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Residual value and production function approaches to valuation of irrigation water in sugar cane production: application to the Lowveld in Swaziland

By

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Submitted in partial fulfilment of requirements for the degree of MSc Agric (Agricultural Economics)

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DECLARATION OF ORIGINALITY

I hereby declare that this dissertation which I submit for the degree of MSc Agricultural Economics at the University of Pretoria is my own work and it has not been previously submitted by me for a degree at this or any other institution of higher learning.

Signature ....
Thabo Thandokuhle Sacolo
Date ....

Approved by:
Signature ....
Dr E.D. Mungatana
Date ....

DEDICATION

I dedicate this dissertation to the Lord God Almighty for granting me the privilege of life and above all for giving me wisdom and strength to take on this demanding task to the end. I fully acknowledge the fact that I would not have made it on my own.

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ABSTRACT

Residual value and production function approaches to valuation of irrigation water in sugar cane production: application to the Lowveld in Swaziland

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Supervisor: Dr E.D. Mungatana

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Key words: Non-market valuation, irrigation water, sugar cane, residual value, production function, technical efficiency, stochastic frontier, Lowveld, Swaziland.

The main objective of the study was to estimate non-market value of irrigation water as an input in sugar cane production in the Lowveld of Swaziland. This study used two independent approaches to non-market valuation, the residual value and production function approaches, to calculate the value that sugar cane farmers in the Lowveld region of Swaziland attach to irrigation water. The former estimated the average value of water, while the latter estimated the marginal value. The study also estimated the output elasticity of irrigation water, identified factors determining irrigation water values, and used stochastic frontier analysis to estimate farmers' technical efficiency (TE) scores, and investigated the relationship hypothesised between irrigation water values and TE. Irrigated sugar cane production was specifically selected for this study on account of its socio-economic importance in Swaziland.

Using data obtained from 78 sugar cane farms, the mean estimated value of irrigation water, measured in Emalangeni per metre cubed, was E1.60/m^3 using the residual value approach, and E1.51/m^3 using the production function approach. A t-test showed that the observed differences between the values estimated from the two independent approaches were not statistically significant, suggesting that either method can be used to value irrigation water employed in sugar cane production in Swaziland. The results from the t-test, in conjunction

with the economic theory of duality, also allow us to conclude that the production technology employed by irrigation sugar cane farmers exhibits constant returns to scale. Irrigation water was output inelastic (0.711), lending additional credence to the constant returns technology conclusion. The value calculated for irrigation water was negatively related to irrigation water quantity, suggesting that price can be used as an instrument to directly regulate the quantity of irrigation water the farmer employs. The value calculated for irrigation water was negatively related to quantities of labour, quantity of irrigation water used, fertilizer and chemicals employed, suggesting that price can be used as an instrument to indirectly regulate the quantity of irrigation water the farmer employs. The value imputed for irrigation water was positively related to farm size and total revenue, suggesting that the more resource-endowed farmers can potentially pay higher for irrigation water. It is thus conceivable to design irrigation water pricing policies with equity considerations. TE scores ranged from 0.397 to 0.955, with a mean of 0.840. Farmers with higher TE scores also had higher implicit values for irrigation water, suggesting that irrigation water pricing can be used as a tool for motivating resource use efficiency.

The key policy implication derived from this study is that price-based instruments have a potential in the management of scarce irrigation water resources in Swaziland.

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LIST OF ACRONYMS

CD	Cobb-Douglas production function
CIA	Central Intelligence Agency
CTC	Consultancy and Training Centre
DWAF	Department of Water Affairs and Forestry
EU	European Union
FA	Farmer Association
FAO	Food and Agricultural Organisation of the United Nations
GDP	Gross Domestic Product
IFPRI	International Food Policy Research Institution
IWSD	Institution of Water Sanitation and Development
KDDP	Komati Downstream Development Project
LUSIP	Lower Usuthu Smallholder Irrigation Project
MLE	Maximum Likelihood Estimation
MPP	Marginal Physical Product
MOAC	Ministry of Agriculture and Cooperatives
O&M	Operation and Management
OLS	Ordinary Least Squares
SADC MAPP	Southern African Development Community Multi-Country Agricultural Production programme
SSA	Swaziland Sugar Association
SWADE	Swaziland Water and Agricultural Development Enterprises
TE	Technical Efficiency
TEEB	The economics of Ecosystems and Biodiversity
TRANSLOG	Transcendental logarithmic production functions
UNCTAD	United Nations Conference on Trade and Development
UNISWA	University of Swaziland
USDA	United States Department of Agriculture
VMP	Value of Marginal Product
WFP	World Food Programme

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Agriculture is the mainstay of the Swaziland economy. It is a primary livelihood activity for about 15 percent of rural households on average, accounting for about 70 percent of rural household income (FAO/WFP, 2007:18). Withdrawals are estimated at 1200m^3 per person per annum and agriculture is by far the largest consumer of water accounting for about 96 percent of all water withdrawals, industry 2.4 percent, domestic uses 1.4 percent and environmental use is unaccounted (Nyagwambo, 2008:3). Partly due to the apparent abundance of surface water, ground water resource is not considered high priority for irrigation purposes in Swaziland and as a result all irrigation water is drawn from rivers and streams (Institution of Water Sanitation and Development (IWSD), 2006:8). Table 1.1 shows that begtween 2006 to 2012, the agricultural sector has been making an average annual contribution of 9 percent to the country's GDP.

Table 1.1: Sector contribution to the economy as a percentage of GDP

Sector	2006	2007	2009	2010	2011	2012
Agriculture	8.5	12.7	7.3	8.9	7.8	8.2
Manufacturing	41	31.7	49.5	-	50.8	47
Service	45.5	50.4	43.2	-	41.4	44.8
Unaccounted	5	5.2	0	-	0	0

Source: Central Intelligence Agency (CIA) - The World Fact Book

The agricultural sector of Swaziland is regarded as one with a dualistic nature comprising of Swazi Nation Land (SNL), land held by the king in trust of the Swazi nation and Title Deed Land (TDL) which is privately owned land. SNL accounts for 74 percent and TDL accounts for the remaining 26 percent of the total area. Sugar cane absolutely dominates the irrigated agricultural sector, in 2002 occupying over 46,000 hectare of the estimated total 50,000 hectares of irrigated land and it is the sole important cash crop on SNL (UNISWA Consultancy and Training Centre (CTC), 2008:32-33).

Statistics released by the Swaziland Sugar Association in 2013 demonstrate that within the agriculture sector, the sugar industry plays a particularly pivotal role in the socio-economic development of the country (Table 1.2). For example at the national level, the industry contributes 59 percent to total agricultural output, 24 percent to manufacturing output and accounts for 35 percent of agricultural wage employment. At the regional level, SADC MAPP (2007:13) reports that the industry provides income and employment to 70 percent of the population of the Lowveld region of Swaziland. Internationally, Table 1.2 shows that the industry contributes to 58 percent of total Swaziland exports to the European Union.

Table 1.2: Contribution of the sugar industry to the agricultural sector

Category	Average contribution (%)
Agricultural output	59
Agricultural wage employment	35
Manufacturing output	24
Manufacturing wage employment	18
Private sector wage employment	16
Formal sector employment	10
Total export earnings	7
Total Swazi export to EU	58

Source: Swaziland Sugar Association, 2013

In Swaziland, sugar cane is grown in two main regions: the Lowveld and the Middleveld, with the former having more than 90 percent of farms. The Lowveld is particularly favourable for sugar cane cultivation for a number of reasons. First, its deep fertile soils, warm temperatures and flat undulating relief provide ideal agro-climatic conditions. In addition, all three sugar mills in the country are located in this region, providing further economic justification for the high concentration of farms. Within the Lowveld, sugar cane farms are concentrated in two locations: the northern part (around Mhlume and Simunye sugar mills), and the southern part (around Big-Bend sugar mill). Table 1.3 shows that the area under sugar cane production has been an increasing over the last three years.

Table 1.3: Total area under sugar cane production in Swaziland

	2010/2011	2011/2012	2012/2013
Area under sugar cane production	53,372	54,000	55,000

Source: United States Department of Agriculture (USDA), 2012

The above table shows that area under sugar cane production increased by 1,628 hectares in three farming seasons. Nearly all sugar cane in the Lowveld is grown under irrigation schemes, with the Lower Usuthu Irrigation Project (LUSIP) and the Nkomati Down Stream Development Project (KDDP) being the main ones. The LUSIP, which is located in the southern part of the Lowveld is not developed to its full capacity owing to insufficient water. In addition, the building of additional dams in the LUSIP to enhance irrigation capacity is not in short-term government development plans (IFPRI, 2010:11). Besides, if South Africa increases abstractions from the reservoirs on the Komati River and exhausts its share, the KDDP (located in the northern part of the Lowveld) would experience severe shortage (Department of Water Affairs and Forestry (DWAF), 2002:5). It follows that Swaziland is faced with the prospects of increasing total land area under sugar cane production and diminishing sources of irrigation water supply. All sugar cane farms in Swaziland are under irrigation and for this reason increase in area under sugar cane production directly translates to increase in irrigation water demand.

Current evidence from Swaziland shows that irrigation farmers do not pay for the water resource. They only meet their capital, operation and maintenance expenditure and use the irrigation water as a free gift from nature. Economic theory predicts that under such conditions, farmers will employ the irrigation water resource inefficiently. It follows that given a fixed supply of irrigation water; the further extension of the area under sugar cane production will require an increase in irrigation water use efficiency on existing farms. One way to enhance efficiency is to introduce demand-oriented approaches to irrigation water management. There are several demand-oriented measures for managing irrigation water, including quota systems and pricing. Pricing as a demand-management approach is further divided into several types, such as volumetric pricing, crop-based pricing and area-based pricing.

The benefits from pricing irrigation water include income redistribution, economic efficiency, resource conservation, revenue sufficiency, equity and fairness (Boland and Whittington, 2000 in Reddy, n.d.:27). Economists favour demand-oriented measures since they have great potential for inducing water use efficiency (e.g., see Abu-Zeid 2001:528). Bate and Dubourg (1997:312) argue that water pricing can yield an efficient allocation only if the non-market value of the resource is known. Arbues and Villanua (2006:2421) argue that since farmers are rational actors, the pricing of water will influence them to take into consideration the value of water relative to its cost. Irrigation water values provide a basis for evaluating whether particular investments in irrigation infrastructure or any other flow regulation and inter-basin transfer or inter-sector transfers are justified (Reddy, n.d.:26). Knowledge of the non-market value of irrigation water resources and the understanding of farmers' potential responses to price changes is useful for policy making (Hassan & Mungatana, 2006:255; Lange & Hassan, 2006:203). Estimates of irrigation water value are useful in the allocation of water rights: the control agent will be able to make a judgement based on the contribution, deduced from the value of the resource, which the prospective licence holder will have to the economy. On the other hand, a water permit holder with the benefit of information on irrigation water value can decide whether to sell or temporarily transfer his or her water right (Medellin-Azuara, Harou & Howitt, 2010:5639).

Consequently, the purpose of this study was to estimate the non-market value of irrigation water, in the Lowveld of Swaziland, which will be an input to the development of a pricing policy as a demand-oriented measure. The estimated value could help in determining whether farmers are capable of paying an amount that will satisfy the full cost recovery principle without compromising the viability of sugar cane growing. Covering operation and management cost is often regarded as an efficiency indicator in most developing countries (Reddy, n.d.:31). This value will also help in comparing different pricing mechanisms, for example comparing volumetric or marginal cost pricing with other pricing mechanisms, such as crop-based or area-based or quota systems. For instance, when the price of irrigation water is less than the actual value of irrigation water, volumetric or marginal cost-pricing appears to be inefficient when compared to crop-based or area-based or quota systems. Estimating the non-market value of irrigation water as an input in sugar cane production can also help in assessing the divergence between private and social value, thereby estimating the loss to society with the current allocation and also identifying the factors influencing the divergence. One notable disadvantage of pricing policy options is that they are often considered as politically infeasible and hence likely to be rejected with the claim that farmers lack the willingness and ability to pay for the resource.

1.2 PROBLEM STATEMENT

About 80 percent of the population of Swaziland depend on agriculture, which they practise on SNL under rainfed conditions, for their livelihoods and only a fraction of the remaining 20 percent engage in commercial crop production under irrigation (UNISWA CTC, 2008:32). In cash crops production irrigation water is one of the most important inputs for improving both agricultural production and productivity. Accordingly, irrigation water resource management remains a crucial integral element of sustainable agricultural development (Sampath, 1992:967; Tamiro, Mdoe & Lutatina, 1998:34). Unlike other commodities, water is often regarded as a public good; consequently, it does not have a well-functioning competitive market and hence no market-determined price tag for various uses (Singh, 2007:680). In the absence of information on the value of water in various uses, water allocative decision is not motivated by any knowledge on the potential contributions by aspiring license holders. As a result, allocations which would result in excess of benefits over costs might be denied, and licences for uses in which costs exceed benefits could be granted. This efficient allocation can only be achieved if the economic value of irrigation water is known, thus enabling the computation of economic costs and benefits in irrigation water supply so as to determine the allocation of irrigation water which could be allocated in a perfectly competitive market (Bate & Dubourg, 1997:312).

Increasing water demand in the face of decreasing availability and increasing supply costs has undermined a supply-oriented approach to the management of irrigation water demand (Nyagwambo, 2008:3). Responding to water demand by increasing current supply through exploitation of new water sources is getting more and more costly, and in some cases may not be feasible, hence demand-oriented approaches have increasingly been viewed as an essential complement to, or even a substitute to, supply-oriented measures (Arbues & Villanua, 2006:2421; Veettil, Speelman, Frija, Buysse & Van Huylenbroeck, 2011:1756; Zhang, 2006:32). Swaziland is no exception to this problem since farmers do not pay for irrigation water and consequently no individual farmer needs to voluntarily prevent the depletion of the water resource by investing in water saving technologies. Under such circumstances, individual rationality results in collective irrationality (Schlager, 2002:803). From an economics viewpoint, this is not only unacceptable but unsustainable. Therefore, owing to the subtractability attribute of the resource, it is likely to be pushed to the brink of its limits. According to Schlager (2002:803), individual rationality that prevails under such a management system results in collective irrationality, lead to what Hardin (1968:1244) describes as “the tragedy of the commons”, unless institutions change the incentives facing appropriators (Ostrom & Gardner, 1993:93-94). Lange and Hassan (2006:204) have a similar view; they argue that the difference between the private and social value of water typically results in inefficient use of the resource. It is for this reason that several economists including Hanemann (1994) and Tiwari (2005) are in favour of a price instrument as a demand management instrument. Economic crisis which is prevalent in Swaziland threaten the existence of government supported projects. It is therefore imperative for government to decentralise the management of water resource to water users.

In response to these realities, the government of Swaziland through the Swaziland Water and Agricultural Development Enterprise (SWADE) is introducing a pricing policy as a demand-oriented measure of irrigation water resource management. Efforts in pursuit of such a policy are motivated by the diminishing supply of water resources, owing to climate change, and the increasing cost of building new reservoirs in the face of increasing water demand (Mabaso, Singwane & Peter, 2010:197). The objective of the demand-oriented measures is to promote efficient use of water by introducing pricing that will influence farmers to take into consideration the economic value of water relative to its cost in allocation decisions (Arbues & Villanua, 2006:2421). The major challenge in getting the price right is that the value of irrigation water, as an input in sugar cane production, is unknown. Implementing a pricing policy in the absence of such information implies that an informed judgement about the efficiency of the pricing mechanism cannot be made, leaving the policy open to criticism. Besides, chances are that the price will be influenced by politics more than it will be guided by economics. As mentioned earlier, knowledge of the value of irrigation water as an input in sugar cane production is imperative when comparing alternative pricing mechanisms such as marginal cost or volumetric pricing with crop-based, area-based and quota systems.

There is no study in the literature, to the knowledge of the author, which has been conducted to estimate the value of irrigation water in Swaziland, yet irrigation water is one of the most resources limiting further development of the sugar industry (United Nations Conference on Trade and Development (UNCTAD), 2000:23). In the empirical studies available, researchers have been focusing efforts on water pricing for domestic uses in both rural and urban areas (Farolfi, Mabugu & Ntshingila, 2007; Mwendara, Manyatsi Magwenzi & Dhlamini, 2002; Mnyatsi & Tfwala, 2012). Moreover, those studies conducted outside Swaziland (eg., Hassan & Mungatana, 2006; Lange & Hassan, 2006; Mesa-Jurado, Piston, Giannoccaro & Berbel, 2008) their objective was not to compared results from two different methods. In the literature there are several methods that can be used to estimate the value of non-market inputs such irrigation water. However, these methods are capable of yielding different results even for the same resource raising question of which one can be used in the valuation of irrigation water as an input in sugar cane production in the Lowveld of Swaziland. Therefore, this study seeks to estimate the non-market value of irrigation water as an input in sugar cane production in the

Lowveld of Swaziland using two independent, benefit-based revealed preference approaches, namely, the residual value and production function methods, and assessing the convergence of their estimates. It is against this background that this study was implemented to meet the objectives listed in the next section.

1.3 OBJECTIVES OF THE STUDY

1.3.1 General objective

The general objective of the study is to estimate the value of irrigation water as an input in sugar cane growing in the Lowveld of Swaziland.

1.3.2 Specific objectives

The specific objectives of the study are:

1. To estimate the value of irrigation water as an input in sugar cane production using two independent approaches, the residual value and the production function methods, and test whether the value of irrigation water obtained from the two independent valuation methods differ statistically.
2. To estimate the output elasticity of irrigation water used in sugar cane production in the Lowveld of Swaziland.
3. To identify factors explaining the variation in estimated value of irrigation water between sugar cane farmers.
4. To assess the effect of TE on implicit value of irrigation water.

1.4 HYPOTHESES

In addressing the above research objectives, the study was informed by the following hypotheses:

1. According to Arbues and Villanua (2006:2423), irrigation water is a normal input and, moreover, a scarce resource, hence it was hypothesised that the value of irrigation water from both approaches would be positive and significantly different from zero.

2. The production function approach uses input and output quantity data and, on the other hand, the residual value method employs accounting data of the same inputs and output. It was hypothesised that the values of irrigation water obtained from the two methods would not be significantly different.
3. Sugar cane farmers are assumed to be rational actors (ie., they were assumed to maximise profit). Therefore, it is hypothesised that they will employ irrigation water up to a point where output is less responsive (inelastic) to changes in quantity of irrigation water employed (MPP is decreasing and the quotient of MPP and AP is less or equals to one)
4. Economic theory postulates that economic agents will have no incentive to use a resource efficiently if quantity of the resource used does not affect the amount paid for using the resource. Farmers do not pay for irrigation water and for this reason it was hypothesised that sugar cane farmers in the Lowveld of Swaziland are not 100% efficient.
5. There is a positive relationship exists between technical efficiency and the implicit value of irrigation water.

1.5 IMPORTANCE AND BENEFITS OF THE STUDY

Understanding the importance of the non-market value of irrigation water resources in the decision making of various economic agents, particularly the regulatory authority and resource users (farmers), justified the need to conduct this study. The non-market value of irrigation water had not been estimated by previous studies, hence the marginal and average value of irrigation water has remained unknown and that is why this study was conducted. This study is rendered even more important by pressing issues in Swaziland, such as the call for more efficient water use resulting from the growing water scarcity, the approaching irrigation water pricing policy for smallholder sugar cane growers, and the critical role in alleviating rural poverty attributed to these smallholder schemes. In face of the prospect of SWADE introducing a pricing policy, this study will add to the on-going discussion on the relevance and applicability of price as a demand-management approach.

Even if the output of the on-going negotiation on irrigation water pricing is that farmers will continue getting irrigation water at no cost, the value of irrigation water estimated in this study can be used to determine if government investment in irrigation infrastructure is justified. Based on resource economics theory, it would be justified for government to provide irrigation water if the cost of providing a unit is less than or equal to the value farmers attach to the unit of irrigation water. Finally, the study provide an empirical justification of using either production function approach or the residual value method in valuing irrigation water as an input in sugar cane production in the Lowveld of Swaziland.

1.6 ORGANISATION OF THE STUDY

The rest of this study is presented as follows. Chapter two presents a review of literature, both theoretical and empirical. Chapter three deals with the methodology and describes the methods used in the analysis of data for the purposes of addressing the objectives of the study. Results and discussion are presented in chapter four while chapter five, which is the last chapter of the study, presents the conclusions and recommendations of the study.

CHAPTER TWO

THEORETICAL AND EMPIRICAL LITERATURE

2.1 THEORETICAL LITERATURE

2.1.1 The concept of non-market economic valuation of irrigation water resource

The concept of non-market valuation of environmental resources originated in the River and Harbour Act of 1902 (Lipton & Wellman, 1995:3). Young (2005:21) defines non-market valuation as the analysis of actual and imaginary human behaviour to elicit approximations of economic value, sometimes called accounting or shadow prices, in monetary terms of goods and services in situations where market prices are either absent or distorted. According to Ostrom and Gardner (1993:93), difficulties of exclusion, emanating from a number of factors such as cost of parcelling the resource and cost of designing and enforcing property rights, result in the absence of a market price.

Irrigation water is a non-market input into the production of most crops. This implies that the resource does not have a price tag since there is no market for it and therefore farmers do not pay for it. Even though farmers do not pay for irrigation water, there is no economic justification that can lead to the conclusion that the value of the resource is zero. At the very least, a resource has an intrinsic value, a concept from ecology, which is the inherent value grounded on the claim that any resource has value in "itself". However, intrinsic value does not provide useful bases for resource management. Economists, on the other hand, are more concerned about the instrumental value of a resource (Philcox, 2007:3). Instrumental value of irrigation water in this particular case would be the value irrigation water has in terms of its contribution to sugar cane output in the Lowveld of Swaziland.

Several methodologies for estimating the non-market value of irrigation have been developed (Young, 2005; Miller, Boersma & Castle, 1965) and these methods have been implemented on several occasions (Hassan & Mungatana, 2006; Lange & Hassan, 2006; Barton & Taron, n.d.). Out of all the available methodologies, the residual value method and the production function approach are of particular interest in this study. These methods were implemented on several occasions for the purpose of estimating the non-market value of water resources where

different values of irrigation water were obtained and they were found to differ over use, location and season. The purpose of this chapter is to present the general theory on which non-market valuation of resources is grounded, present the theories on which the methodologies used are based, and present an empirical comparison of empirical literature.
A resource is said to have economic value if it has the following characteristics: human beings value the resource, either directly or indirectly; the value is relative and is therefore measured in terms of trade-offs; money is used as a unit of account; and lastly, the societal value is the summation of individual values. The idea on which the economic definition of value is rooted is that all resources are scarce (Lipton & Wellman, 1995:3-11).

In this study, the use of residual value method and production function approach which estimate the average value and the marginal value, respectively, was deemed necessary for the following reasons. The average value that economic agents attach on a unit of a resource, especially non-market resources or public goods, is used to determine if it is justified for the control agent or government to provide that public good. For example, it is justified for government to provide the resource in the cost of providing a unit of the resource is less than or equal to the average value that economic agents attach on the unit of the resource. On the other hand, marginal value is useful when making resource allocation decisions. Efficient allocation of resources requires that an additional unit a scarce resource should be allocated to use from which it will yield most returns. The two methods were then found to be capable of achieving the goal of the study which was to assist policy maker with information needed for making either investment decisions on irrigation infrastructure or allocative decisions of irrigation water in the Lowveld of Swaziland. The output of the study will also feed into discussion about relevance and applicability of a pricing policy as a demand management approach to irrigation water management.

2.1.2 Theory underlying the residual value method

According to Young (2005:22), the residual value method, also called the residual imputation method, is grounded in the product exhaustion theory and on the planning context in which it is implemented. Postulations of this theorem are: there is free competition in factor and product market; prices and wages are not distorted; quantity data of factors are available; technology is fixed; taste for the commodity does not change; output is fixed and capital is fixed; and there is a single wage rate. Even though some of these postulations are not always met, the assumption of rational behaviour by producers is likely to be reasonably estimated in most real-world situations. The residual value method uses deductive methods, starting from the general, such as the assumption that farmers are rational actors (maximise profit), to the specific, i.e. the irrigation water value. This benefit-based revealed preference is an accounting approach for non-market valuation which is grounded in the theory that the value of a resource (price multiplied by quantity of the resource) can be partitioned into the quantity of each input multiplied by its mean value (Hellegers & Davidson, 2010:933). The other assumption is that all factors, except water, have a price tag. In cases where there are owned factors, such as family labour, a shadow price has to be used.

The issue of owned inputs was not encountered in this study since sugar cane farms are fully commercialised to the extent that, even if family members took part in farm activities, they were entitled to same wage rate as hired labour. In implementing the residual value method, all production costs are deducted from revenue and then that residual amount is divided by the total quantity of the non-market resource used I the production process. This method yields the average value of irrigation, since the total share for resource is divided by the total amount of resource used.

Young (2005:193-212) asserts that this method better suits cases, such as the production of staple agricultural crops, where the production process is standardised, simple and stable over time, and irrigation water has a significant contribution to the value of output. This is an apt description for the production process of sugar cane in the Lowveld of Swaziland and for this reason the residual value method was deemed fit for the estimation of non-market value of irrigation water. The residual value method, although it has a long history of use and relative adaptability, flexibility and simplicity, should be applied with due caution. Application of this method warrants vigilant acknowledgment of the full theoretical apparatus, while using applicable and precise data.

2.1.3 Theory underlying the production function approach

Production function is the technical relationship depicting how inputs are converted into output. Similar to the residual imputation method, the production function approach is grounded in the theory of the firm: the profit maximising behaviour of firms implies that producers employ inputs in a manner that will optimise output, therefore maximising profit.

This inductive method starts from empirical data to build a general statistical representation that models how different inputs contribute to output. The production function approach is implemented in two stages. In the first stage, the task is to estimate the econometric model of the production technology (Miller, Boersma and Castle, 1965).

In the second stage we apply the first order condition for profit maximisation (equi-marginal condition) which requires that the value of marginal product (VMP) equals the price of the input resource (Speelmen, Frija, Perret, D'haese, Farolfi & D'haese n.d.:4). This inductive empirical approach for non-market valuation uses econometric estimates to directly estimate the non-market economic value of the resource as an input in the production process (Medellin-Azuara *et al.*, 2010:5640).

2.1.4 Theory underlying frontier approach to technical efficiency measurement

When estimating efficiency using stochastic frontier models, the technology used by different economic agents in producing a particular output is assumed to be constant (Orea & Kumbhakar, 2004:169). This assumption holds for the sample units of this study (sugar cane farmers in the Lowveld of Swaziland). Neo-classical economics postulates that economic efficiency is achieved when economic agents are given complete freedom (freedom of entry and exit) such that they work freely and competitively (Kirsten, Karaan & Dorward, 2009:10). Since the institutional arrangement of the sugar industry of Swaziland violates some of these assumptions of neo-classical economics, there is no reason to believe that economic agents in the action domain, such as the sugar cane farmers, are operating efficiently. The possible deficit in efficiency implies that the same amount of output can be produced using lesser inputs, or more output can be produced using the same amount of inputs. This therefore justifies the empirical measure of efficiency in order to assess the magnitude of the potential gains that might be realised by improving performance in sugar cane production with a given technology.

2.2 EMPIRICAL LITERATURE

Although a number of researchers have dedicated their effort toward the estimation of non-market value of various non-market goods and services, very few have focused attention on the convergence of different approaches to valuation. Barton and Taron (n.d.) appreciate the importance of assessing convergence validity of different approaches but could not incorporate such analysis in their technical briefing, citing insufficiency of data which hindered the estimation of the production function. This section gives findings from selected studies on non-market valuation of irrigation water resource, which are of particular interest in this study.

Deductive methods, such as the residual value method, when compared to inductive methods, such as the production function approach, have been found to yield higher estimates of irrigation water value (Scheierling *et al.*, 2006:1; Young, 2005:231). According to Medellin-Azuara *et al.* (2010:5640), the residual value method is highly sensitive to the error of omitting variables. They further assert that deductive approaches require knowledge of the mathematical model and good model building skills. From their argument a conclusion can be drawn that the bias observed in the residual imputation method is not inherent in the approach (bias is not a result of methodological limitation) but is due to model misspecification on the part of the researcher. There is, therefore, no reason to believe that deductive and inductive approaches, such as the residual value method and the production function approach, are not capable of yielding statistically similar results. In pursuit of this claim, this study aims at assessing whether the difference between estimates obtained from the inductive method (production function approach) and the deductive method (residual value method) is statistically significant (assessing convergence validity).

Hassan and Mungatana (2006) applied the production function approach in the valuation of irrigation water used in a range of crops, including sugar cane and citrus fruits in South Africa. In their study the value of irrigation water used in sugar cane growing of R1.77/m^3 was the second largest after cotton, which has a value of R1.95/m^3. Their findings show a positive value of irrigation water, similar to Mesa-Jurado *et al.* (2008) who found a residual value of 0.25 €/m^3 in 2005 and projected a value of 0.17 €/m^3 for 2015, which is equivalent to E2.97/m^3 and E2.02/m^3, respectively (ABSA, 2012). However, Mesa-Jurado *et al.* (2008) provide an average value of irrigation water across different crops. Though Hassan and

Mungatana (2006) present two methods, they concentrate on methods that estimate the marginal rather than the average value of irrigation water and they make no effort to assess the convergence of the two methods. In this study, similar to their study, the two methods were used, although residual value estimates average and the production function approach estimates marginal value of irrigation water. This study also focused on assessing convergence of the two methods, rather than merely reporting findings from the two methods.

Speelmen, *et al.*, (n.d.) also estimated the value of irrigation water used in the production of vegetables in the North-West Province of South Africa. They reported a value of 0.188US$/m^3 (E1.71/m^3). Although they did not make adjustments, they reported that their value was biased upwards owing to input subsidies received by farmers. Accordingly, there is a reason to believe that the value after removing the effect of the subsidies is even closer to the one found in this study. Moreover, they refer to the fact that without input subsidies, farmers hardly realise profit from some irrigated crops.

Bate and Durboug (1997) made an effort in the direction of Speelmen *et al.* (n.d.) by assessing the implication of subsidies on the computed value of irrigation water used in the production of potatoes and winter wheat. They employed a deductive method, net-back analysis, which utilises accounting data and is grounded on similar theory as the residual value method. In their quest they compared estimates of irrigation water value with and without the subsidies. They report that after deducting subsidies, the value of irrigation water used in all the crops studied becames negative, with the exception of potatoes. In Swaziland, smallholder sugar cane growers get support from the European Union (EU) but this support is in the form of capital infrastructure, such as land clearing before first planting, irrigation systems, roads, dams and on site reservoirs. This kind of subsidy does not have a direct impact on the short run production costs and therefore does not affect the computation of irrigation water value estimated in this study.

Perhaps Bate and Durboug's estimation procedure contained an erroneous assumption since they used data on crop water requirement, rather than data on actual water used. This implies that they assumed that farmers are one hundred percent efficient in terms of water use, which is contrary to findings of several studies on water use efficiency (Nieuwoudt, Backeberg & Du Plessis, 2004:167). In their study, Nieuwoudt *et al.* (2004) assert that agriculture supports the lowest GDP per million, making it an inefficient user of water resource. Estimates derived by Bate and Durboug (1997) can therefore be viewed as the maximum possible value which irrigation water can yield, which is rather a theoretical value. It is likely that even the estimated value from the "without subsidy" scenario was an overestimation of the actual value because farmers are less likely to apply just the required amount of irrigation water.

Indeed, previous studies have revealed that farmers apply more than what the crop requires. Various studies (Young, 2005; Berbel, Mesa-Jurado & Piston, 2011) have shown that the amount of water used is inversely related to the estimated value of irrigation water and for this reason it is understandable to expect the actual value of irrigation water to be less than what users report.

2.3 CONCLUDING SUMMARY

The purpose of this Chapter was to provide a theoretical framework of analysis for the non-market valuation of irrigation water, as well as to review the theoretical and empirical literature pertaining to non-market economic valuation of irrigation water. The review of theoretical and empirical literature on non-market economic valuation of irrigation water revealed the importance of knowledge of non-market value of economic resources. It also revealed that there is a gap in the knowledge of convergence of the residual value method (deductive method) and the production function approach (inductive method).

The reviews also revealed that there is a significant knowledge gap concerning irrigation water valuation in Swaziland. The studies reviewed dated as far back as 1965 and as recent as 2012. In the majority of the studies, the major emphasis was on the accuracy of data, especially data on quantity of water used in irrigating the crop of interest. The overall conclusion, therefore, is that even though the two methods have been found to give different estimates, there has been no attempt to assess the convergence of the two methods. Moreover, even though policy makers in Swaziland are considering pricing options with keen interest, there has been inadequate effort in the direction of empirical justification of irrigation water pricing.

CHAPTER THREE

METHODOLOGY

3.1 STUDY AREA

The study was conducted in the Lowveld of Swaziland where the cross-sectional primary data were collected. The region is located on the eastern side of Swaziland and it runs linearly from North to South, as shown in Figure 3.1 below. This region consists of flat to gently rolling hills, with altitudes ranging from 150 to 300 metres (492 to 984 feet) above sea level. This region experiences a tropical and semiarid climate with a mean annual temperature and precipitation of 22 degrees Celsius and 550 mm (22 inches), respectively (Brown, 2011:9). The Lowveld of Swaziland is characterised by high pressure meteorological systems and associated dry, descending air masses, which is unfavourable for rain formation. It is, therefore, not surprising that the region's average annual rainfall of about 550 mm is well below the world average of 860 mm. Accordingly, irrigation water is employed in 96% of this region.

Figure 3.1: Climatic regions of Swaziland
Source: Adapted from Mappery.com

3.2 SAMPLING

A combination of purposive and simple random sampling techniques was used in selecting the farmers who were interviewed. The selection of the Lowveld of Swaziland was purposively done because it is where more than 90% of the sugar cane farms are located. Furthermore, in this region there are two irrigation projects, the Lower Usuthu Smallholder Irrigation Project (LUSIP) and the Komati Downstream Development Project (KDDP), which are funded by the European Union (EU). Farms using the minimum irrigation technology of sprinklers were deliberately chosen to form the target population of the study. This was done to minimise variations in water used owing to variations in technology, thereby improving the homogeneity of the population. Another reason for choosing sprinkler technology over other irrigation technologies was that this technology is used by the majority of smallholder sugar cane growers in the Lowveld of Swaziland. This, therefore, implies that the sugar cane farms falling under the Vuvulane Project were not part of the target population of this study since they all use the furrow irrigation method. The other criterion used in selecting farms to be part of the population was that the farm should have reached at least the first dry period of the season. This then left out farms which were found to be at the early stage of their first planting season, since they would have had incomplete data for the requirements of this study. A list of smallholder sugar cane grower was obtained from SWADE. This study targeted a population of 120 farms, from which 78 farms were randomly selected. This population comprised individual farmers (privately owned farms), farmer companies and farmer associations (FAs). In determining the sample size, several techniques were use including review of literature on similar studies conducted in Swaziland, considering data requirement of methods used, sample calculator and lastly the budget at hand was considered.

The procedure for random selection started with assigning a unique three digit code, ranging from 001 to 120, to each farm. These codes were printed on small, separate pieces of papers which were then put together in a bag and one piece of paper was drawn at a time without replacement. The farm corresponding to the code drawn was then selected to be part of the sample. Random sampling was done to give the farms an equal chance of being part of the sample, thus avoiding sample selection bias (Leedy & Ormrod, 2010:207).

3.3 SURVEY INSTRUMENT DEVELOPMENT

Considerable time was spent developing the survey questionnaire. Literature sources provided the basis for developing the questionnaire and the study supervisor was consulted on several occasions to ensure that the survey instrument was sufficient for the task. The survey instrument was developed bearing in mind that farmers do not always keep records, and even if they do, the information may either be incomplete or insufficient for the purposes of the study. Accordingly, the major objective was to develop comprehensive questions that would ease the effort of recall when that was needed.

A pre-test was conducted where five farmer supervisors from five different farmer companies were interviewed. Over and above this pre-test, the researcher had a detailed discussion with an extension officer from SWADE and on a different occasion with one of the farm supervisors. These discussions were about the different activities involved when growing sugar cane and about the institutional arrangement of the farms. The most important objective of the pre-test, among other things, was to determine if the data collected using the survey instrument were sufficient for the calculation of the quantity of irrigation water used and also to determine the reliability and accuracy of the method used to calculate the quantity of water used, as described in section 3.7. During this exercise (pre-test and the discussion with the supervisor) it transpired that the survey instrument was not sufficient for the purpose of collecting adequate data.

For example, the initial plan was to use electricity costs to check the validity of the data on the quantity of water used. The expectation was that the average amount spent on electricity (Emalangeni per hectare) would be positively related to the quantity of water applied, such that spending more money per hectare will translate to applying more water per hectare. However, during the exercise it was ascertained that the cost of electricity is mostly affected by the position of the pump house (whether on the upper or lower part of the farm). This position, then, determines what level of pressure system is required (high or low pressure system). Farms with pump houses on the lower side were found to use high pressure systems, which incur higher electricity costs than those farms with pump houses on the upper side, which use low pressure systems. During the pre-test, interviews took between 20 to 30 minutes, on average. After the pre-test, the survey instrument was adjusted and amended as deemed appropriate.

The questionnaire was divided into eight parts, as follows: part “A” contained general information, while part “B” required the socio-demographic data of the respondent. Part “C” required information about the type of land ownership and the composition of total land under sugar cane production, followed by Part “D” which asked about membership to farmers’ organisations. The next section, Part “E”, required information pertaining to farmers’ access to sources of credit, while Part “F” required information on input utilisation and costs of producing sugar cane. This was followed by Part “G”, concerning the quantity of water used in the irrigation of sugar cane in the Lowveld of Swaziland. Lastly, Part “H” contained information on the output produced that enabled the computation of farm gross income.

3.4 SURVEY IMPLEMENTATION

Face-to-face interviews were conducted with smallholder sugar cane growers in the Lowveld of Swaziland. The researcher moved from farm-to-farm implementing the questionnaire. This method was chosen over the use of enumerators because of its relative low average cost of filling a questionnaire. Interviews were conducted on the farm in farm offices or other places, where record books were kept, such as the pump house for those farms whose offices were still incomplete. The questions were well explained and repetition of questions was done whenever it was necessary until the respondents confirmed that they understood the question. A response rate of 98.7% was achieved during this survey; only 1 out of 79 farmers preferred not to participate in the survey.

For those whose levels of education did not put them in a good position to fully comprehend the letter of consent and the questions in the survey instrument, the interviewer had to use their first language, which is also the interviewer's first language, thus the probability of misunderstanding was very low. At the end of each day of data collection, the filled survey instruments were reviewed in order to identify possible errors of recording and consistency.

3.5 DATA ANALYSIS

An Excel spread sheet was created for the primary data collected before the data were imported into STATA, from which summary statistics were obtained for the purpose of checking possible outliers that would affect the results. Data from the 78 randomly selected farms in the Lowveld of Swaziland were analysed using STATA version 12 and frontier version 4.1. The major aim of the analysis was to estimate the non-market value of irrigation water, estimate out elasticity of irrigation water, identify factors affecting implicit value of irrigation water and estimate farmers' technical efficiency.

3.6.1 Estimating non-market value of irrigation water

3.6.1.1 The residual value method

A two-stage procedure was followed in implementing the residual value approach. First, production costs (defined as the costs of labour, fertilizer, chemicals and electricity) were subtracted from total revenue to obtain the residual revenue. The residual revenue was then divided by the quantity of irrigation water the farmer employed in producing the sugar cane output. This resulted in the residual value of irrigation water per metre cubed of water employed. By virtue of the formula for the residual value, this method yields the average value of irrigation water.

Various studies have employed this method for non-market valuation of irrigation water resources (Davidson & Hellegers, 2011; Messa-Jurado, *et al.*, 2008). This method of estimating the average value of irrigation water is grounded in the theory that the value of output produced is the sum of the values of inputs employed in producing it (Davidson & Hellegers, 2011:934; Young, 2005). Assuming a constant technology (doubling input will result in doubled output) and variable inputs, the total value of output can be represented by equation (3.1) below.

$$Y.P_y = (VMP_F.X_F) + (VMP_C.X_C) + (VMP_{L.}.X_L) + (VMP_W.X_W) \quad (3.1)$$

Where: Y is output (sucrose tonne), P is price, X is quantity of input and the subscripts; Y, F, C, L and W denote output fertilizer, chemicals, labour and water, respectively.

The aforementioned assumption of profit maximising behaviour allows equation (3.1) to be written as:

$$Y.P_y = (P_F.X_F) + (P_C.X_C) + (P_{L.}.X_L) + (P_W.X_W) \quad (3.2)$$

The right hand side of equation (3.2) can be simplified such that the resultant equation can be expressed as follows:

$$Y.P_y = \sum P_{X_i}.X_i + P_W.X_W \quad (3.3)$$

The first term on the right side is the sum of the values of all marketable inputs and the second term is irrigation water value which has an unknown term P_W, the only unknown term in the equation. The average price for irrigation water can therefore be expressed as follows (Young, 2005):

$$P_W = \frac{Y.P_y - \sum P_{Xi}.X_i}{X_W} \quad (3.4)$$

From equation (3.4) it is clear that the accuracy of the estimated price largely, but not only depends on the accuracy of the data on the physical quantity of water used in the production of sugar cane. Over estimating the quantity of water that was used in the production process will result in the under estimation of the value of irrigation water, and the inverse is true. As show in equation (3.4), to obtain P_W the difference between the value of output and the total value of all marketable inputs was divided by the quantity of irrigation water used.

3.6.1.2 The production function approach

In the empirical application of the production function method, the OLS approach was used to regress sugar cane output (physical units) against the physical quantities of the following inputs using the methodology in section 3.2: land (hectares), labour (man hours), chemicals (litres), irrigation water (metre cubed) and fertilizers (kilogram). All regressions were implemented in STATA. Considering that the choice of functional form is an empirical matter, a number of specifications of the production function were estimated. The choice of the final form was based on two criteria: *a priori* expectations of the signs of the input coefficients, and statistical superiority (i.e. statistical significance of individual coefficients and of the overall regression). Most importantly, the model was selected because of its ability to isolate, with greater precision, the effect of irrigation water on sugar cane output. This unique feature of the model is fundamental since the accuracy of the estimated price depends in the accuracy of the marginal product of irrigation water.

This is another direct method of non-market valuation which utilises quantity data. This approach was deemed sufficient for the task because demand for irrigation water in sugar cane cultivation in the Lowveld of Swaziland is not directly observable as there is no information pertaining to sale price and volume of water bought by different farmers. However, input quantity data, including quantity of water used, and the corresponding output realised was available to enable the estimation of a production function. After trying several specifications including the Cobb-Douglas and Transcendental logarithmic (Translog) production functions, a semi-log function was found to be the best representation of the performance of technology in sugar cane production in the Lowveld of Swaziland. The regression outputs of the Cobb-Douglas and Translog production function are presented in appendix five. The Translog production function, in particular was rejected due to multicollinearity. Similar to the residual value method, the accuracy of the marginal value of irrigation water estimated using the production function approach, and moreover, the estimated marginal value, is highly sensitive to model specification (Lange & Hassan, 2006:203).

$$lnY = \beta_0 + \beta_{Lan}X_{Lan} + \beta_{Lab}lnX_{Lab} + \beta_C lnX_C + \beta_W lnX_W + \beta_F lnX_F + \mu \qquad (3.5)$$

Where: Y denotes output, X represent quantities of inputs and the subscripts (Lan, Lab, C, W and F) denote land, labour, chemicals, water and fertilizer, respectively.

To compute the price of irrigation water, the first step was to derive VMP_w which in turn necessitates the computation of MP_w, which is the first partial derivative of equation (3.5) with respect to X_w. Equation (3.6) and (3.9) below represent respectively marginal product of water and value of marginal product of water. For the aforementioned reason, VMP_W is equal to the price of irrigation water P_W.

$$\frac{\partial lnY_i}{\partial X_i} = \frac{\beta_W}{X_W} \qquad (3.5)$$

$$\frac{1}{Y_i} = \frac{\beta_W}{X_W} \qquad (3.7)$$

$$1 = \frac{\beta_W}{X_W}Y_i \;\; = MP_W \qquad (3.8)$$

$$\frac{\beta_W}{X_W}Y_iP_Y \;\; = \; MVP_W = P_W \qquad (3.9)$$

The assumption that farmers are rational actors implies that farmers operate within the economic region of the production function (stage two of the classical production function), where marginal productivity of inputs increases at a decreasing rate: $f'(X_i) > 0$ and $f''(X_i) < 0$. The assumption of rationality also implies that farmers would only employ inputs to a point where the value of a marginal product (VMP) is equal to the price of the resource (P_{Xi}), where VMP is equal to the product of marginal physical product (MPP) and price of output (Gonzalez-Alvarez, Keeler & Mullen, 2006). For this reason, equation (3.9) yields the estimated value of irrigation water.

To compute the value of irrigation water (Emalangeni per metre cubed of irrigation water employed in sugar cane production), the following variables were substituted into equation (3.9) (which represents the first order condition for profit optimisation): the coefficient for water obtained from Table 4.2 (0.7110), the quantity of water employed by the individual farmer (obtained from the household survey), the quantity of sugar cane produced by the individual farmer (obtained from the household survey) and the market price for sugar cane (Emalangeni per tonne).

3.6.2 Output elasticity

The price elasticity of demand for irrigation water (ε_W), which is the responsiveness of quantity of water demanded by farmers to a unit change in the price of water, was computed from equation (3.5) by taking the first derivative with respect to water (X_W). The derivation of ε_W is shown in equations (3.10) to (3.12) below. Equation (3.10) presents the general formula for own elasticity of demand, while equation (3.10) presents derivation of elasticity and equation (3.12) presents the solution to this particular problem.

$$\varepsilon_W = f'(X_W).\frac{X_W}{Y} \tag{3.10}$$

$$\varepsilon_W = \frac{\beta_W}{X_W}Y.\frac{X_W}{Y} \tag{3.11}$$

$$\varepsilon_W = \beta_W \tag{3.12}$$

3.6.3 Factors affecting the implicit value of irrigation water

To identify the factors affecting the implicit value of irrigation water, estimated by the two methods, a multivariate regression, in STATA, where implicit value was regressed on land, labour, chemicals, fertilizer, farm revenue and quantity of irrigation water used was employed. The signs of the coefficient were used to make conclusions on the relationship between the implicit value and the particular explanatory variable and the magnitude of the coefficient was used to make deduction about the impact of a unit change of the explanatory variable on the dependent variable. The econometric model was specified as follows:

$$P_W = f(\Omega_i) \tag{3.13}$$

Where: P_W – irrigation water value

Ω_i – a vector of explanatory variables (land, labour, chemicals, water and fertilizer)

To do this, the resultant implicit values were regressed against the following regressors: land, labour, chemical inputs, fertilizer inputs, revenue and the quantity of irrigation water employed.

3.6.4 Stochastic frontier model

A stochastic frontier model was used to measure TE of sugar cane farmers in the Lowveld of Swaziland. The strategy used in estimating the stochastic frontier model was adopted from Battese and Coelli (1995). Similar to the production function, this approach specifies the technical relationship between output obtained and inputs used. However, the notable difference between the production function and stochastic frontier is that the later has two error terms. One of the error terms is the ordinary error term, such as the one in production function, which is assumed to have a mean of zero and a constant variance. The other error term, however, is specific to this model and it represents the technical inefficiency which is estimated by the Maximum Likelihood Estimation method (MLE). The generic stochastic frontier model used in this study is shown below.

$$Y = f(X_{ai}, \beta)e^{E} \qquad (13.14)$$

Where, Y = sugar cane output

X_{ai} is a vector of input quantities (subscript a denote a particular farm while *i* denotes a particular input

β = is a vector of parameters to be estimated

E = is a stochastic disturbance term

The error term E consists of u and v, such that E= u+v as described below. A Cobb-Douglas frontier production function was assumed and specified as follows:

$$lnY = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + U_i + V_i \quad (3.15)$$

Where, Y = sugar cane output in tonnes
X_1 = land measured in hectares of cultivated area
X_2 = labour measured in hours
X_3 = chemicals measured in litres
X_4 = water measured in cubic metres
X_5 = fertiliser measured in kilograms
β_0 is the intercept and β_1 to β_5 are coefficients of the various inputs.

V_i is a random error term due to misspecification of the model and variation in output as a result of exogenous factors outside the farmer's control. U_i is the inefficiency component of the error term and the inefficiency is specified as;

$$U_i = d_0 + d_1X_1 + d_2X_2 + d_3X_3 + d_4X_4 + d_5X_5 \quad (3.16)$$

Where U_i= technical inefficiency
d_0 to d_5 are the parameters to be estimated.

Because the dependent variable U_i in equation (3.16) represents the mode of inefficiency, a negative sign of an estimate parameter implies that the associated variable has a positive effect on efficiency but a negative effect on inefficiency and vice versa (Bravo-Ureta & Pinheiro, 1997:52-54).

To estimate an efficiency score for individual farms and a mean efficiency, a Cobb-Douglas stochastic frontier production frontier (SFPF) was estimated in Frontier, version 4.1. These resultant efficiency scores were regressed against the following regressors: residual value of irrigation water, price of water from the production function approach (P_w) and farm revenue.

To test whether a relationship exists between technical efficiency and the implicit value of irrigation water, an Ordinary Least Square regression was used, where the implicit value of irrigation water was regressed on a number of explanatory variables including technical efficiency scores. Equation (3.17) presents the functional form of the model.

$$P_W = f(\propto_i) \tag{3.17}$$

Where; $\propto_i$ is a vector of explanatory variables (land, labour, chemicals, water, fertilizer and technical efficiency scores).

The residual value of irrigation water was regressed against TE scores and a number of other regressors, including land, labour, chemicals, fertilizer, revenue and water. The table below presents *a priori* expectation, as postulated by economic theory, of signs of the coefficient of the variable used in equation (3.17).

Table 3.1: A priori expectation of signs of coefficients of the variable used in the model

Dependent variable is the non-market value of irrigation water	
Variable	**Expected sign**
Land	+
Labour	-
Chemicals	-
Water	-
Fertilizer	-
Technical efficiency score	+

3.6 DESCRIPTION OF VARIABLES

Data collected during the survey for the purpose of answering the research question include physical quantities of inputs and output. Accounting data (input costs and revenue) were also collected. However, because of the high level of commercialisation and government support through SWADE, smallholder sugar cane growers in the Lowveld of Swaziland were able to keep fairly good records of their farm operations.

Inputs in this study included all physical requirements (land measured in hectares, labour measured in hours, chemicals measured in litres, fertilizer measured in kilograms and water measured in cubic metres) that are used in producing sugar cane. Output was either the physical quantity (biomass) of sugar cane harvested, or sucrose tonnage. The reason for considering output in these two forms was that farmers produce sugar cane but the millers buy sucrose. Therefore, farm output was sugar cane but for the purpose of computing the value of output, sucrose was the output. Costs and revenue were measured in local currency Emalangeni (E) and one Lilangeni was equivalent to one South African Rand or

US$0.113222 (International Monetary Fund (IMF), 2012). Where records were not available the researcher relied on the respondent's (farm supervisor's) recall. Input prices were obtained from Enviro Applied Product (Pty) Ltd, a company that supplies inputs such as fertiliser and chemicals to sugar cane farmers in Swaziland.

As mentioned to earlier in this section, output was measured in two forms, cane tonne (biomass) and sucrose tonne. The reason for considering the two forms of output was that farmers produce sugar cane such that the dependent variable (Y) in the production function is tonne of cane, yet the sugar millers buy only the sucrose in the cane and not the biomass. For example, if farmers X and Y both supply 200 tonnes of cane but with sucrose levels of 13% and 14%, respectively, farmer X and Y will receive payment for 26 and 28 tonnes of sucrose, respectively. In the production function approach, output is measured as the biomass (tonnes of cane). However, to enable the computation of revenue for the residual value method, output was measured in sucrose tonnes. Data on sucrose, which is expressed as a percentage of total cane mass, were therefore collected for this purpose

Land was the total area, measured in hectares, under sugar cane cultivation. This excluded idle land owned by the farmer or any other piece of land within the farm premises but dedicated to other crops. Therefore, in this study the variable "land" may not be equal to the area enclosed by the fence or any other form of boundary of the farm.

Labour was the amount of time, measured in hours, spent by hired individuals working on the farm. Family labour was not considered separately because family members who took part in operations of the farm were regarded as hired labour, such that they were entitled to a wage and the rating was equivalent to that of non-family member (hired individuals). Labour was divided into two categories, seasonal and permanent labour. Seasonal labour was further divided according to the task hired for: trash management, spot weeding, spraying, weeding, fertilizer application and smut management. Permanent labour, on the other hand, consisted of farm supervisors, farm clerks, security personnel and irrigators. Working hours per day was a factor of operation under consideration, whether condition and the speed of the particular individual. The labour variable was captured as follows:

$$\Phi = \omega/(\theta/\alpha)\,\delta\theta$$
$$= 60/(10/2)*4*10 \quad (3.18)$$
$$= 480 \text{ hours}$$

Where: ω – farm size

θ - total number of workers

α – number of workers per hectare

δ – hours worked per day

The total number of hours spent in the other operations was computed in a similar way and the sum of time spent across operations was then taken to the production function as labour hours.

Cost of labour was divided into two, variable (wages of seasonal labour) and fixed costs (salaries of permanent labour). The cost of labour on weeding, for example, is the product of the number of workers, number of days and wage per worker per day. In the above example, the cost of labour for weeding, given a wage of E30 per worker per day, would be E3600. Labour costs for the other operations were computed in a similar manner and the sum of costs on different operations, plus salaries for permanent labour, form the labour costs in the computation of residual value.

Water was the total amount of the blue water resource, measured in cubic metres, used in the irrigation of sugar cane. Though most farms had water metering devices, some did not, which necessitated the collection of data that would enable an estimation of the physical quantity of water used in irrigating sugar cane. These data included: pump capacity, number of operating sprinklers, sprinkler interval, sprinklers' stand time, number of irrigation cycles per month, the number of consecutive cycle at first irrigation required for maximum soil moisture level, and the length of the dry-off period. These data were collected from all the farms including those with metering devices. This was done to check the accuracy of the method used to estimate the amount of water used, by comparing the value obtained from the computation with the value from the water meters.

For example, on one particular farm the following data were collected: pump capacity was found to be 50.5 litres per second, 120 operating sprinklers, spacing between sprinklers was

18 metres, stand time of 8 hours, initial irrigation consists of three consecutive cycles followed by four cycles per month for the first six months after harvest and making two cycles per month for four months and allowing a dry-off period of two months. It was assumed that leakages along distribution pipes were insignificant, which allowed the application of the law of continuity (the volume of water that passes through the pump is equals to the volume of water discharged by the sprinklers) (Ellis, 2008:74). To compute the total amount of water used for irrigation on this particular farm, the following steps were followed.

Area covered by operating sprinklers, for computational purposes: it was assumed that the 120 sprinklers were arranged in one row such that the length L of the covered portion can be calculated as follows:

$$
\begin{aligned}
L &= \psi \dagger \\
&= 120*18 \\
&= 2160\text{m}
\end{aligned}
\quad (3.19)
$$

Where: L – Length of area covered by operating sprinklers

Ψ – number of operating sprinklers

Ϯ – sprinkler interval

Give the sprinkler radius *r* of nine metres and therefore a diameter of eighteen metres, area covered by operating sprinklers (A) can be calculated as:

$$
\begin{aligned}
A &= L2r \\
&= 2160\text{m}*18\text{m} \\
&= 38880\ \text{m}^2 \\
&= 3.888\ \text{ha}
\end{aligned}
\quad (3.20)
$$

The next step was to calculate the quantity of water used for irrigating the covered area per season. This was achieved through the following steps. From the data collected, it transpired that there were 35 cycles over the whole season. Total time per spot per season (TSP) was computed as shown below.

$$TSP = \theta þ$$
$$= 35*8 \quad (3.2.1)$$
$$= 280 \text{ hours}$$

Where: ϴ – number of cycle per season

þ – stand time in hours

The volume of water (W) used per 3.888ha block per season was calculated as follows:

$$W = PC * TSP$$
$$= 50.455 \text{ l/sec} * 280(60^2)$$
$$= 50.455 \text{ l/sec} * 1008000 \text{ sec} \quad (3.22)$$
$$= 50858640 \text{ litres}$$
$$= 50858.64 \text{ m}^3$$

Where: PC – pump capacity (flow rate)

Volume of water per hectare per season (Wh) is computed from the expression below:

$$Wh = \frac{W}{A}$$
$$=13080.92 \text{ m}^3. \quad (3.23)$$

Because the other blocks were managed the same way, the total quantity of water TW used was the product of farm size and volume of water per hectare per season which was calculated as:

$$TW = \omega Wh$$
$$= 60 \text{ ha}*13080.92 \text{ m}^3 \text{ per ha} \quad (3.24)$$
$$= 784855.2 \text{ m}^3.$$

During the survey period, some farms were on their first harvesting season and so the meter readings were then reflecting the total amount of water used that season. This was the most accurate data because these farmer companies were only growing sugar cane. Where some farmers were growing vegetables, these were few in and for subsistence purposes, and the quantity of water used was assumed to be insignificant.

Chemicals used by farmers were of types various types including herbicides, measured in litres, which were used for weed control. Data on chemicals were in the form of application rates, such as 3 litres of *ametryn* per hectare. The total amount of herbicide used was the product of the application rate and farm size and the total herbicides was the sum of the quantities of the different herbicides.

3.7 SUMMARY

This chapter presented the methodological approach adopted in this study. The major purpose of this chapter was to explain in details how the methods that were used in study were implemented and highlight their strengths and weaknesses. The residual value and production function methods were used to estimate the value of irrigation water as an input in sugar cane production in the Lowveld of Swaziland. A semi-log production function was found to be the best representation of the technology used by smallholder sugar cane farmers in the Lowveld of Swaziland.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

Table 4.1 below presents the socio-economic characteristics of the farmers or other personnel who were in the position of giving information about the farm.

Table 4.1: Socio-economic characteristics respondents

Characteristics of interest	Number of respondents
Total respondents	78
Gender:	
Female	12 (15.38%)
Male	66 (84.62%)
Average household size	7
Age structure:	
Adult male (age ≥ 15 years)	151 (27.66%)
Adult female (age ≥ 15 years)	147 (26.92%)
Children (age < 15 years)	248 (45.42%)
Marital status:	
Single	17 (21.79%)
Married	60 (76.92%)
Widowed	1 (1.28%)
Education level:	
No formal education	0 (0%)
Primary	5(6.41%)
High school level	73 (93.59%)
Tertiary level	0 (0%)
Position held:	
Sole owner	8(10.26%)
Farm supervisor and shareholder	16 (20.51%)
Farm supervisor	45 (57.69%)
Farm clerk	6 (7.69%)
Secretary	2 (2.56%)
Chairperson	1 (1.28%)
Average annual income (E)	
Below 15, 000	2 (2.56%)
Between 15, 000 - 20, 000	6 (7.69%)
Above 20, 000	61 (78.21%)

Non-responses	1 (1.27%)

Source: Own data

Table 4.2 below presents the summary statistics of the variables investigated in the empirical models.

Table 4.2 Summary statistics characteristics of farms and famers

Variables	Mean	Standard deviation	Minimum	Maximum
Age (years)	35.87	11.74	20.00	69.00
Gender (nominal)	1.15	0.36	1.00	2.00
Education level (nominal)	1.94	0.25	1.00	2.00
Number of years in business (years)	5.72	6.24	1.00	25.00
Marital status (nominal)	1.78	0.42	1.00	2.00
Land (ha)	89.70	76.40	3.00	357.50
Labour (hours)	2451.77	1713.00	151.50	8765.33
Chemicals (litres)	651.90	547.21	19.50	2423.75
Water (m^3)	1333187.00	1112577.23	53818.18	5402323.97
Fertilizer (kg)	43657.50	44232.22	1200.00	196625.00
Cane yield (tonnes)	8965.49	7653.62	310.00	33962.50
Sucrose yield (tonnes)	1232.06	1078.41	41.42	4749.72
Revenue (E)	2,833,734.72	2,480,336.89	95,256.80	10,924,344.50
Electricity costs (E)	359,628.21	346,815.16	12,000.00	1,300,000.00
Fertilizer cost (E)	244,481.97	247,700.41	6,720.00	1,101,100.00
Labour costs (E)	95,353.61	57,507.38	9,975.00	297,099.24
Chemicals costs (E)	16,297.44	13,680.31	487.50	60,593.75

Source: Author's own construct (1 Lingangeni = 0.11US$)

4.2 ESTIMATED VALUE OF IRRIGATION WATER

The first objective of this study was to estimate the value of irrigation water (in Emalangeni per metre cubed of irrigation water employed in sugar cane production) using two independent non-market valuation approaches, viz. the residual value and the production function approaches. This objective was also designed to test whether the resulting unit values of irrigation water obtained from the two independent methods were statistically different. Table 4.3 presents frequency distribution of the results obtained and estimates corresponding to individual farms are given in Appendix three.

Table 4.3: Frequency distribution of the value of irrigation water (Emalangeni per metre cubed) using the residual value approach

Residual value (E/m^3)	Frequency of estimated values	Percent
≤ 0.20	1	1.3
0.21 – 0.40	0	0.0
0.41 – 0.60	2	2.6
0.61 – 0.80	1	1.3
0.81 – 1.00	3	3.8
1.01 – 1.20	5	6.4
1.21 – 1.40	13	16.7
1.41 – 1.60	18	23.1
1.61 – 1.80	13	16.7
1.81 – 2.00	22	28.2
Total	78	100

Source: Own data

The method produced a mean residual value of E1.60m^{-3} (95% confidence interval of E1.48 m^{-3} and E1.71 m^{-3}), with a standard deviation of E0.51m^{-3}(95% confidence interval of E0.44 m^{-3} and E0.61 m^{-3}), and a median residual value of E1.51 m^{-3}. Mesa-Jurado *et al.* (2008) employed the residual value method in estimating the value of irrigation water in the production of olive trees, cotton, rice, maize, vegetables and winter cereals (mainly wheat) in the Guadalquivir River area in Europe. Their results revealed a value of €0.25 m^{-3} (E2.97 m^{-3}) in 2005 and a projected value of €0.17 m^{-3} (E2.02 m^{-3}) in 2015 (ABSA, 2012). It is however, worth mentioning that their study was conducted in a different environment (different in terms of level of economic growth). Therefore the difference in the level of economic growth and exchange rate might be the cause of the observed difference between the value they obtained and the one obtained in this study.

We also tested for multicollinearity, using the correlation matrix, which we found to be less than perfect. We adopted the “do nothing” school of thought, as suggested by Blanchard (1967) in Gujarati (2006:363), for the following reasons: It is possible to estimate regression coefficient as long as multicolliniearity is not perfect. Even if multicollinearity is near perfect, ordinary least squares (OLS) estimators remain unbiased and the property of minimum variance is not destroyed. Theory suggests that all the variables in this model are fundamental therefore excluding one of them will result in specification error (under specification). The presence of multicollinearity results in insignificant t-ratios but high f-statistics which implies that the effect of a single explanatory variable cannot be isolated, with greater precision, from the effects of the rest. However, the combined effect of the explanatory variables can be estimated relatively efficiently.

In the model below the variable of interest (irrigation water) is highly significant. This implies that the marginal effect of irrigation water on output (MPP of water) can be isolated, from the effects of the other explanatory variables, with greater precision. For this reason marginal value product will also be estimated with high precision hence the estimated price can be regarded relatively precise (Gujarati 2003:347-364). It is worth mentioning that, in this study, the major goal when estimating the production function for sugar cane was to elicit the marginal effect of irrigation water which will later be used in the computation of the value of irrigation water. Table 4.4 presents the regression output of the production function and table 4.5 present STATA output of the correlation matrix of the coefficients of the regression model.

Table 4.4: Estimated production function for sugar cane growing in Swaziland (dependent variable—natural log of sugar cane output)

Variables	Coefficient (SEE)	t-statistics (p-value)
Constant	-3.2249	-2.5700**
	(1.2572)	(0.0120)
Land	0.0002	0.2600
	(0.0009)	(0.7940)
ln_labour	0.0099	0.1200
	(0.0839)	(0.9060)
ln_chemicals	0.1639	1.4000
	(0.1174)	(0.1670)
ln_water	0.7110	5.0300***
	(0.1413)	(0.0000)
ln_fertilzer	0.1053	1.2800
	(0.0823)	(0.2050)
78 observations, F(5,72) = 142.39, Prob> F = 0.0000, R^2 = 0.9082, Adjusted R^2 = 0.9018		

** and *** represents statistical significance at the 5% and 1%, respectively
Source: own data

Table 4.5: Correlation matric of coefficient of regression model

Variables	Land	ln_labour	ln_chemicals	ln_water	ln_fertilizer
Land	1				
ln_labour	-0.02	1			
ln_chemicals	-0.02	-0.01	1		
ln_water	-0.29	-0.23	-0.68	1	
ln_fertilizer	-0.25	-0.32	-0.22	-0.20	1

Source: Own data

The positive sign for all input coefficients is consistent with standard restrictions that economic theory imposes on the production function: positive marginal productivity and monotonicity in the economically relevant region of production. The coefficient for water is relatively high and highly significant, consistent with the agronomic characteristics of sugar cane production (high water demand). The production approach, as referred to above, yields the marginal value of irrigation water. The results of this analysis are summarised in Table 4.6.

Table 4.6: Frequency distribution of the value of irrigation water (Emalangeni per metre cubed) using the production function approach

Value range (E)	Frequency of estimated values	Percent
≤ 0.20	0	0.0
0.21 – 0.40	0	0.0
0.41 – 0.60	2	2.6
0.61 – 0.80	1	1.3
0.81 – 1.00	5	6.4
1.01 – 1.20	9	11.5
1.21 – 1.40	12	15.4
1.41 – 1.60	19	24.4
1.61 – 1.80	18	23.1
1.81 – 2.00	12	15.4
Total	78	100

Source: Own data

The production function approach produced a mean value of irrigation water E1.51 per m^3 (95% confidence interval of E1.41 m^{-3} and E1.59 m^{-3}), with a standard deviation of E0.40 per m^3 (95% confidence interval of E0.35 m^{-3} and E0.48 m^{-3}) and a median value of E1.51 m^{-3}. Looking at the distribution of the values produced by the two approaches, it appears that the results of the residual value approach were skewed to the left. Consequently, a t-test was used to confirm whether the results produced by the two methods were statistically different. Prior to performing the t-test, the individual values were initially normalised by a log transformation to guard against the distortionary influence of possible outliers.

Results showed that the observed mean difference of E-0.03 between the logs of the mean values from the two methods was not statistically significantly different from zero (95% confidence interval of E-0.06 m^{-3} and E0.00 m^{-3}), with a standard deviation of E0.15 m^{-3} (95% confidence interval of E0.12 m^{-3} and E0.17 m^{-3}). From the probability (p) of 0.06 a conclusion was made that the null hypothesis which stated that the mean difference is equal to zero cannot be rejected ($p > 0.05$) at 5 percent level of significance. It can thus be concluded that the results produced by these two independent methods converge. This suggests that either of the two methods can be used to value irrigation water used in sugar cane cultivation in the Lowveld of Swaziland. This result, in conjunction with economic theory of duality, led to the conclussion that farmers, in terms of irrigation water utilisation, are operating at the lower boundary of the economic region of the classical production function, where average product is equal to marginal product. This leads to the conclusion that the technology used exhibits constant returns to scale.

It was expected that the value of irrigation water in the Lowveld of Swaziland will be close to the value of irrigation water as an input in sugar cane production of R1.77 obtained by Hassan and Mungatana (2006) in South Africa because South Africa is a developing country such as Swaziland. It was also expected that the estimated value in this study will be less than the value 0.25 E/m^3 obtained by Mesa-Jurado *et al*., (2008) in Spain because Spain is a developed country therefore farmers in Spain were expected to be using water saving technologies. A conclusion can be made that the value of irrigation water obtained in this study falls within the expected range.

4.3 OUTPUT ELASTICITY OF IRRIGATION WATER

The second objective of this study was to use output from the production function approach to estimate the output elasticity of irrigation water used in sugar cane production. Considering that the estimated relationship between output and the irrigation water input was of the double log form (see equation 3.10), the input coefficient for irrigation water (0.7110) is also the output elasticity. An elasticity of less than 1 in absolute value implies inelastic output, which means that output is less responsive to changes in the quantity of irrigation water employed (Nicolson, 2002:177), which adds more credence to the constant returns to scale conclusion made about the technology used by sugar cane farmers in the Lowveld of Swaziland. This result also implies that sugar cane farmers are operating in the economic region (region two) of the classical production function, suggesting that sugar cane farmers are indeed rational actors (ie., they exhibit profit maximising behaviour).

4.4 FACTORS AFFECTING IMPLICIT VALUE OF IRRGATION WATER

The third objective of this study was to identify factors that influence the implicit values of irrigation water the farmers in the study sample. The results from this analysis are presented in Table 4.7.

Table 4.7: Determinants of the implicit values for irrigation water used for sugar cane production in Swaziland

	Dependent Variable (natural log of residual value)		Dependent Variable (natural log of value from production function method)	
Variables	**Coefficient (SEE)**	**t-statistic (p-value)**	**Coefficient (SEE)**	**t-statistic (p-value)**
Constant	-7.3144 (0.7090)	-10.3200*** (0.0000)	-5.0685 (0.5017)	-10.1000*** (0.0000)
Land	0.0086 (0.0016)	5.2800*** (0.0040)	0.0086 (0.0012)	7.4400*** (0.0000)
ln_labour	-0.1724 (0.0585)	-2.9500*** (0.0040)	-0.1042 (0.0414)	-2.5200*** (0.0140)
ln_chemicals	-0.4166 (0.0745)	-5.5900*** (0.0000)	-0.2935 (0.0527)	-5.5700*** (0.0000)
ln_fertilizer	-0.1983 (0.0589)	-3.3700*** (0.0010)	-0.0804 (0.0417)	-1.9300* (0.0580)
ln_revenue	0.9505 (0.0716)	13.2700*** (0.0000)	0.6200 (0.0507)	12.2300*** (0.0000)
Water	-9.15e-07 (1.06e-07)	-6.7200*** (0.0000)	-6.83e-07 (7.53e-08)	-9.0800*** (0.0000)
78 observations, F(6, 71) = 40.39 Prob> F = 0.0000, R-squared = 0.7734, Adjusted R-squared = 0.7543			78 observations, F(6, 71) = 43.91 Prob> F= 0.0000, R-squared = 0.7877 Adjusted R-squared = 0.7698	

***, **, and *** represent significance at 10%, 5% and 1%, respectively. Figures in parenthesis are standard errors.**

Source: Own data

For both regressions, the coefficients for revenue and land are both positive and statistically significant ($p<0.01$). This result suggests that the implicit values farmers hold for irrigation water increase with the farmers' income (the higher a farmer's income, the more the farmer afford to pay for irrigation water), which seems consistent with the predictions of economic theory. This result also suggests that farmers with larger parcels of land have higher implicit marginal valuations for irrigation water than farmers with smaller parcels of land. Farmers with larger parcels of land are also likely to be the ones with higher outputs, which translates to higher incomes and is thus consistent with the relationship between values and income. This result suggests that the estimated value of irrigation water varies with the level of resource endowment, therefore necessitating the consideration of equity issues when formulating a pricing policy.

On the other hand, the coefficient for water is negative, suggesting that there is a negative and significant relationship between the implicit value of irrigation water and the quantity of irrigation water consumed. This emanates from the law of demand which postulates that less is demanded at a higher price.

Finally, the coefficients for labour, chemicals and fertilizer are negative and statistically significant ($p<0.05$). This result suggests that there is a negative but significant relationship between the implicit valuation of irrigation water and the employment of these inputs. As farmer's marginal values for irrigation water increase, the results show that he or she will consume less and less water. The negative coefficients for labour, chemicals and fertilizer suggest that as the farmer consumes less and less water as a result of increase irrigation water price, the farmer will also reduce the employment of labour, chemicals and fertilizer. This suggests that water, labour, chemicals and fertilizer move in the same direction, which confirms that they are complements in production.

4.5 ESTIMATED TECHNICAL EFFICIENCY OF SUGAR CANE FARMERS

The final objective of this paper was to estimate the technical efficiency (TE) of sugar cane farmers in the Lowveld of Swaziland and to further identify the determinants of efficiency among the sugar cane farmers in this region. The results are presented in Table 4.8.

Table 4.8: OLS and ML estimates of the Cobb-Douglass SFPF

Variable	Parameter	OLS estimate (standard error)	ML estimates (standard error)
Intercept	β_0	5.8100*** (1.49810)	5.3903** (1.3161)
Land	β_{Lan}	1.2755*** (0.1775)	1.237*** (1.6003)
Labour	β_{Lab}	-0.1210* (0.0662)	-0.0918 (0.0600)
Chemicals	β_C	-0.1107 (0.0968)	-0.1222 (0.0852
Water	β_W	-0.0103 (0.1439)	0.0506 (0.1318)
Fertiliser	β_F	-0.06163 (0.0650)	-0.0835 (0.0578)
Sigma-squared	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.0460	0.0768*** (0.0177)
Gamma	$\gamma = \sigma_u^2/\sigma^2$		0.7518*** (0.1042)
LLF		12.5076	16.3529

***, **, and *** represent significance at 10%, 5% and 1%, respectively. Figures in parenthesis are standard errors.**
Source: own data

The coefficient for land, from both the OLS and ML, is positive and highly significant ($p<0.01$). This implies that an increase in farm size increases technical inefficiency. It can thus be concluded that small sugar cane farms are more technically efficient that large ones. Contrary to the *a priori* expectation, the coefficient for labour is negative and significant at 10% level of significance. This implies that as labour increases, output per unit of labour increases. However, this is not surprising when taking into account the agronomic characteristics of sugar cane. Sugar cane is highly sensitive to weeds and the timing of fertiliser application. This being the case, it can be posited that those farmers who employ more labour will protect their crop from the weed infestation within the shortest possible time, and so their yield will be less affected by weeds. Similarly, if more people were hired for fertiliser application, they would apply the fertiliser within the shortest possible time and so yields would not be compromised owing to late application of fertiliser to all parts of the farm. Coefficients for chemicals, water and fertiliser also prove to be contrary to *a priori* expectations, although they are not statistically significant.

Table 4.7 presents the frequency of efficiency scores, for sugar cane farmers in the Lowveld of Swaziland, obtained from Frontier version 4.1. The individual efficiency scores are presented in Appendix Five. Efficiency score estimates for the 78 farms included in the stochastic frontier model range from a minimum of 0.397 to a maximum of 0.955, with a mean of 0.840, standard deviation of 0.0820 and 95% confidence interval of the mean between 0.8587 and 0.8223.

Table 4.9: Frequency of technical efficiency scores among sugar cane farmers in the Lowveld of Swaziland

Technical efficiency (TE) score	**Frequency of technical efficiency**	**Percentage**
0.30-0.40	1	1.28
0.41-0.50	0	0
0.51-0.60	1	1.28
0.61-0.70	1	1.28
0.71-0.80	8	10.26
0.81-0.90	54	69.23
0.91-1	13	16.67
Total	78	100

Source: Own data

There were few farmers who were found to be operating at the extremes of the range. Only one farm was relatively inefficient, with an efficiency of 39.7 percent, and 13 were found to be at the upper end of the range. A majority (96.2 percent) of the farmers fell between 0.81 and 0.9, which implies that they were relatively efficient. The reason for estimating technically efficiency scores was to assess the claim that farmers who were found to be more technically efficient farmers would be expected to have higher implicit values for irrigation water. Table 4.8 presents the results.

Table 4.10: Factors affecting residual value of irrigation water among sugar cane farmers in the Lowveld of Swaziland

	Dependent Variable (residual value of irrigation water)	
Variables	**Coefficient (SEE)**	**t-statistic (p-value)**
Constant	-5.8330	-14.27***
	(0.4087)	(0.0000)
Land	0.0096	10.6000***
	(0.0009)	(0.0000)
ln_labour	-0.0872	-2.6400***
	(0.0330)	(0.0100)
ln_chemicals	-0.1832	-4.0700***
	(0.0451)	(0.0000)
ln_fertilizer	-0.1639	-5.0200**
	(0.0327)	(0.03800)
ln_revenue	0.5234	10.0900***
	(0.0519)	(0.0000)
Water	-7.04e-07	-11.9800***
	(5.88e-08)	(0.0000)
TE scores	2.5973	12.7500***
	(0.2037)	(0.0000)
78 observations, F(7, 70) = 42.34, Prob> F = 0.0000, R-squared = 0.9091, Adjusted R-squared = 0.9000		

***, **, and *** represent significance at 10%, 5% and 1%, respectively. Figures in parenthesis are standard errors.**
Source: own data

The exogenous variables were found to be jointly significant (F<0.01), at 1% level of significance, in explaining the variation in the dependent variable (residual value of irrigation water), with an adjusted R-square of 0.4897. An adjusted R-square of 0.9 confirms goodness of fit of the specified model. All variables were also individually significant in explaining changes in residual value of irrigation water. In consonance with *a priori* expectations, TE positively affects residual value of irrigation water and the coefficient is highly significant (p<0.01). This means that a unit increase in TE results in a significant 1.6613 units increase in residual value, with a 95 percent confidence interval between 1.3184 and 2.0042. This result suggests that irrigation water pricing can be used as a tool for inducing efficiency in the use of this resource. Since the assumption of rationality was found to hold, farmer will respond to an increase in the price of irrigation water price by reducing the quantity of irrigation water they employ therefore becoming technically more efficient.

4.6 SUMMARY

This chapter presented the empirical findings and discussions of the study. The findings of the study reveal that irrigation water used in the growing of sugar cane in the Lowveld of Swaziland has a positive non-market value which is significantly different from zero, according to the both methods used. Moreover, it transpired that the values obtained from these methods are not statistically different. It was also found that sugar cane output was inelastic with respect to irrigation water. The results also show that the non-market value of irrigation water was positively influenced by farm size and farm revenue, and negatively influenced by input quantities. TE was found to vary between farms and, as expected, it transpired that farmers who were found to be more technically efficient also had higher implicit values of irrigation water.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

The main objective of the study was to estimate the non-market value of irrigation water as an input in sugar cane production in the Lowveld of Swaziland. Another objective was to test if the values obtained from residual value and production function methods differed statistically. The study also estimated the output elasticity of irrigation water used in sugar cane cultivation in the Lowveld of Swaziland and identified the factors affecting the implicit value of irrigation water. The stochastic frontier model was used to estimate sugar cane farmers' TE and to further to assess the relationship that was hypothesised to exist between the implicit value of irrigation water value and TE. The data obtained from 78 farms were used to estimate value of irrigation water as an input in sugar cane production in the Lowveld of Swaziland. The residual value and production function methods were used for this task. The values of irrigation water estimated using the two methods were positive and statistically different from zero.

5.2 CONCLUSIONS

The study was conducted to inform policy on non-market value of irrigation water as an input in sugar cane production in the Lowveld of Swaziland. Non-market value of irrigation water was unknown before this study was conducted yet it is one of the most important factors considered when developing a pricing policy. For this reason, the main objective of the study was to estimate the non-market value of irrigation water as an input in sugar cane production in the Lowveld of Swaziland. The non-market value of irrigation water was estimated using residual value method and the production function approach. From the results of the study it transpired that these two methods give statistically similar estimates. The observed difference between the two mean estimates is not statistically significantly different from zero. This implies that either of the two methods can be used to estimate the implicit value of irrigation water used in sugar cane production in the Lowveld of Swaziland.

This result, in conjunction with the theory of duality, leads to the conclusion that the technology used by sugar cane farmers in the Lowveld of Swaziland exhibits constant returns to scale since farmers are operating at the point where marginal physical product is equal to average product. From this result, it can be concluded that sugar cane farmers in the Lowveld of Swaziland were rational actors (profit maximising behaviour) since they were operating within the economic region (region two) of the classical production function.

The other conclusion that can be drawn from the results of the study is that sugar cane farmers in the Lowveld of Swaziland have the ability to pay for irrigation water. This was revealed by the positive estimates of the value of irrigation water, which was statistically significantly different from zero. Implicit values of irrigation water were negatively related to quantity of irrigation water used, lending more credence to the conclusion of the profit maximising behaviour of sugar cane farmers.

From the above results, it is clear that water pricing instruments can play a significant role in irrigation water demand management by inducing efficiency in sugar cane farmers. Furthermore, when taking into account the fact that agriculture is the largest consumer of the water resource in Swaziland (Nyagwambo, 2008:3; IWSD, 2006:3), a slight improvement in farmers' technical efficiency could free sufficiently large quantities of water that can be made available to other sectors.

A pricing policy can also play a crucial role in internalising the natural scarcity of irrigation water and externalities associated with its use (Tiwari, 2005:1). It can also ensure the achievement of objectives related to equity, cost recovery, local acceptability, simplicity and transparency (Hanemann, 1994:20). It is, however, a remarkable challenge to set a price and pricing mechanism for irrigation water since this resource is considered a basic need, a basic human right and a pivotal environmental resource (Abu-Zeid, 2001:527. The revealed positive relationship between TE and implicit values of irrigation water also implies that price can induce the efficient use of resources by sugar cane farmers in the Lowveld of Swaziland.

Potential spillovers, at farm level, from the efficient use of irrigation water are expected. One possible spillover could be the reduction in electricity cost owing to the reduction in the amount of water used by farmer. Another possible benefit to the farmer could be the reduction in soil nutrients leaching. Benefits to the environment will be the reduced underground water pollution attributable to leaching nutrients.

5.3 RECOMMENDATIONS

Two recommendations are made based on the relationship between the implicit value of irrigation water and the factors affecting it, as found in the study:

- Recommendation based on the negative relationship between the implicit value of irrigation water and the quantity of water employed. It has been concluded that a pricing policy has the potential to benefit irrigation water management by inducing efficiency in sugar cane farmers. Accordingly, properly calibrated pricing instrument should be considered as an option in irrigation water management.

- Recommendation based on the positive relationship between the implicit value of irrigation water and the level of resource endowment of sugar cane farmers. The study found that it is necessary to take into account equity issues when developing a pricing instrument so as not to disadvantage those farmers with fewer resources, such as those with smaller areas of land for cultivation.

5.4 LIMITATIONS OF THE STUDY

The methods used (the residual value method and the production function approach) were based on assumptions of fixed technology, policy and market environments, under static rather than dynamic models. Therefore, this static model should not be extended to estimate future benefits without running the risk of considerable bias. Some of the data required in this study were not available, and under such circumstances the researcher relied on the farmers' recall memory. The results of the study should be used with due caution if the planning horizon stretches to the long run.

5.5 AREA FOR FURTHER RESEARCH

A possible extension could be assessing the sufficiency of the obtained value in meeting the full cost recovery principle. Farmers' attitudes towards the introduction of a pricing mechanism can also be assessed.

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APPENIX ONE: LETTER OF CONSENT

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Agricultural

and Natural Sciences

Consent for participation in an academic research study

Department of Agricultural Economics, Extension, and Rural Development

Title of study

RESIDUAL VALUE AND PRODUCTION FUNCTION APPROACHES TO VALUATION OF IRRIGATION WATER IN SUGAR CANE PRODUCTION: APPLICATION TO THE LOWVELD IN SWAZILAND

Research conducted by:

Mr.T.T. Sacolo

Cell: 0786852250

Dear Respondent

You are invited to participate in an academic research study conducted by Thabo Sacolo, Masters Student from the Department Agricultural Economics, Extension and Rural Development at the University of Pretoria.

The purpose of the study is to provide policy makers with the necessary information to make an informed decision on how to improve irrigation water use efficiency and as a means of managing the water resource.

Please note the following:

This study involves an anonymous survey. Your name will not appear on the questionnaire and the answers you give will be treated as strictly confidential. You cannot be identified in person based on the answers you give.

1. Your participation in this study is very important to us. You may, however, choose not to participate and you may stop participating at any time without any negative consequences.

2. The results of the study will be used for academic purposes only and may be published in an academic journal. We will provide you with a summary of our findings on request.
3. Please contact our study leader, Dr E.D. Mungatana on tel. +27 124 203253 (e-mail: eric.mungatana@up.ac.za) if you have any questions or comments regarding the study.

Please sign the form to indicate that:

1. You have read and understood the information provided above.
2. You give your consent to participate in the study on a voluntary basis.

Respondent's signature   Date

APPENDIX TWO: SURVEY INTRUMENT

RESEARCH QUESTIONNAIRE FOR SMALHOLDERSUGACANE PRODUCTION IN THE LOWVELD OF SWAZILAND

Please carefully read and complete the questionnaire. All revealed information will be treated confidentially. Where exact figures are not available, please provide careful estimates. The questionnaire should be completed for the 2011/2012 production season.

PART A: GENERAL INFORMATION

1 Farm code or name ....

2 Constituency *(Inkhundla)*..

3 Geographic region ....

4 Village/community ....

5 Name of interviewer ....Date of interview ....

PART B:SOCIO DEMOGRAPHIC DATA(SMALLHOLDER SUGAR CANE FARMER)

6 Please enter the details of respondent requested in the following table

Gender*		Age [Years]	No. of dependents	No. of school going kids	Marital Status*				Education level*				Primary source of income*		
M	F				S	M	W	D	N	P	H	T	GE	SC	O
1	2				1	2	3	4	1	2	3	4			

* **M**= male **F**= female **S**= single **M**= married **W**= windowed **D**= divorced

***N**= No formal education **P**= Primary level **H**= High school level **T**= Tertiary level

***GE**=gainful employment (specify) **SC**= sugar cane farming

O= other (specify) ___________________

7 What is your household size including yourself? Please specify below.

Household member	**Number**
Adults male (age 15 years and above)	
Adults female (age 15 years and above)	
Children (below 15 years)	

Total household size	

8 In what year did you started growing sugar cane? ....

9 What is your position in the farm?

a) Sole owner [ ]

b) Farm supervisor [ ]

c) Supervisor and shareholder [ ]

d) Chairperson [ ]

e) Farm clerk [ ]

f) Secretary [ ]

PART C: TYPE OF LAND OWNERSHIP AND THE COMPOSITION OF TOTAL LAND AREA UNDER SUGAR CANE PRODUCTION

(Note: This section pertains to the ownership system of the land, in hectares (ha), on which sugar cane was grown last farming season).

Please provide information in the table below, about the ownership of the land on which you grew sugar cane last farming season.

	YES	**NO**	**If YES # of hectares**
Swazi National Land			
Title Deed Land			
Lease Land			

10 Total land owned by you and rented or leased out to others last season .... ha

PART D: MEMBERSHIP TO FARMERS' ORGANISATION

11 Were you a member of any of the following farmers' organisation last farming season? Please indicate if you were a committee member your organisation last farming season?

	Membership		**Committee Member**	
	YES	**NO**	**YES**	**NO**
Farmers Union				
Farmers' cooperative				
Producer organisation				
Other (Specify)				

PART E: ACCESS TO SOURCES OF CREDIT

(Note: This section requires information about the source or sources from which fund for financing the sugar cane farm come from last season).

12 Did you finance your sugar cane farm through credit last farming season?

Yes [ ] No [ ]

13 If YES in No. 12, please indicate below your source of credit and if more than one source was used, please specify the amount obtained from each source.

Source of agricultural credit	YES	NO	If YES Specify amount (E)
Commercial banks			
Farmers' organisations			
Friends and relatives			
Private lenders			
Other (specify)			

PART F: INPUT UTILIZATION AND COST OF PRODUCTION OF SUGAR CANE

(Note: This section seeks to capture information on physical quantities of inputs, and costs of these inputs, that were used in the production of sugar cane. 50kg = a bag of fertilizer; 1000kg = 20 bags of fertilizer. Illustrate this clearly to the farmers for all quantities to be specified in kg).

14 Please provide information in the table below about the quantities of inputs that were used in the production of sugar cane last farming season.

Input	Type of input	Quantity	Total Cost
Leased land			
Fertilizer (kg)	1.		
	2.		
	3.		
Pesticides (kg or litres)	1.		
	2.		
	3.		
	5.		
Herbicides (litres)	1.		
	2.		
	3.		
Others (please specify)	1.		
	2.		

	3.		
	4.		

15 Which one of these varieties did you grow in your farm last season?

Variety	**YES**	**NO**
NCo376		
N14		
N19		
N23		
N25		
N32		
N36		
N40		
N41		
N46		
N49		

16 The table below refers to the use of family labour on sugar cane production last season. Please fill out as accurately to the extent possible.

	Adult male		**Adult female**		**Children**	
Type of activity	**No. of members**	**No. of days**	**No. of members**	**No. of days**	**No. of members**	**No. of days**
Trash clearing						
Weeding						
Fertilizer application						
Spraying						
Management of smut disease						
Other (specify) 1.						
2.						
3.						
Total						

17 Did you hire labour to work on your sugar cane farm last season? Yes [ ] No [ ]

18 If YES in17, what was the labour cost per day in your area last farming season for each of the following categories?

Category	**Cost Per Day (E)**
Adult male	
Adult female	
Children	

19 If YES in No. 16, please fill the table below with respect to hired labour on your sugar cane farm.

Type of activity	Adult male		Adult female		Children	
	No. of members	No. of days	No. of members	No. of days	No. of members	No. of days
Trash clearing						
Weeding						
Fertilizer application						
Spraying						
Management of smut disease						
Other (specify) 1.						
2.						
3.						
Total						

PART G: QUANTITY OF WATER USED IN IRRIGATION OF SUGAR CANE

(Note: This section pertain the physical quantity of water, in m^3, used in irrigation of sugar cane and the pattern of irrigation throughout the farming season. In cases whereby water used is given in other units such as litres, these units will be converted to cubic metres).

Section I

20 Did you irrigate your sugar cane last farming season? YES [ ] NO [ ]

21 If YES in No. 20, did you irrigate your sugar constantly or the irrigation intensity varied at various stages of growth?

6 Constant irrigation [ ]

7 Varying irrigation [ ]

22 Please provide the information required in the table below.

Note: if irrigation varies at various stages of growth, please specify in the spaces provided in the table below.

Sugar cane growth stage	Duration of stage in months	Sprinklers' stand time	No. of cycles per month	Total No. of hours spent irrigating
1.				
2.				

3.				
4.				
Capacity of pump m^3/hr				
Number of operating sprinklers				
Sprinklers' spacing (m)				

23 Apart from the private pumping cost, did you pay to the municipality for irrigation water?

YES [ ] NO [ ] If YES, go to No. 23. If NO, go to part II

24 If YES in No. 23, how much did you pay for irrigation water last farming season (per unit employed?)? E ....

Section II

In part one of this section you mentioned that you did not pay for irrigation water last season. Now I would like you to think of a scenario whereby the municipality is planning to implement a water catchment protection project that will guarantee sufficient and sustainable irrigation water supply. This project will enable you, as a farmer, to expand your sugar cane farm without running the risk of irrigation water shortage.

25 Do you think this would be a good idea?

YES [ ] NO [ ] If YES, go to No. 26

26 If NO in 25, please explain why you think this is not a good idea.................
....
....
....

27 Since you view this is a good idea, which guarantee sustainability and sufficient supply of irrigation water, this however, may require the municipality to invest into this project. In implementing such a project, the municipality will have to spend money and disburse other resources. The municipality may decide to charge for irrigation water in order to raise funds for the operations and maintenance of the project. Assuming all other farmers will pay the same amount as you will and the municipality guarantees proper use of the funds, will you be willing to pay for irrigation water, so that the municipality will have the necessary funds to operate and maintain the project? YES [ ] NO [ ]

28 If NO in 27, please explain ……………………………………………………….
……………………………………………………………………………………………

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

PART H: OUTPUT PRODUCED AND GROSS FARM INCOME

29 In what month did you cut your sugar cane last season?......................................

30 Did you allow dry off period before you cut the sugar cane last season

YES [ ] NO [ ]

31 If YES in 30, how long was the dry off period? ....month ....weeks .... days.

32 Please complete the table below for your sugar cane production last farming season.

Area planted (ha)	Area harvested (ha)	Cane yield (ton)	Sucrose yield (%)

33 Apart from income earned from your own farming operations and lease of land, did you have any other income last farming season? Yes [ ] No [ ]

34 If yes in 33, specify how much you received from any of the sources.

Source of income		Amount (E)
Pension		
Old aged grant		
Wages from non-agricultural work		
Others (Specify)		

APPENDIX THREE: ESTIMATES OF IRRIGATION WATER VALUE

Average value of irrigation water in year 2912 (Residual value method)

Farm code	Residual value (E)	Farm code	Residual value (E)
01	1.37	41	1.98
02	1.35	42	1.62
03	0.91	43	1.41
04	1.86	44	1.98
05	1.59	45	2.26
06	1.68	46	1.71
07	1.56	47	2.93
08	1.34	48	1.87
09	1.85	49	1.46
10	2.31	50	1.65
11	1.28	51	1.24
12	0.44	52	1.51
13	1.09	53	1.49
14	0.96	54	1.56
15	1.71	55	1.19
16	0.72	56	1.93
17	1.36	57	1.71
18	0.20	58	2.40
19	1.69	59	2.06
20	0.81	60	2.00
21	1.23	61	0.51
22	1.10	62	1.63
23	1.16	63	1.82
24	1.18	64	1.57
25	1.72	65	2.59
26	1.96	66	1.48
27	1.66	67	2.84
28	1.45	68	1.57
29	1.60	69	1.54
30	1.25	70	1.70
31	1.54	71	1.86
32	1.31	72	1.77
33	2.63	73	1.44
34	1.42	74	1.66
35	1.56	75	1.52
36	1.27	76	1.93
37	2.44	77	1.30
38	2.77	78	1.21
39	1.98	**TOTAL**	**124.45**
40	1.26	**AVERAGE**	**1.60**

Marginal value of irrigation water in year 2012 (Production function approach)

Farm code	Marginal value (E)	Farm code	Marginal value (E)
01	1.16	41	1.64
02	1.15	42	1.43
03	0.93	43	1.32
04	1.93	44	1.69
05	1.63	45	2.00
06	1.49	46	1.68
07	1.46	47	2.44
08	1.33	48	1.67
09	1.62	49	1.36
10	2.01	50	1.69
11	1.18	51	1.56
12	0.60	52	1.55
13	0.94	53	1.70
14	0.97	54	1.44
15	1.56	55	1.37
16	0.83	56	1.83
17	1.32	57	1.77
18	0.46	58	2.36
19	1.58	59	1.78
20	0.87	60	1.77
21	1.26	61	0.71
22	1.13	62	1.56
23	1.07	63	1.70
24	1.14	64	1.60
25	1.57	65	2.29
26	1.72	66	1.40
27	1.51	67	2.42
28	1.38	68	1.58
29	1.51	69	1.49
30	1.18	70	1.61
31	1.46	71	1.78
32	1.17	72	1.73
33	2.21	73	1.42
34	1.32	74	1.61
35	1.49	75	1.44
36	1.09	76	1.89
37	1.96	77	1.36
38	2.32	78	1.33
39	1.72	**TOTAL**	**117.55**
40	1.31	**AVERAGE**	**1.51**

APPENDIX FOUR: FARM EFFICIENCY SCORES

Efficiency scores for sugar cane farm in the Lowveld of Swaziland

Farm code	Efficiency score	Farm code	Efficiency score
01	0.8601	41	0.8742
02	0.8638	42	0.8609
03	0.7966	43	0.8253
04	0.7720	44	0.8995
05	0.8433	45	0.9116
06	0.8631	46	0.8803
07	0.7700	47	0.9432
08	0.7573	48	0.8182
09	0.8846	49	0.8257
10	0.9541	50	0.9075
11	0.7846	51	0.8485
12	0.6449	52	0.8898
13	0.8049	53	0.8763
14	0.8110	54	0.8938
15	0.8841	55	0.8882
16	0.8029	56	0.8578
17	0.7660	57	0.8342
18	0.3971	58	0.9264
19	0.8557	59	0.8814
20	0.8597	60	0.9108
21	0.8656	61	0.5195
22	0.8623	62	0.8480
23	0.8023	63	0.8443
24	0.7439	64	0.8167
25	0.8379	65	0.8556
26	0.8263	66	0.8032
27	0.9138	67	0.9552
28	0.9147	68	0.8381
29	0.8643	69	0.8093
30	0.8397	70	0.8452
31	0.8937	71	0.8257
32	0.8111	72	0.8381
33	0.9262	73	0.8290
34	0.9200	74	0.8124
35	0.8317	75	0.8293
36	0.8795	76	0.8249
37	0.9454	77	0.8289
38	0.9192	78	0.8354
39	0.8641	**MEAN EFFICIENCY**	**0.8405**
40	0.8103		

APPENDIX FIVE: MODELS

Cobb-Douglas production function

Dependent variable is the log of sugar cane output (cane tonne)

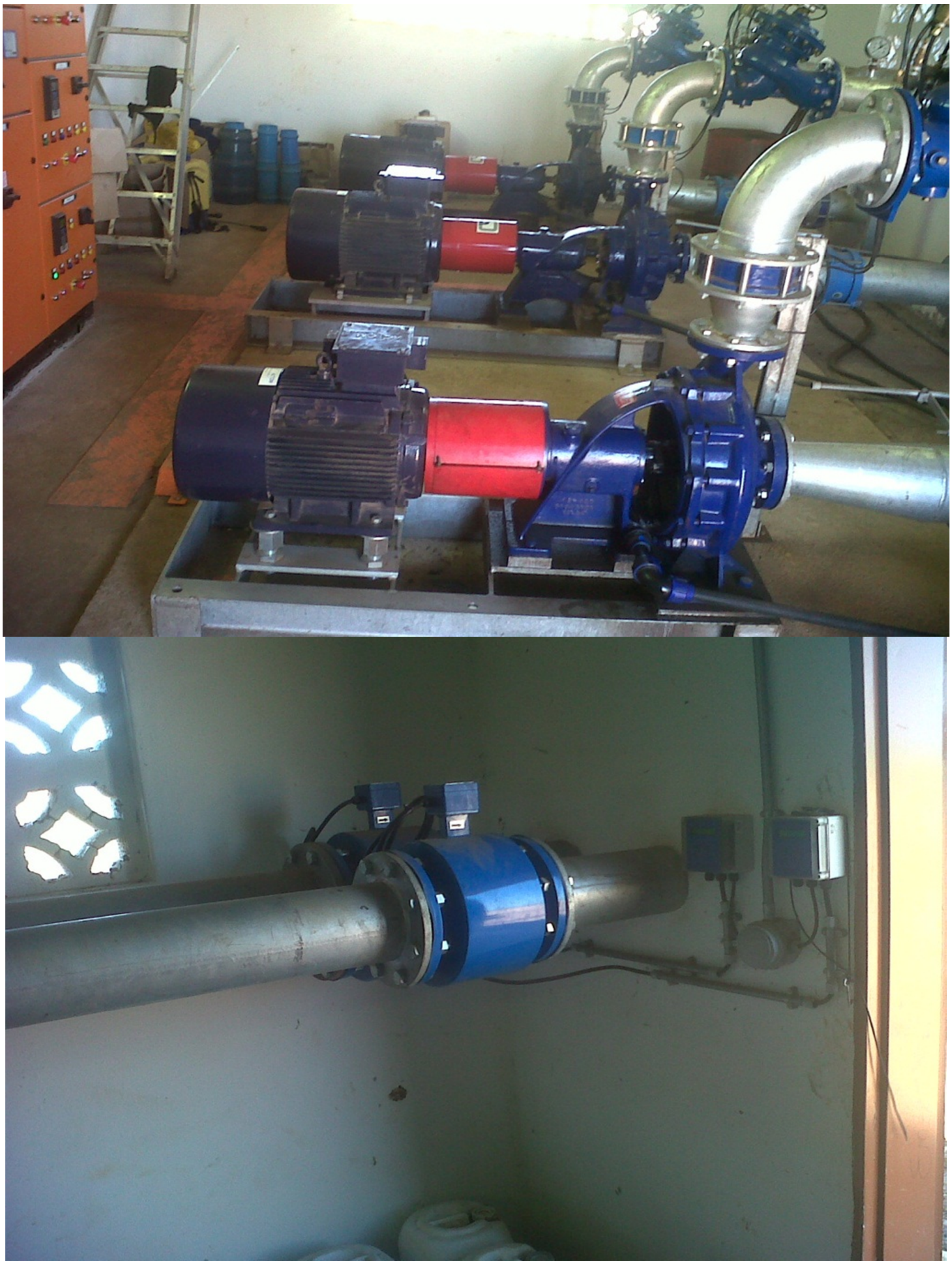
Variables	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
lland	1.276	0.175	7.280	0.000	0.926	1.625
llabour	-0.121	0.066	-1.830	0.072	-0.253	0.011
lchemicals	-0.111	0.097	-1.140	0.256	-0.304	0.082
lwater	-0.010	0.144	-0.070	0.943	-0.297	0.277
lfertilizer	-0.062	0.065	-0.950	0.346	-0.191	0.068
_cons	5.810	1.491	3.900	0.000	2.838	8.782
Number of observation = 78, F(5,72) =257.41, Prob >F = 0.000, R-Square = 0.947, Adj R-square = 0.9433						

Translog production function

Dependent variable is the log of sugar cane output (can tonne)

lcane_yield	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
land	-0.013	0.011	-1.100	0.274	-0.035	0.010
labour	0.000	0.000	0.870	0.389	0.000	0.001
chemicals	0.000	0.001	-0.240	0.813	-0.003	0.002
water	0.000	0.000	1.180	0.243	0.000	0.000
fertilizer	0.000	0.000	0.040	0.969	0.000	0.000
sqr_land	0.000	0.000	0.750	0.454	0.000	0.000
sqr_labour	0.000	0.000	-1.270	0.210	0.000	0.000
sqr_chemicals	0.000	0.000	0.630	0.528	0.000	0.000
sqr_fertilizer	0.000	0.000	0.890	0.376	0.000	0.000
sqr_water	0.000	0.000	-1.740	0.086	0.000	0.000
lland_labour	0.000	(omitted)				
lland_chemicals	0.000	(omitted)				
lland_water	2.013	0.580	3.470	0.001	0.852	3.173
lland_fertilizer	-0.183	0.191	-0.960	0.340	-0.564	0.198
llabour_chemicals	0.944	0.454	2.080	0.042	0.036	1.851
llabour_water	-1.169	0.513	-2.280	0.026	-2.195	-0.143
llabour_fertilizer	0.000	(omitted)				
lchemicals_water	-1.130	0.489	-2.310	0.024	-2.108	-0.152
lchemicals_fertilizer	0.000	(omitted)				
lwater_fertilizer	0.000	(omitted)				
_cons	9.703	4.795	2.020	0.047	0.118	19.288
Number of observation = 78, F(15, 62) =89.85, Prob >F = 0.000, R-Square = 0.956, Adj R-square = 0.9454						

APPENDIX SIX: PUMP HOUSE



Water pumps and water meters in a pump house of sugar cane farm