scheme? *0. Poor. (Not reliable at all) 1. Fair 2. Average 3. Good 4. Excellent (very reliable)*	
B35: Is water supply reliable to meet your agricultural needs outside the scheme? *0. Poor. (Not reliable at all) 1. Fair 2. Average 3. Good 4. Excellent (very reliable)*	
B36. Is water supply reliable to meet your non-agricultural needs outside the scheme ? *0. Poor. (Not reliable at all) 1. Fair 2. Average 3. Good 4. Excellent (very reliable)*	
B37: How far is your homestead from the main canal? *0= (0 - 0.5km) 1= (0.6 – 1.5km) 2= (1.6 -2.5km); 3= (2.6 -4.0km) 4= (>4km)*	
B38: Does your participation in irrigation water management improve access to government support? *0. Strongly disagree 1.Disagree 2. Neutral 3. Agree 4. Strongly agree*	
B39: Does your participation in irrigation management increase your feeling of responsibility to manage water? *0. Strongly disagree 1.Disagree 2. Neutral 3. Agree 4. Strongly agree*	
B40: Does your participation in water related meetings help to lobby for local organisations to solve irrigation? *0. Strongly disagree 1.Disagree 2. Neutral 3. Agree 4. Strongly agree*	
B41a: Do you draw water directly from the Mooi River or other nearby rivers? *1= Yes ; 0 = No* B41b: If yes, for what purpose: ………………………………………………. ………………………………………………………………………………	
B42a: Do you use tap water for irrigation purposes? *1 =Yes , 0=No*	

C: INSTITUTIONS, GOVERNANCE, AND WATER ACCESS

Question	**Response**
C1: What is your level of canal water access for irrigation purposes inside the scheme? (Tick appropriate) *0. No access 1. Poor 2. Average 3. Good 4. Excellent (unlimited access)*	
C2: What is your level of canal water access for activities outside the scheme? *0 = No access 1.Poor 2. Average 3. Good 4. Excellent (unlimited access)*	

C3a: How many days were you without irrigation water the past week?……………days

C3b: What are the reasons for not having irrigation water? …………………………………

………………..……………………………………………………………………………

C4-13: What is the importance of the following uses of canal water to you? Please rank the importance on a scale of 1-5: *(0=Don't use the water for that purpose; 1= unimportant; 2=don't know; 3 = important; 4=very important)*

Water use	**Rank (0-4)**
Agricultural uses	
C4: Irrigating plots within the scheme	
C5: Irrigating plots outside the scheme (not gardens)	
C6: Irrigating homestead gardens	
C7: Watering Orchard (household fruit trees & ornamental plants)	
C8: Livestock watering	
C9: Other (Specify)	
Non-Agricultural uses	
C10: Laundry	
C11: Domestic use (Cooking, bathing, Drinking)	
C12: House construction	
C13: : Brick making	
Other (specify)	

Please answer the following questions:

Aspect	**Response**
C14: What is the nearest block in which homestead is located?	
C15: Have you ever been involved in water related conflicts, with fellow farmers, community members or authorities? *1= Yes, 0=No*	
C16: Are there water measurement devices at the specific diversion points where you get water for your irrigation? *1=Yes, 0=No*	
C17a: Have you ever been penalised for using water without authorisation 1=Yes, 0 =No C17b: If so, what was the offence? ………………………………………………. C17c: What was the penalty: …………………………………………………..	
C18: How many days do you irrigate per week?	
C19: Do you belong to a group/cooperative that uses canal water for its activities? *1. Yes, 0=No*	
C20: Do you have any personal relations with canal rangers? *1=Yes, 0=No*	
C21: Do you have any personal relations with committee members? *1. Yes 0=No*	
C22: Do you have any personal relations with Indunas/Inkosi? *1.=Yes 0=No*	
C23: Have you received any water management training? *1. Yes 0=No*	
C24: Are you consulted when decisions that affect flow or supply of water are made? *0 = Never; 1. At times; 2. Regularly*	
C25. Are you aware of what is deliberated in water related meetings by the committee members? *1. Yes 0. No*	

C26: Has the involvement of any of the following authorities in water management improved water access in your area? Rank as follows: (*0. Never been involved; 1. No improvement 2. don't know; 3. Good improvement 4. Very good improvement)*

Variable Description	**Rank (0-4)**
Government management	
C27: Involvement of local Department of Agriculture officials in water management (local managers and extension officers.	
C28: Involvement of government canal rangers in water allocation	
C29: Involvement of Department of Water Affairs personnel	
Local/Community management	
C30: Involvement of block committees	
C31: Involvement of ordinary non-committee members	
C32: Involvement of traditional authorities (headmen/Izindunas)	
C33: Involvement of the Water Users Association (WUAs)	

C34. In your opinion, would the following measures help to improve water availability among farmers in the scheme? *0. Strongly disagree 1.Disagree 2. Neutral 3. Agree 4. Strongly agree*

Management Authority	**Rank (1-5)**
C35. Water education and awareness campaigns	
C36. Empower the local Water User Association to deal with the problem	
C37. Empowerment of community to deal with water related problem	
C38. Department of Agriculture to deal with water issues in the area	
C39.. Department of Water affairs to deal with water problems in the area	
C40. Empower traditional leadership (indunas, inkosi) to deal with the problem	
C41. Empower political leadership (councillors, MPs) to deal with the problem	
C42. Other measures(specify)	

C43. Can you rank the following as they pertain to irrigation water access and water-use security? Use the following scores: **[1**.= *Strongly disagree, 2= Disagree 3. Neutral 4.Agree 5. Strongly Agree]*

Variable	**Scale (**1-5)
Water distribution/sharing at farm level is fair	
Water is supplied in adequate quantities	
Water supply to my plot is reliable	
Conflict resolution mechanisms are effective	
The penalty system for non-compliance is effective	
I have the capacity to pay for infrastructure maintenance	
I often participate in infrastructure maintenance	
Management committees are effective	
I participate fully in decision making relating to water allocation in the scheme	

C44: If there are any additional points/issues that we didn’t raise but you would like to raise or inform us regarding the irrigation scheme, their management and water use, we would appreciate it;

....

…………………………………………………………………………………………………

THANK YOU FOR YOUR COOPERATION!

Appendix 2: Checklist for focus group discussions on irrigation scheme governance, MRIS, 2012

UNIVERSITY OF KWAZULU-NATAL
School of Agricultural, Earth and Environmental Sciences
Discipline of Agricultural Economics

The information captured in this questionnaire is strictly confidential and will be used for research purposes by staff and students at the University of KwaZulu-Natal (School of Agricultural, Earth and Environmental Sciences - Discipline of Agricultural Economics), Institute of Natural Resources and Water Research Commission. Participation in the survey is not compulsory but voluntary and no financial or non-financial benefits are paid during or after participation. Answers are solicited for all daily activities that the farmer performs on a specific crop from land preparation, planting, maintenance and marketing.

Q1a: What is the irrigation water used for? ***(****Identify other multiple uses of water which is meant for irrigation)*

Q1b.Is it clearly documented as to who should/not use canal water? Explain

Q2: Do scheme members have a source for domestic water?

Q3: What support (from government/private) is the scheme currently getting to improve water availability and usage, for agriculture Please specify the nature and source of support e.g. finance, training etc.

Q4: Do scheme members /Irrigators pay for irrigation water?

Q5: At your block, describe how water delivered to the plots? (Include source of power and frequency)

Q6: If relevant, specify pumping costs per season/annum (or week/month): R………

Q7a: Describe the scheme leadership structures and their responsibilities.

Q7b: How are rules enforced? Explain using examples.

Q7: Is there a Water User Association (WUA) in this area? 1: Yes 2: No

Explain: ……………………………………………………………………………………..

Q8: Are members satisfied with the work being done by the WUA in your area? 1: Yes 2: No

Explain:………………………………………………………………………………………..

Q9. Where do members get technical maintenance support for the irrigation infrastructure?

Explain:…………………………………………………………………………………………..

Q11. Is total amount of water used for farming measured? If so explain how? If not, how do irrigators ensure equitable distribution of water?

Q12: Describe system of water release and allocation (who controls and enforces policies)?

Q13: Is the water available for irrigation adequate for irrigation activities at the scheme?

1: Yes 2: No

Explain: ………………………………………………………………………………………

Q14: Rank the factors that affect access to irrigation water in the scheme?

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

Factor	**Ranking** (1-5)
Amount supplied not adequate	
Illegal access by non-scheme members	
Illegal access by scheme members	
Weak regulatory framework	
Absents of regulatory policies	
Leakages along the conveyance structures	
Increase in users (due to population increase and non-agric uses)	
Increase in area under irrigation (due to expansion)	

Q5: What are people currently doing in order to cope with water challenges?

Explain: ……………………………………………………………………………

Appendix 3: Data collection form for water valuation, MRIS, 2013

UNIVERSITY OF KWAZULU-NATAL
School of Agricultural, Earth and Environmental Sciences
Discipline of Agricultural Economics

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Household Details:

Date		Household Number	
Farmer Name		Gender	
Age		Village Name	
Block No		Total size of plots (ha)	
Crop		Variety	
Area planted (ha)		Date planted	
Date of first harvest		Date of final harvest	

1. How the plot was ploughed (eg. hoe, donkeys, tractor)? ……..… Cost: R …………
2. *Seeds*: were seeds kept from last year or purchased? ……… …
3. If purchased, amount in grams: ….…. Where purchased? ……….. Cost: R ……..
4. Seedlings: Quantity purchased …………Where purchased? ……… Cost R …………

5. What is your labour usage?

Operation	**Family labour/Week**		**Hired labour/Week**		
	Number of days	Number of people	Number of days	Number of people	Payment (Rands)
Clearing the plot					
Planting					
Ploughing					
Weeding					
Watering					
Chemical spraying (pests and diseases)					
Physical/Mechanical control of pest and disease control (e.g covering crops, hand picking of pests etc)					
Harvesting					
Canal maintenance					
Infield fallow/feeder maintenance					
Packaging					
Marketing					
Pumping labour					
Pump maintenance					
Fertiliser application					
Other (specify)					

6. What are your average working time for family labour in the field per day (this week)?
Start time: …………. Finish time: ………Total hours worked …………………..hours

7. What are the average working time for hired labour in the field per day (this week)?
Start time: …………. Finish time: …………. Total hours worked ………………..hours

8: What are the average irrigation hours per day (this week)?
Start time: …………. Finish time: …………. Total hours worked………………..hours

8. Chemicals used to control pests and diseases (within the last one week):

Pest or disease	Name of chemical	Amount (Units)	Cost
Total			

9. Chemical fertilizers applied before planting:

Name/type	Amount in kg	Cost
Total		

10. Organic fertilizers applied before/after planting (eg kraal manure, compost):

Type	Amount	Source	Cost
Total			

11. Chemical fertilizers used as top dressing:

Name/type	Amount in kg	Cost
Total		

12. Yields (The unit of measurement will vary with crop eg crates, buckets, kg, bags, heads, etc.)

	Quantity	Units(eg bags, buckets, etc)
Used in farmer’s home		
Given to others as gifts		
Used to pay workers		
Sales for cash		

12. If sales took place, to who was the crop sold? (Complete the details in table below). Crop…………………………………………………………….

	Number of buyers	Quantity(units)	Price per unit
Directly to consumers			
To hawkers			
To traders with vans / bakkies			
To shops			
Others			
Total			

13. Marketing costs

Costs	Quantity	*Costs*
Travel (taxi fares/hiring)		
Materials (eg bags)		
Market research		
	Total	

Thank you!

Appendix 4: Descriptive Statistics for proxies to measure perception of water security

	Mean	Std. Dev	min	max
W_DISTR	3.350	1.744	1	5
W_ADEQ	3.150	1.739	1	5
RELWAT	2.320	1.090	1	5
EF_PENLT	1.725	1.722	1	5
INV_CONF	1.890	1.210	1	5
RELCOM	1.780	1.364	1	5
WAT-CONS	1.101	1.293	1	5
CAPAY	1.603	1.732	1	5

Source: Survey data (2013)

Appendix 5: Descriptive statistics for proxies to measure collective participation

	Mean	Std. Dev	min	max
Providing labour for main canal cleaning (CANCLEN)	3.221	1.011	0	4
Canal repairs (RPCANAL)	2.091	1.604	0	4
Repair of infield distribution canals (INFILDCA)	2.590	1.484	0	4
Pump repairs (REP_PUMP)	0.726	1.243	0	4
Contribute funds for pump repairs (FUNDPUM)	0.902	1.413	0	4
Contribute towards Water User Association (FUNDWUA)	0.782	1.085	0	4
Attend water-related meetings (ATTMEET)	2.648	1.283	0	4
Attend irrigation training (ATRAING)	1.596	1.448	0	4
Participating in meetings (IDEAS_IN)	1.906	1.426	0	4
Engage water authorities (ENGAGE)	1.638	1.325	0	4
Disseminate water-related information (INFODISTR)	2.668	1.129	0	4
Informally train others on water management (TRAINWAT)	1.873	1.435	0	4
Report unlawful use of water (RPT_UNLAW)	1.775	1.400	0	4
Report equipment theft (RPT_EQUP)	1.739	1.388	0	4
Report damages and leakages (RPT_LKGS)	2.296	1.377	0	4

Source: Survey data (2013)