

ASSESSING THE PERFORMANCE OF SMALLHOLDER IRRIGATION IN SOUTH AFRICA AND OPPORTUNITIES FOR DERIVING BEST MANAGEMENT PRACTICES

T Gomo

Submitted in partial fulfilment of the requirements
for the degree of MScEng

School of Bioresources Engineering and Environmental Hydrology
University of KwaZulu-Natal
Pietermaritzburg
South Africa

March 2010

Supervisor: Dr A.S.D. Senzanje

Co-Supervisor: Dr. M. Mudhara

ABSTRACT

Literature pertaining to performance irrigation schemes has been explored in this document culminating in a research proposal to assess performance in smallholder irrigation schemes in South Africa. Performance in smallholder irrigation schemes is multi-dimensional and can be looked at from different perspectives. Ntsonto (2005) and Yokwe (2009) evaluated performance of Zanyokwe irrigation scheme from an economic point of view, while on going research work at Tugela Ferry irrigation scheme seeks to address socio-institutional practices (Cousins, 2009), but technical performance assessment has been lagging behind. Shongwe (2007) evaluated water distribution only in a section of Tugela Ferry irrigation scheme. However, technical performance assessment studies often ignore farmers` views (Kuscu *et al.*, 2009).

Performance of smallholder irrigation around the world has been reported to be below expectations (Svendsen *et al.*, 2009). Ownership and responsibilities were transferred from governments to farmers (Garces-Restrepo *et al.*, 2007) in a bid to enhance resource-use but several factors, among them dysfunctional infrastructure and lack managerial know-how among the farmers, have been reported to influence performance at scheme level (Bembridge, 2000). Different authors and international organisations developed various performance indicators (Rao, 1993), which could be used for identification of malfunctioning components of different schemes. The performance indicators relate to the various disciplines of irrigation performance – technical, socio-economic and institutional set up. The technical performance indicators relate mainly to water conveyance, delivery and use and they include delivery performance ratio, discharge capacity of ratio, output per unit irrigation supply, and output per unit water consumed by crop, among others. All these have been reviewed in this document.

Farmers` perceptions about the scheme performance are of paramount importance. It is against this background that ways to incorporate and analyse their view of performance have been reviewed. Three analytical models, namely, Logit Model, Probit Model and Linear Probability Model have been evaluated. The review ends with a research proposal to assess technical performance of Mooi-River Irrigation Scheme in Msinga district in the Midlands region of KwaZulu-Natal province of South Africa. A few performance indicators related to water, since water is more constrained in South Africa (NWA, 1998), were selected.

TABLE OF CONTENTS

1. INTRODUCTION.....	1
2. SMALLHOLDER IRRIGATION.....	3
2.1 Smallholder Irrigation Development.....	4
2.2 Management of Smallholder Irrigation Schemes.....	4
2.3 Revitalization and Rehabilitation of Smallholder Irrigation Schemes.....	6
3. IRRIGATION PERFORMANCE.....	8
3.1 Irrigation Performance Assessment	9
3.2 Performance Indicators	9
3.2.1 External performance indicators.....	10
3.2.2 Internal performance indicators.....	15
3.3 Smallholder Irrigation and Performance Assessment	17
4. FARMERS` EVALUATION OF IRRIGATION PERFORMANCE	18
4.1 The Linear Probability Model (LPM)	18
4.2 The Logit Model (LM).....	19
4.3 The Probit Model	21
5. DISCUSSION AND CONCLUSIONS	22
6. PROJECT PROPOSAL	24
6.1 Problem Identification and Context	24
6.2 Research Objectives	25
6.3 Research Methodology.....	25
6.4 Work Plan, Deliverables and Resources required.....	27
7. REFERENCES.....	29

LIST OF ABBREVIATIONS

ARDC	Agricultural and Rural Development Corporation
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
IB	Irrigation Boards
ICON	Iterative-Consultative Approach
IMT	Irrigation Management Transfer
IPTRID	International Program for Training and Research in Irrigation and Drainage
ITRC	Irrigation Training and Research Center
IWMI	International Water Management Institute
KZN	KwaZulu Natal
LPM	Linear Probability Model
MOM	Management, Operation and Maintenance
MRIS	Mooi-River Irrigation Scheme
NWA	National Water Act 36 (1998)
NWRS	National Water Resource Strategy
PIM	Participatory Irrigation Management
RAP	Rapid Appraisal Process
RESIS	Revitalization of Smallholder Irrigation Schemes
RIS	Relative Irrigation Supply
RWS	Relative Water Supply
SGVP	Standardized Gross Value of Production
SSA	Sub-Saharan Africa
TFIS	Tugela Ferry Irrigation Scheme

1. INTRODUCTION

Food and Agriculture Organization (FAO) predicted that food production must increase by 70% globally and that the developing countries must double production to match a 40% increase in world population by 2050 (Mukherji *et al*, 2009). However, unpredictable climate, depleted water resources and the critical shortage of other production resources pose a challenge to increased food production. In anticipation of a food deficit in future, most researchers in the agriculture sector are looking at efficient resource utilisation (Mukherji *et al*, 2009). The general consensus among researchers and various stakeholders in agriculture seems to be the need to improve management of available resources.

Water is a critical agricultural resource which is becoming scarcer due to increasing demands and its efficient use in irrigation may combat the effects of hunger. Molden et al (2007) reported that a fifth of the world's population lives in areas where water is physically scarce and around 25% live in economically water-scarce basins. These statistics are a cause for concern especially in countries which lie in the intersection of physical and economic water scarcity. South Africa is faced with water scarcity and capacity problems in water management. The South African Minister of Agriculture conceded to this when she highlighted the need for efficient use of water: "We believe household food security in rural areas can be ensured through subsistence farmers, who will be assisted with basic technology for water management and water harvesting. It requires a huge mind-set change on how to use water," (Joemat-Pettersson, 2009).

Despite the irrigation sector contributing less than 4% to the Gross Domestic Product (GDP) (Perret, 2002), it is reportedly South Africa's largest water user, accounting for 62% of the water withdrawals from the country's stored water (NWRs, 2004). As water supply becomes scarcer due to increasing demands from other users, water-use in the irrigation sector has come under scrutiny. The government has channelled significant financial resources in the range of R30000 to R60000 per hectare towards revitalisation of smallholder schemes (Denison and Manona, 2007) around the country in a bid to enhance performance in these schemes. Smallholder schemes have been targeted because the government has been pursuing the idea of creating and supporting strata of smallholding farms, which they believe are more productive than commercial

farms (Nkwinti, 2009), and soon will emerge as the biggest water user in the agriculture sector. The creation and funding of the smallholder schemes have necessitated the continuous monitoring of their performance.

This literature review focuses on the performance of smallholder irrigation schemes in South Africa and opportunities for deriving the best ways through which the available resources can be managed to produce the maximum possible returns. Special focus is given to the technical aspects of irrigation performance taking into consideration the farmers` perceptions. There are 7 chapters in this document. The history of smallholder irrigation development is described in detail in Chapter 2. The issues of management, revitalisation and rehabilitation around the world and in Sub-Saharan Africa and South Africa are also reviewed in the same chapter. In Chapter 3, irrigation performance and performance indicators are explored with the aim of giving insight into those chosen for a study proposed in Chapter 6. A review of the statistical methods available for use in taking the farmers` perceptions and expectations is presented in Chapter 4. Chapter 5 consists of the conclusions and discussions. Chapter 6 contains the details of a proposal to assess the performance of smallholder schemes in KwaZulu Natal and the opportunities for deriving best management practices.

2. SMALLHOLDER IRRIGATION

Smallholder irrigation involves the diversion of water from one area into a relatively small area for the purpose of supplementing available water for crops (FAO, 2001). The techniques of diverting the water include use of gravity through canals or pipes and lifting water through the use of pumps for application in the fields through various irrigation methods (FAO, 2001) with the objective of increasing crop production. The terms smallholder, small-scale, subsistence, communal and emergent farmers have been loosely used to mean the same thing although they have different meanings. Of interest in this document is the smallholder irrigator who, Cornish (1998) described as farmer who practices both commercial and subsistence farming for deriving a livelihood and the family is the principal source of labour. Cornish (1998) added that the smallholder farm may also include a small section where high value crops are grown for commercial purposes, and the smallholder farmer usually earn a living from an irrigated area usually less than 5 hectares (ha). However, this may vary from one country to another.

Smallholder irrigation also includes small individual farms and groups where the farmers have taken on the responsibility for managing the distribution of water among the members of their group (FAO, 2001). In South Africa, the smallholder farm is located in the former homelands with the majority of the small farms being owned by historically disadvantaged races and groups (Denison and Manona, 2007). Homelands are areas which were reserved for occupation only by the marginalised races during the apartheid era.

From the above definition, South Africa has about 317 smallholder irrigation schemes covering some 50 000 ha and these schemes are mainly located in former homelands (Denison and Manona, 2007). The schemes are estimated to support approximately 32 000 families across the country. In a database of smallholder irrigation schemes compiled by Denison and Manona (2007) it is shown that about 57% of the smallholder schemes are found in Limpopo province located in the northern part of the country, 23% in the Eastern Cape and 11% in KwaZulu Natal. The remaining 9% is distributed across the other four provinces Mpumalanga, North West, Free State and Western Cape (Denison, 2009). The other two provinces, Gauteng and Northern Cape were excluded because it could not be established if there are any smallholder schemes. Denison

and Manona (2007) noted that, in post-1994 South Africa, most of these schemes were supported financially by the government but there is a notion that these schemes have not performed to expectations (Backeberg *et al.*, 1996; Ntsonto, 2005)

2.1 Smallholder Irrigation Development

Over the past five decades, the trend in irrigation across the world has been from the large scale towards the smallholder. Demographic shifts, scarcity of land and water resources for irrigation, need for food security starting from family level (Joemat-Pettersson, 2009), technology as well as poorly maintained large scale infrastructure, which does not cater for individual farmer`s needs (Bembridge, 2000), have favoured smallholder irrigation subsector development. Smallholder irrigation has become main source of income for the rural poor, and therefore the need to improve resource use in this subsector. As such, there has been development towards more efficient resource use, from gravity-fed earth canals to sophisticated real-time overhead systems which save water and labour. The optimal use of these critical resources in irrigation will not only help produce enough food for everyone but will also ensure sustainability.

2.2 Management of Smallholder Irrigation Schemes

Smallholder irrigation schemes present special management problems, especially where water is scarce and supply is often less than the demand (Albinson and Perry 2002). Water distribution in smallholder irrigation schemes has proved to be a challenge at scheme management level. Scheme management failures have frequently resulted in chaos involving illegal tempering with water conveyance structures and water shortages at different locations within the scheme (Albinson and Perry 2002), thus affecting the irrigation performance. These management problems are often prevalent in the developing world where farmers have no access to advanced technology to meet ‘on-demand’ water deliveries to their crops.

Since the 1950s, governments across the globe managed smallholder irrigation schemes through parastatals and other agencies (Garces-Restrepo *et al.*, 2007), and farmers were usually relegated to mere farm workers despite the fact that they were supposed to pay for the services rendered by

the agencies. In South Africa, government agencies such as the Agricultural and Rural Development Corporation (ARDC) in the Northern Province managed the smallholder schemes (Shah *et al.*, 2002).

Garces-Restrepo *et al.* (2007) noted that the dissatisfaction among the farmers triggered a non-payment cycle and the general performance of the schemes declined. With the aim of reducing recurring government expenditure on these irrigation schemes, and the general disappointment with the performance of irrigations systems, the governments of China, Bangladesh and the United States of America initiated Irrigation Management Transfer (IMT) in the early 1970s (Garces-Restrepo *et al.*, 2007). The fundamental aim of the IMT reform process was to improve performance of the schemes through handing over the ownership and management responsibilities to the farmers (Perret, 2002). Garces-Restrepo *et al.* (2007) noted that the underlying assumption was that greater participation by the farmers would induce a sense of ownership and responsibility, and hence improve resource use efficiency

Some governments in Sub-Saharan Africa handed over management of smallholder schemes to the farmers in the face of IMT. Due to budgetary reprioritisation as well as the need for IMT in the late 1990s in South Africa, financial support for management, operation and maintenance of smallholder irrigation was withdrawn (Maritz, 2001), and ownership and management responsibilities were handed over to the farmers. In 2002, 57 countries, representing 76% of the FAO-irrigated area of the world, had embarked on some form of reform which included IMT (Garces-Restrepo *et al.*, 2007). Some countries, however, opted for Participatory Irrigation Management (PIM), a moderate reform of just increasing farmer participation in irrigation management rather than replacing the role of government as in IMT (Giordano *et al.*, 2006), while some, like South Africa, adopted both reforms.

However analyses as to whether the objective of improving irrigation performance was fulfilled have painted a gloom picture as successes have been reported in countries such as Turkey, Mexico, USA and New Zealand (Shah *et al.*, 2002) and failures or no change being reported in the developing world. A decline in the cropping intensity and an increase in the irrigated area were reported in the Senegal Valley, while in Nigeria an improvement in water delivery to tail-

end farmers in the Kano project was recorded following the adoption of IMT (Shah *et al.*, 2002). In Kenya, the government had to provide financial aid to assist in the resuscitation of infrastructure at Mwea Irrigation scheme barely 6 years after transfer owing to lack of skilled labour, machinery and financial resources for scheme maintenance among the farmers (National Irrigation Board, Kenya, 2007). In South Africa, the overall performance of these schemes has either been reported to be on the decline or no change has been noted yet (Backeberg *et al.*, 1996; Ntsono, 2005).

2.3 Revitalization and Rehabilitation of Smallholder Irrigation Schemes

Irrigation revitalization can be defined as a process of technical, managerial and institutional upgrading, including rehabilitation, of irrigation schemes with the aim of enhancing resource utilization and improving water delivery to the schemes (Renault *et al.*, 2007). The process is not limited to the upgrading of infrastructure, but also includes fundamental transformations to resource management techniques. In dealing with revitalization, an interrelated concept, referred to as modernization, is often encountered. The concept involves the introduction of modern hardware and software (Renault *et al.*, 2007) as well as upgrading the human resources to operate the new technology (Faures *et al.*, 2007)

Most of the revitalization work around the world was done alongside IMT and PIM programmes with funding from international donor agencies (Bucknall *et al.*, 2003). The aim was to re-establish the physical configuration of the original system and then hand over responsibility to the farmers. In central Asia, the most common objective of rehabilitation was to restore the irrigation potential of the various schemes whose infrastructure deteriorated following the collapse of the Soviet Union, for example in Kazakhstan, Kyrgyz Republic, and Uzbekistan where 12 schemes were rehabilitated with the World Bank as the financier (Bucknall *et al.*, 2003). In Africa, the main objective has been to upgrade the collapsing structures constructed during the colonial era before handing the schemes to the farmers. In some instances, the schemes were first handed over to the farmers and rehabilitation is still underway (Bembridge, 2000).

Of particular concern to the government of South Africa has been the dilapidated water conveyance infrastructure in smallholder irrigation schemes. This has seen the government rolling out the Revitalization of Smallholder Irrigation Schemes (RESIS) programme throughout the country, although in many cases the process has been restricted to rehabilitation (Denison and Manona, 2007). In the Limpopo province, the RESIS programmes included WaterCare and RESIS Recharge, while in the Eastern Cape province, the revitalization programmes included the Iterative-Consultative approach (ICON) which emphasized farmer involvement and participation from design to the implementation and management processes of their schemes. Similar programmes were run in other provinces with divergent intervention styles and objectives but embracing revitalization principles (Denison and Manona, 2007).

3. IRRIGATION PERFORMANCE

Irrigation performance can be defined as the level at which resources such as water, land and labour are being effectively utilised (Bos *et al.*, 2005) for the production of food. The resource use in many smallholder irrigation schemes has been reported to be below expectations especially in water management, service to the farmers and cost effectiveness of infrastructure management (Renault *et al.*, 2007). Over the past three decades, irrigation management reforms have been adopted and promoted as part of the effort to increase performance across the globe. However, the results have usually been disappointing (Renault *et al.*, 2007). Few changes are reported to have met the intended targets of performance, especially in the developing world (Shah *et al.*, 2002). This brought to the fore the real causes of poor performance and the challenges of improving irrigation performance.

Despite the effort to enhance resource utilisation, several problems are reported to be affecting general performance of smallholder schemes. Molden *et al.* (1998) noted that dysfunctional infrastructure, lack of inputs and technology, severe financial constraints and inadequate managerial skills among the farmers as well as socio-economic settings are the major causes of poor performance in the smallholder irrigation subsector. Oosthuizen, (2002) concurred with Bembridge (2000) and added inefficient water management strategies and lack of farmer participation in scheme management, as well as lack of markets, among other constraints. Plusquellec (2002) added behavioural reasons to the list, hence the need to consider the farmers' perspectives from the design stages of a scheme. In South Africa, all these problems have been reported to compromise optimal scheme performance (Bembridge, 2000). Water conveyance infrastructure and management are probably the major variables reducing performance.

However, if focus is given to the management of fundamental irrigation inputs – land, water, labour and finance – it should be possible to see, in a broad sense, improved performance within various settings. Optimal irrigation performance might be the solution to provide additional food to the growing population requiring improved diets but faced with severe resource shortage. This can be achieved by constantly monitoring, documenting and interpreting the important parameters of a scheme and intervening where necessary.

3.1 Irrigation Performance Assessment

Irrigation performance assessment can be described as the regular observation of certain irrigation performance parameters with the objective of acquiring important information pertaining to resource-use within an irrigation scheme, and allows irrigation managers to make well informed decisions in terms of resource management (Bos *et al.*, 2005). This process provides feedback information to scheme management at all levels, thus allowing a review of operations and evaluation of the efficiency with which resources are used at system, scheme, catchment and national levels. Murray-Rust and Snellen (1993) stated that the performance evaluation must provide sufficient information to irrigators and irrigation managers on the best ways to enhance performance.

Performance assessment can be used in a variety of ways to satisfy different set objectives on different schemes but the procedure will vary depending on the system and purpose of assessment. The assessment can be done to obtain the level of service pertaining to operation, strategic, diagnostic and comparative, that is relative to other schemes in terms of management environments, and for evaluation of the impacts of management interventions such as PIM and IMT. It can also used to assess the trend in performance of a specific scheme over time or for the purpose of benchmarking with other schemes exhibiting good performance. This process can be done on different types of irrigation scheme ranging from large scale to smallholder or highly technical computer-controlled schemes to simple gravity-fed schemes. However, the objective of the assessment will remain the same; that of optimizing the resource use yet producing the maximum possible output.

3.2 Performance Indicators

Performance indicators reflect the level of adequacy in the use of resources to obtain the final outputs in an irrigation schemes (Bos *et al.*, 2005). Data on key parameters of the system is collected and analysed by comparing it with the intended or critical values of the indicators, which then provides the information on the level of performance. Several performance indicators

have been developed by different analysts and international organizations for measuring and comparing the performance of irrigated agricultural systems.

Rao (1993) summarized the various indicators proposed by different authors for measuring irrigation system performance and has explained their use, but only a few examples of cross-system comparisons are available (Murray Rust and Snellen, 1993). In the past the focus has mainly been on the irrigation systems, as seen in the summary by Rao (1993), but the scheme as a whole would require a holistic performance evaluation. The difference between an irrigation system and an irrigation scheme is that an irrigation system is the part of the scheme which deals with conveyance structures while an irrigation scheme encompasses socio-economic and institutional sub-systems such as road networks, temporary storage facilities, human resources, irrigated land and villages (Bos *et al.*, 2005). These various sub-systems within the scheme have different effects on each other and on the general performance of the scheme, hence the need to look at the scheme holistically when carrying out performance assessment.

The performance indicators can either be external or internal. A review of these performance indicators is presented below, with more attention given to technical indicators applicable to performance assessment in smallholder irrigation schemes.

3.2.1 External performance indicators

Molden *et al.* (1998) described this category of indicators as those that analyse the inputs into and outputs from irrigation projects such as land, labour, water, cost of scheme operation and maintenance as well as the value of production. Molden (1998) developed a set of nine external performance indicators for describing performance at scheme level. Malano and Burton (2001) developed a similar set of external indicators but added environmental indicators to the list. However, these indicators do not provide specific information on what needs to be done to improve performance, but they are important for comparison of performance between different schemes or for study of impacts of management interventions. Burt and Styles (1998) used the external indicators to determine the difference in performance following adaptation of new water management practices in sixteen irrigation projects, with most of them from developing countries.

The external performance indicators can be sub-divided into four different categories, namely agricultural performance indicators, water supply and delivery indicators, economic and environmental indicators (Greaves, 2007). These categories are further expanded below.

Agricultural performance indicators generally analyse the output from an agricultural system in relation to the inputs into the system; that is agricultural productivity. They are summarised in Table 3.1. Molden *et al.* (1998); Burt and Styles (1998); Malano and Burton (2001) and Burt (2002) all strongly concur on the use of the first four indicators (Greaves, 2007). Molden *et al.* (1998), however, points out that these indicators must be viewed in context to the region in which they are used. Where water is the more constraining resource compared to land, then output per unit water maybe more important than output per unit land. The reverse is true for a region where land is more constrained (Greaves, 2007).

Table 3.1 Summary of agricultural performance indicators (greaves, 2007)

Indicator	Computation formula
Output per cropped area (kg/ha)	$\frac{\text{Production}}{\text{Irrigated cropped area}}$
Output per unit command area (kg/ha)	$\frac{\text{Production}}{\text{Command area}}$
Output per unit irrigation supply (kg/m ³)	$\frac{\text{Production}}{\text{Diverted Irrigation supply}}$
Output per unit water consumed (kg/m ³)	$\frac{\text{Production}}{\text{Volume of water consumed by crop ET}}$
Achieved production factor	$\frac{\text{Production with Irrigation}}{\text{Production with out irrigation}}$
Potential Production factor	$\frac{\text{Potential production with irrigation}}{\text{production with irrigation}}$

Water supply and delivery performance indicators provide insight into the efficiency of water conveyance and use in the schemes. Water has been considered the most strategic resource in irrigation and most of the indicators are somehow related to the amount of water applied or used (Ricardo *et al.*, 2003). The primary concern has been matching water supplies to irrigation

demands, and its use once it is delivered to the schemes. Several checks which look at the water adequacy, reliability of delivery, equity of distribution, variability of flows at outlets along canals as well as timeliness of water supply and delivery have been developed the world over with the aim of continuously monitoring and improving the water use in irrigation schemes.

Bos *et al.* (2005) categorised water related external performance indicators as water balance, water service and maintenance. The same authors went on to suggest that the indicators could be presented either as a function of time or with respect to their spatial distribution. Depending on the presentation, the information inferred from the indicators will have different meanings, as shown in Table 3.2, which gives a summary of the indicators.

Table 3.2 Summary of water balance, water service and maintenance performance indicators (Bos et al, 2005)

Indicator	Computation Formula	Information provided when indicator is used to show:	
		A trend in time	The spatial distribution
Overall Consumed Ratio (OCR)	$\frac{ET_p - P_e}{\text{Volume of water supplied to command area}}$	Degree to which farmers water requirements were met	Difference in water supply to users at various locations within command area
Field Application Ratio (FAR)	$\frac{ET_p - P_e}{\text{Volume of water delivered to field}}$	Changes of water use by irrigators	Influence of boundary conditions on efficiency of irrigation water use
Depleted Fraction (DF)	$\frac{ET_a}{P_e + V_c}$	Changes in actual water use	Quantifies differences in the water balance of considered area
Drainage Ratio (DR)	$\frac{\text{Total water drained from area}}{\text{Total water entering into the area}}$	Degree to which water within the drainage basin is consumed	Identifies areas where water resources can be developed
Outflow over inflow ratio	$\frac{\text{Total water supply from canal}}{\text{Total water diverted or pumped into canal}}$	Quantifies the need for maintenance of the system	For identification of system components that need maintenance/ modernization
Delivery Performance Ratio (DPR)	$\frac{\text{Actual flow of water}}{\text{Intended flow of water}}$	Shows changes in quality of service to users	Quantifies the uniformity and equity of water delivery
Dependability of interval between water applications	$\frac{\text{Actual irrigation interval}}{\text{Intended irrigation interval}}$	Shows changes in service (timing only) to farmers	Illustrates the equity of water delivery service to farmers
Canal water level ratio	$\frac{\text{Actual canal water level}}{\text{Design canal water level}}$	Quantifies need for maintenance of system components	Identifies system components that need repair/ replacement
Canal Discharge Capacity Ratio	$\frac{\text{Actual canal discharge capacity}}{\text{Design canal discharge capacity}}$	Quantifies need for maintenance of system components	Identifies system components that need repair/ replacement

ET_p = potential evapotranspiration; ET_a = actual evapotranspiration from the gross command area; P_e = effective precipitation; V_c = volume of surface water flowing into the command area

Molden *et al.* (1998), Burt and Styles (1998), Burt (2002) and Malano and Burton (2001) also developed water supply indicators some of which were summarised by Greaves (2007) as shown in Table 3.3. The indicators include Relative Water Supply (RWS) which was first presented by Levine (1982) and Relative Irrigation Supply (RIS) developed by Perry (1996). Both RWS and RIS relate water demand to the supply of water in a scheme, and thus, they provide information on water availability, hence are important to water-scarce countries such as South Africa. However, Lorite *et al.* (2004) concluded that these two indicators are directly affected by rainfall, and Molden (1998) cautions on the interpretation of both RWS and RIS.

Table 3.3 Summary of other water supply indicators (Greaves, 2007)

Indicator	Computation Formula
Relative Water Supply (RWS)	$\frac{\text{Total water supply}}{\text{Crop demand}}$
Relative Irrigation Supply (RIS)	$\frac{\text{Irrigation supply}}{\text{Irrigation demand}}$
Irrigation Efficiency (%) (IE)	$\frac{\text{Volume of irrigation water beneficially used}}{\text{Vol. of irrig. water applied} - \Delta \text{ storage of irrig. water}}$
Annual irrigation water per unit irrigated area ($\text{m}^3 \cdot \text{ha}^{-1}$)	$\frac{\text{Total annual volume of irrigation supply}}{\text{Total annual irrigated crop area}}$

The external performance indicators are, however, insufficient for decision making, planning and control operations in a dynamic irrigation environment. They do not reflect all dimensions of organizational performance in a balanced and integrative framework (Jusoh *et al.*, 2008), hence the need to include financial and environmental indicators. Financial indicators concentrate on the costs and returns, in monetary value and they include cost recovery ratio; maintenance cost to revenue ratio, total cost of management, operation and maintenance per unit command area and revenue collection performance (Greaves, 2007), while the environmental indicators concentrate on sustainability of irrigation, pollution of both land and water as well as the effects of irrigation on the surroundings. Greaves (2007) noted that environmental indicators include cropped area ratio, change in water table depth over time and salinity of the soil.

3.2.2 Internal performance indicators

Burt and Styles (1998) realised that the external indicators were not adequate to describe irrigation performance and they included internal indicators for evaluation of performance within the irrigation schemes. In order to enhance performance, it is necessary to have a comprehensive understanding of the internal processes within an irrigation scheme. Internal indicators examine the mechanisms of water control and allocation at all levels of the project and provide systematic rating of hardware, management and service throughout the entire system (Kuscu *et al.* 2009). An example of an internal indicator is shown in Table 3.4

Burt (2002) pointed out that most internal indicators have sub-components, called sub-indicators and each of the sub-indicators is assigned a weighting factor. In the case of Table 3.4, each sub-indicator, of the indicator I-1, has maximum potential of 4 (best case) and a minimum of 0 (worst case). Burt and Styles (1998) assigned weighting factors to each sub indicator to get the value of the internal indicator. The weighting factors were only relative to each other with the indicator group. The weighted sub-indicators were then summed up and the final value was adjusted based on a possible scale of 0-4 (4 indicating the most possible conditions).

The aim of evaluating both the external and internal indicators of an irrigation scheme is to reflect all the organizational dimensions and identify system components that require maintenance or modernization. In the developing world, where economies are based on agriculture, it is necessary to carry out thorough irrigation performance assessments using both categories of indicators. The inclusion of internal indicators implies that the performance assessment would incorporate corporate and social evaluation, stakeholder satisfaction and participation for continuous improvement of quality, standards and excellence (Kuscu *et al.*, 2009).

In South Africa water demand is expected to exceed supply as early as 2013 in some metropolitan provinces and spread throughout the whole country by 2025 (Zulch, 2010). The evident capacity problems in water management call for the utilization of both external and internal indicators for a comprehensive evaluation to increase productivity and performance in all sectors. With agriculture, particularly irrigation being the biggest water user, water management and efficiency evaluation in this sector is imperative.

Table 3.4 An example of an Internal Process Indicator: Actual water delivery service to irrigation scheme (Burt, 2002)

Sub-Indicator	Ranking Criteria	Weight
Measurement of volumes to the individual units (0-4)	4 - Excellent measurement and control devices; properly operated and recorded. 3 - Reasonable measurement and control devices, average operation. 2 - Useful but poor measurement of volumes and flow rates. 1 - Reasonable measurement of flow rates, but not of volumes. 0 - No measurement of volumes or flows.	1
Flexibility to the individual units (0-4)	4 - Unlimited frequency, rate, and duration, but arranged by users within a few days. 3 - Fixed frequency, rate, or duration, but arranged. 2 - Dictated rotation, but it approximately matches the crop needs. 1 - Rotation deliveries, but on a somewhat uncertain schedule. 0 - No established rules.	2
Reliability to the individual units (0-4)	4 - Water always arrives with the frequency, rate, and duration promised. Volume is known. 3 - Very reliable in rate and duration, but occasionally there are a few days of delay. Volume is known. 2 - Water arrives about when it is needed and in the correct amounts. Volume is unknown. 1 - Volume is unknown, and deliveries are fairly unreliable, but less than 50% of the time. 0 - Unreliable frequency, rate, duration, more than 50% of the time, and volume delivered is unknown.	2
Apparent equity to individual units (0-4)	4 - All fields throughout the project and within tertiary units receive the same type of water delivery service. 3 - Areas of the project receive the same amounts of water, but within an area the service is somewhat inequitable. 2 - Areas of the project receive somewhat different amounts (unintentionally), but within an area it is equitable. 1 - There are medium inequities both between areas and within areas. 0 - There are differences of more than 50% throughout the project on a fairly widespread basis.	4

3.3 Smallholder Irrigation and Performance Assessment

Smallholder irrigation is important in many developing countries in terms of agricultural food production, incomes for rural people and public investment for rural development (Small and Svendsen, 1992), yet dissatisfaction with the performance of smallholder irrigation schemes is widespread in these countries. This is despite them being at the centre of agricultural and general rural growth. They perform far below their potential (Small and Svendsen, 1992), due to a number of factors, chief among them scheme management capacity.

The unprecedented development of smallholder irrigation around the world warranted the need to check the performance in this subsector against set targets. Performance evaluations have been carried out the world over on individual smallholder schemes; schemes in a basin; and schemes at national level for specific types such as those public-operated and transferred to users' associations or cross-system comparison of schemes, all with the aim of enhancing efficiency of resource utilization (Kuscu *et al.*, 2009).

4. FARMERS' EVALUATION OF IRRIGATION PERFORMANCE

A complex set of factors influence the performance of smallholder irrigation and hence the satisfaction of the farmers utilising the irrigation service. To get a better understanding of the performance, one needs to analyze many possibilities and scenarios which generally present challenges. The problems that arise in trying to analyse data in irrigation performance evaluations include subjective judgements and multicollinearity of the different factors considered (Magingxa *et al.*, 2006). Multicollinearity is a situation whereby some of the variables are dependent on others (Hill *et al.*, 2008). The maintenance of irrigation and drainage canals has an effect on the adequacy of water delivered to the field, but both factors affect the performance of the scheme. In this case, it becomes very difficult to analyze data as the factors might be highly correlated leading to biased parameter estimates. The availability of analytical tools capable of handling quantitative or qualitative subjective data means such challenges can be solved.

Several analytical tools are available but the challenge is the selection of the best model. Corty (2007) stated that there is no statistic model which is the right one for a specific research problem, but there is the best, which can be described as offering more ways to infer about specific characteristics. Of the three models explored in this review, one will be selected and applied in data analysis in the proposed study in Chapter 6. Three models are being discussed because of their ability to handle discrete, subjective and qualitative data which is usually associated with irrigation performance assessment studies (Damisa *et al.*, 2008).

4.1 The Linear Probability Model (LPM)

There are different factors that can influence farmer satisfaction in irrigation schemes. Some of the factors are technical, social or economic while some are institutional. Of importance is how the farmer reached the decision of being satisfied or not. Let the farmer's decision be y , and then the linear regression model for explaining the decision will be given by (Hill *et al.*, 2008):

$$y = E\{y\} + e = p + e \quad (4.1)$$

in which $y = \begin{cases} 1 & \text{farmer is satisfied by taking irrigation service} \\ 0 & \text{farmer is not satisfied by taking the irrigation service} \end{cases}$

where $E\{y\} = p =$ probability that the farmer is satisfied ($y = 1$)
 $e =$ random error

Assuming that the probability of satisfaction is linearly related to the set of explanatory factors, X_i , determining farmer satisfaction, then

$$E\{y\} = p = \beta_0 + \sum_{i=1}^k \beta_i X_i \quad (4.2)$$

Where β_0 and β_i represent the intercept and the slope of the regression function, respectively. And therefore

$$y = E\{y\} + e = \beta_0 + \sum_{i=1}^k \beta_i X_i + e \quad (4.3)$$

Equation 4.3 is called the linear probability model. However, the problem with this model is that the error term, e , is heteroskedastic, that is, the variance of e varies with different observations. There is also a possibility of obtaining estimated p that are either less than 0 or are greater than 1 and the process of adjusting them adds to the inaccuracies in interpretation.

4.2 The Logit Model (LM)

Logit regression analysis allows for estimating probability that an event occurs or not by predicting a binary dependent outcome from a set of independent variables. A farmer's satisfaction status with taking the irrigation service is dependent on a number of factors. The basic ideas underlying the Logit model is given below (Kuscu *et al.*, 2009):

$$P_i = E\{Y = 1|X_i\} = \beta_0 + \sum_{i=1}^k \beta_i X_i \quad (4.4)$$

Where P_i represents the probability of the farmer being satisfied by taking an irrigation service, X_i denotes the set of explanatory factors determining farmer satisfaction and Y is the dependent variable (satisfaction or dissatisfaction). β_0 and β_i are as explained in Equation 4.2.

Equation 4.4 can be written as below

$$P_i = E\{Y = 1|X_i\} = \frac{1}{1+e^{-(\beta_0+\sum_{i=1}^k \beta_i X_i)}} \quad (4.5)$$

If Z is to denote $\beta_0 + \sum_{i=1}^k \beta_i X_i$, then equation 2 can be written as

$$P_i = E\{Y = 1|X_i\} = \frac{1}{1+e^{-Z_i}} \quad (4.6)$$

From equation 4.6, the probability of a farmers being dissatisfied with the irrigation service is then given by $(1 - P_i)$, and

$$(1 - P_i) = \frac{1}{1+e^{Z_i}} \quad (4.7)$$

This can be written as:

$$\frac{P_i}{(1-P_i)} = \frac{1+e^{Z_i}}{1+e^{-Z_i}} \quad (4.8)$$

Taking natural logarithms both sides of equation 4.8 will leave us with (Kuscu *et al.*, 2009):

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \sum_{i=1}^k \beta_i X_i \quad (4.9)$$

L_i is called the Logit model. The assumption here is that the farmer's decision is reached after considering different factors related to water supplies and deliveries, and farmer satisfaction is a measure of irrigation performance. The significance of the technical factors that the farmers consider can be tested and Principal Component Regression (PCR) applied within a maximum likelihood estimation framework to determine the technical performance level.

4.3 The Probit Model

This model uses the same principles as the Logit model and applies to binary choice model. However, the Probit Model assumes that the error term is normally distributed and if z is the standard normal random variable, then the probability density function is defined as (Hill *et al.*, 2008):

$$\varphi(z) = \frac{1}{\sqrt{2\pi}} e^{-0.5z^2} \quad (4.10)$$

The probit function is (Hill et al, 2008):

$$\varphi(z) = P[Z \leq z] = \int_{-\infty}^z \frac{1}{\sqrt{2\pi}} e^{-0.5u^2} du \quad (4.11)$$

The Probit statistical model that expresses the probability p , that the farmer is satisfied with taking the irrigation service ($y = 1$) is derived from Equation (4.11) and is (Hill *et al.*, 2008):

$$p = P[Z \leq \beta_0 + \sum_{i=1}^k \beta_i X_i] = \varphi(\beta_0 + \sum_{i=1}^k \beta_i X_i) \quad (4.12)$$

The Probit model is sometimes referred to as the Normit model, taking its name from the normal distribution. In order to predict the individual decision that the farmer is satisfied with taking the irrigation service, we compute the estimates through likelihood estimation. Qualitatively, the probit model gives similar results to those from the logit model.

It is necessary to take into consideration the farmers' perspective of technical performance (Plusquellec, 2002) and these three models have been described considering their capability to handle qualitative data. The data collected from the farmers is very subjective, but at the same time it is their satisfaction with taking the irrigation service which can measure the performance of an irrigation scheme.

5. DISCUSSION AND CONCLUSIONS

Understanding the performance of smallholder irrigation projects is critical for proper planning and evaluation of land and water management strategies (Magingxa *et al.*, 2006). Governments across the globe believe that smallholder irrigation is a tool to fight hunger and alleviate poverty, especially in developing countries which have agriculture-based economies. As such, governments have tended to support the smallholder subsector (Nkwinti, 2009), in a bid to create employment for the rural poor, and improve food security at household level. However, a complex set of factors that affect the operation, management and maintenance of the smallholder schemes has kept the performance very low (Small and Svendsen, 1992).

A comprehensive understanding of these factors may assist not only in improving the livelihood of the rural poor, but will also enhance smallholder irrigation performance, thus saving scarce agricultural resources and ensuring sustainability of the schemes. There are several performance issues that one can look at in smallholder irrigation schemes ranging from technical and economic to social and institutional, and can be explored from different stakeholders' perspectives (Naik and Kalro, 2000). Research studies on smallholder irrigation performance have been carried out from the farmers' perspective (Kuscu *et al.*, 2009) but, in South Africa, more concentration has been given to economic returns (Ntsonto, 2005; Yokwe, 2009) and on the smallholder irrigation development (Van Averbeke and Mohamed, 2006). Technical performance research studies related to water conveyance, delivery and use in the smallholder schemes and implementation of the recommendations have usually sidelined the farmers (Plusquellec, 2002; Kuscu *et al.*, 2009)

Different analytical tools are available to evaluate the satisfaction status of the various stakeholders as outlined in Chapter 4. However, the most appropriate model, which has been used before, for the purpose of analysing the farmers' satisfaction status is the Logit Model because it has the following advantages (Damisa *et al.*, 2008) over the other models:

- The computation of the logistic distribution ensures the rate of the probabilities estimated always lie between 0 and 1

- The probability does not increase linearly with a unit change in value of the explanatory variables, as it does in Linear Probability Model, and so the problem of heteroskedasticity is eliminated.
- It is easier to compute and interpret than the Probit Model

As a water-scarce country, South Africa requires concerted efforts from all agriculture stakeholders in planning and implementation of water-saving programmes to reduce the severe effects of expected water shortage by 2013 (Zulch, 2010).

6. PROJECT PROPOSAL

A project proposal to assess the technical performance of smallholder irrigation in South Africa and the opportunities for deriving best management practices is presented in this chapter. The project is proposed to be carried out in the KwaZulu-Natal (KZN) province.

6.1 Problem Identification and Context

The South African government sees smallholder irrigation as a tool for improving rural livelihoods, food security and empowering and mainstreaming the previously disadvantaged farmers in the local, national and international economy (Joemat-Pettersson, 2009). As such the government has invested significant financial resources into the rehabilitation of smallholder schemes across the country and mobilized strong technical support for these schemes through various partnerships between non-governmental organizations and local governments in the different provinces (Joemat-Pettersson, 2009). The financial resources are in the ranges of between R30 000 – R60 000 per hectare for infrastructure rehabilitation and human resources development (Denison and Manona, 2007) and are comparable to figures of rehabilitation in other parts of the world (Inocencio *et al.*, 2007).

It is of great interest to know how the smallholder schemes are performing now and determine whether the farmers are satisfied or not with the irrigation service, and what can be done to sustain the schemes operations. This research will be carried out in two stages: assessment of the technical performance of two schemes and then determination of the level of satisfaction of the farmers with irrigation performance and identification of the factors affecting their assessment of the performance. There is a clear relationship between the satisfaction of the farmers with the current irrigation service and the performance of the scheme. With the development of different analytical tools which can handle subjective and dichotomous data, evaluating the levels of satisfaction has been made relatively easy.

6.2 Research Objectives

The specific objectives of the proposal are:

- To assess the technical performance of Mooi-River (MRIS) Irrigation Schemes,
- To determine the farmers' subjective assessment of performance and the factors underlying their assessment at MRIS,
- To derive the best management practices from the key factors identified above.

6.3 Research Questions

This research seeks to answer the following questions:

- How is the Mooi-River Irrigation scheme performing with respect to technical aspects?
- What are the farmers' perceptions on the current performance of the scheme?
- How best can the performance be improved from the available knowledge?

6.4 Research Methodology

The research will be carried out at Mooi-River Irrigation Scheme located in Msinga district in the Midlands region of KZN province. The scheme spans approximately 600 hectares with around 800 farmers. The scheme is divided into 0.1 ha plots. Water is diverted from Mooi River and conveyed to the scheme through a 13km concrete-lined parabolic canal from which distributary canal of different shapes branch to supply the plots. The scheme was chosen because it is one of the biggest smallholder schemes in KZN exhibiting water shortages and therefore need to there is need to investigate the causes.

The research methodology will include assessment of selected technical performance indicators for two irrigation seasons and then comparing them to standards and expected values. In the second stage, a suitable number of farmers from the same scheme are to be interviewed through questionnaires related to the performance indicators used in the first stage. Satisfaction with the irrigation service being provided in relation to an indicator will be denoted by a 1 (one) and

dissatisfaction will be denoted by 0 (zero). The investigation is set to be carried out at only two schemes because of resource constraints. The methodology to be employed is as follows:

Objective 1: Technical performance assessment of Mooi-River smallholder schemes

The irrigation performance indicators below will be assessed:

- a) Water balance, water service and maintenance – Delivery Performance Ratio, Dependability of Irrigation intervals between water applications, Outflow over Inflow ratio, Water level ratio and Discharge capacity ratio
- b) Agricultural performance indicators – Output per unit irrigation supply, Output per unit water consumed

These were selected based on the fact that both water and land are constrained (Molden et al, 1998) in South Africa (NWA, 1998) and after a pilot survey of the problems the farmers were facing at Mooi-River irrigation schemes and other smallholders gardens in the study area. They will be assessed as outlined in Bos et al (2005).

Objective 2: Determination of the farmers' subjective assessment of irrigation performance and the factors underlying their assessment at MRIS

The current operation, maintenance and management practices at MRIS are documented. Factors affecting performance for the selected indicators (in Objective 1), are identified and ranked following the Rapid Appraisal Process manual (Burt, 2002), which allows for investigation of internal processes within the schemes.

A questionnaire will be administered to farmers in the scheme. Satisfaction will be represented by 1, while 0 will represent dissatisfaction with taking the irrigation service. The Logit Model will show the level of farmer satisfaction and corrective measures if the farmers are not satisfied. The Logit Model has been selected because it is easier to compute and interpret than the other models described and has been applied to similar research problems in other countries (Damisa *et al.*, 2008)

Objective 3: Derivation of the best management practices (BMP) from the key factors identified above and level of farmer satisfaction.

The best technical practices will follow from rectifying the problems highlighted by the farmers in the questionnaire: addressing the sections where the farmers are not satisfied with the irrigation service. This research will address the technical practices. Other management issues to deal with institutional and social practices would need to be studied.

6.4 Resources required, Deliverables and Work Plan

The estimated resources required for this project are below:

Table 6.1 Resources required for the project

Resource	Total Costs	Source
Transport (to and from MRIS) (10 x2 trips x 180km)	R 10 000	UKZN
Flow measurement meters	R30 000	UKZN
Laptop & stationery	R 8 000	UKZN
Field Assistance (20 days per month x R100 per day for 6 months)	R 8 000	UKZN
Technical assistance	R 5 000	UKZN
Sundry expenses (food, accommodation, etc for 6 months)	R 10 000	UKZN
GRAND TOTAL	R71 000	

Below are the main deliverables of the project:

- Journal article on irrigation performance of MIRS
- Conference paper on best management practices in smallholder irrigation schemes in South Africa
- Final MSc Thesis

The summary of timeframes for this research is presented in Table 6.2

Table 6.2 Timeframes for the project.

	June 2010	July 2010	Aug 2010	Sept 2010	Oct 2010	Nov 2010	Dec 2010	Jan 2011	Feb 2011
Activity									
Installation of measuring devices									
Measuring the water flows (1 st Season)									
Measuring the water flows (1 st Season)									
Measuring the water flows (1 st Season)									
First Harvest Interview									
Measuring the water flows (2 nd Season)									
Measuring the water flows (2 nd Season)									
Measuring the water flows (2 nd Season)									
Second Harvest Interview									
Final MSc. Thesis Document									

7. REFERENCES

- Albinson, B., and Perry, C. J. 2002. Fundamentals of Smallholder Irrigation: The Structured System Concept Research Report 58. IWMI Publications. Colombo, Sri Lanka
- Backeberg, G.R., Bembridge, T.J., Bennie, A.T.P., Groenewald, J.A., Hammes, P.S., Pullen, R.A, and Thompson, H. 1996. Policy Proposal for irrigated agriculture in South Africa. Water Research Commission report number KV 96/96. Pretoria, South Africa
- Bembridge, T.J. 2000. Guidelines for rehabilitation of small-scale farmer irrigation schemes in South Africa. Water Research Commission report number 891/1/00. Pretoria, South Africa.
- Bos, M.G., Burton M.A, and Molden, D. J. 2005. Irrigation and Drainage Performance Assessment: Practical Guidelines. CABI Publishing, London, UK.
- Bucknall, J., Klytchnikova, I., Lampietti, J., Lundell, M., Scatasta, M., and Thurman, M. 2003. Irrigation in Central Asia: Social, Economic and Environmental Considerations. World Bank Publications. Washington, USA.
- Burt, C. 2002. Rapid Appraisal Process (RAP) and Benchmarking: Explanation and Tools. [Internet] Available from: <http://www.watercontrol.org/tools/rap-eng-2002>. [Accessed on 04/02/2010]
- Burt, C.M. and Styles S.W. 1998. Modern water Control and Management Practice in Irrigation: Impact on Performance. ITRC, California Polytechnic State University, USA.
- Cornish, G. 1998. Modern irrigation technologies for smallholders in developing countries. Intermediate Technology Publications in association with HR Wallingford UK.
- Corty, E.W. 2007. Using and Interpreting Statistics. Mosby, Inc. St. Louis, Missouri, USA.
- Cousins B. 2009. Personal communication. Ongoing research at Tugela Ferry. University of Western Cape, Cape Town, RSA, 10 Dec 2009.
- Damisa, M.A., Abdulsalam, Z., and Kehinde, A. 2008. Determinants of Farmers` Satisfaction with their Irrigation System in Nigeria. *Trends in Agriculture Economics Journal* 1 (1): 8-13.
- Denison, J. 2009. Personal Communication, jdenison@umhlabacg.co.za. Umhlaba Consulting Group (Pty) Ltd. East London, RSA, 10 November 2009.

- Denison, J. and Manona, S. 2007. Principles, Approaches and Guidelines for the Participatory Revitalisation of Smallholder Irrigation Schemes Volumes 1 & 2. Water Research Commission Report No TT 309/07. Pretoria, South Africa
- FAO. 2001. Smallholder Irrigation Technology: Prospects for Sub-Saharan Africa. IPTRID Secretariat Food and Agriculture Organization of the United Nations Paper Number 3 – March 2001. Rome, Italy.
- Faures, J.M., Svendsen, M., and Turrall, H., and Others. 2007. Reinventing Irrigation: In Water for food Water for life: A comprehensive Assessment of Water Management in Agriculture. Earthscan, London. UK
- Garces-Restrepo, C., Vermillion, D., and Muñoz, G. 2007. Irrigation Management Transfer: Worldwide efforts and results. FAO Water Report 32. FAO Publications, Rome, Italy
- Giordano, M. A., Samad, M., Namara, R. E. 2006. Assessing the outcomes of IWMI's research and interventions on irrigation management transfer Research Report 106. Colombo, Sri Lanka
- Greaves, K.R. 2007. Quantifying and Benchmarking Irrigation Scheme Performance with Water balances and Performance Indicators. Unpublished MSc Thesis, University of KwaZulu Natal
- Hill, R.C., Griffiths, W.E., and Lim, G.C. 2008. Principles of Econometrics Third Edition. John Wiley & Sons, New Jersey, USA.
- Inocencio, A., Kikuchi, M., Tonosaki, M., Maruyama, A., Merrey, D., Sally, H., de Jong, I. 2007. Costs and performance of irrigation projects: A comparison of sub-Saharan Africa and other developing regions Research Report 109. IWMI Publications. Colombo, Sri Lanka
- Joemat-Pettersson T. 2009. Raising the Stakes. The Financial mail Volume 202, number 11. The business Media Company. Rosebank, South Africa.
- Jusoh, R., D. N. Ibrahim, Y. D. N., Zainuddin. Y. 2008. The performance consequence of multiple performance measures usage: Evidence from the Malaysian manufacturers, *International Journal of Productivity and Performance Management*, Vol. 57 (2), pp.119-136
- Kuscu, H., Boluktepe, F.E., Demir, A.O. 2009. Performance assessment for irrigation water

- Management: A case study in Karacabey Irrigation Scheme in Turkey. African journal of Agricultural Research Vol. 4(2), 124 -132
- Lahiff, E. and Cousins, B. 2004. The Prospects for Smallholder Agricultural Production in South Africa: A Discussion Document, PLAAS, University of Western Cape, 2004.RSA
- Levine G. 1982. Relative water supply: an explanatory variable for irrigation systems. Technical Report Number 6.Cornell University, Ithaca, New York, USA
- Lorite I. J, Matoes, L. and Fereres, E. 2004. Evaluating irrigation performance in a Mediterranean environment – Model and general assessment of an irrigation scheme. *Irrigation Science 23 (2): 77-84.*
- Magingxa, L.L., Alemu Z.G., and van Schalkwyk, H.D. 2006. Factors influencing the success potential in smallholder irrigation projects of South Africa: A Principal Component Regression. International Association of Agricultural Economists Conference. August 12 – 18 2006, Gold Coast, Australia
- Malano, H. and Burton, M. 2001. Guidelines for Benchmarking Performance in the Irrigation and Drainage Sector. IPTRID and FAO, Rome, Italy
- Maritz, P.J. 2001. Irrigation Management Transfer: Sharing Lessons from Global Experience: Comments on Overview Paper. National Department of Agriculture, Pretoria, South Africa
- Molden, D., Oweis, T.Y., Steduto, P., Kijne J.W., Hanjra M.A., Bindraban P. S. and Others. 2007. Pathways for increasing agricultural water productivity in Water for Food Water for life: A Comprehensive Assessment of Water Management in Agriculture. IWMI publications, Earthscan. London, UK.
- Molden, D. J., Sakthivadivel, R., Christopher, J. Perry, C.J. and de Fraiture, C. 1998. Indicators for Comparing Performance of Irrigated Agricultural Systems Research Report 20. IWMI Publications, Colombo, Sri Lanka
- Mukherji, A., Facon, T., de Fraiture, C., Faures, J.M., Fuleki, B., Giordano, M., Molden, D. and Shah, T. 2009. Revitalizing Asia`s Irrigation: to meet tomorrow`s food needs. IWMI Publications. Colombo, Sri Lanka.
- Murray – Rust, H. and Snellen, B. 1993. Irrigation system performance assessment and diagnosis. International Irrigation Management Institute Publications. Colombo, Sri Lanka.

- Naik, G. and Kalro, H. 2000. A methodology for assessing the impact of irrigation management transfer from farmer`s perspective. *Water Policy* 2: 445 – 460.
- National Irrigation Board (Kenya). 2007. Mwea Irrigation Scheme: History of the Scheme. [Internet] Available from <http://www.nib.or.ke/> [Accessed 25 February 2010]
- Nkwinti, G. 2009. Raising the stakes. *The Financial Mail* Volume 202, number 11. The business Media Company. Rosebank, South Africa.
- Ntsonto, N.E. 2005. Economic performance of Smallholder Schemes: a case study of Zanyokwe, Eastern Cape, South Africa. Unpublished MSc Thesis, University of Pretoria
- NWA. 1998. Government of South Africa: *National Water Act, 1998, Act No. 36 of 1998* Government Gazette No 19182, 26 August 1998
- NWRS, 2004. National Water Resource Strategy – First Edition, September 2004. Department of Water Affairs and Forestry, Pretoria, RSA
- Oosthuizen L.K. 2002. Land and water resources management in South Africa. Integrated Land and Water Resources Management (WG-ILWRM), 18th ICID Congress, Montreal, Canada
- Perret, S. 2002. Water policies and smallholding irrigation schemes in South Africa: a history and new institutional challenges. *Water Policy*. 4 (3): 283 – 300.
- Perry C.J. 1996. Quantification and measurement of a minimum set of indicators of the performance of irrigation systems. International Irrigation Management Institute, Colombo Sri Lanka
- Plusquellec, H. 2002. How design, Management and Policy affect the performance of Irrigation projects: emerging modernization procedures and design standards. FAO publications. Bangkok, Thailand.
- Pourzand, A. 2002. Irrigation Advisory Services and Participatory Extension in Irrigation Management. FAO – ICID Workshop. Montreal, Canada
- Rao, P.S. 1993. Review of selected literature on indicators of irrigation performance. International Irrigation Management Institute. IIMI Publications. Colombo, Sri Lanka
- Renault D.1998. Modernization of irrigation system operations: proceedings of the 5th network international meeting, Aurangabad, 28-30 October 1998. FAO Publications. Available from: <http://www.fao.org/docrep/003/x6626e04.htm>. [Accessed: 25/01/2010]
- Renault, D., Facon, T., and Wahaj, R. 2007. Modernizing Irrigation Management – the

- MASSCOTE approach: Mapping System and Services for Canal Operation Techniques. FAO Irrigation and Drainage Paper 63. FAO Publications. Rome, Italy
- Ricardo A., Brito L., Bastings I.W.A., Bortolozzo, A. R. 2003. The Paracatu/Entre-Ribeiros irrigation scheme in South-eastern Brazil: Features and challenges in performance assessment. *Journal of Irrigation and Drainage Systems* 17: 285–303
- Shah, T., van Koppen, B., Merrey, D., de Lange, M. and Samad, M. 2002. Institutional Alternatives in African Smallholder Irrigation: Lessons from International Experience with Irrigation Management Transfer Research Report 60. IWMI Publications, Colombo, Sri Lanka
- Shongwe, M. 2007. Water management practices in small-scale irrigation schemes in South Africa: A case of Tugela Ferry Irrigation scheme in KwaZulu-Natal, South Africa. Unpublished MSc Thesis, University of Pretoria
- Small, L.E., and Svendsen, M. 1992. A framework for assessing irrigation performance. Working Papers on Irrigation Performance 1. International Food Policy Research Institute. Washington, DC, USA
- Svendsen, M., Ewing, M. and Msangi, S. 2009. Measuring Irrigation Performance in Africa. International Food Policy research Institute Discussion Paper 00894. Washington DC, USA
- Van Averebeke, W. and Mohamed, S.S. 2006. Smallholder irrigation schemes in South Africa: Past, present and future. [Keynote address read at the 2nd Symposium of the South African National Committee on Irrigation and Drainage, 15-17 November 2006, Aventura Swadini, Mpumalanga]. Available from: <http://www.sancid.org.za/files/keyNotesAdd.doc>. [Accessed: 21/01/2010].
- Yokwe S. 2009. Water productivity in smallholder irrigation schemes in South Africa. *Agricultural Water Management Journal* 96 (2009) 1223–1228
- Zulch, L. 2010. Water demand to exceed supply by 2025. [Internet]. Available from: <http://www.news24.com/Content/SouthAfrica/News>. [Accessed on 04/02/2010]