COMPARATIVE ANALYSIS OF TECHNICAL EFFICIENCY ON DIFFERENT MANAGEMENT SYSTEMS OF IRRIGATION SCHEMES IN LIMPOPO PROVINCE, SOUTH AFRICA: A STOCHASTIC FRONTIER PRODUCTION APPROACH

By

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ABSTRACT

Various types of management practices/institutional arrangements of the irrigation schemes exist in the world. According to the principles delineated in literatures, these irrigation schemes are categorized in terms of their management practices. The study was designed to compare the level of technical efficiency of farmers at different management practices of the irrigation schemes (i.e. integrated, specialised and multipurpose water management practices of the irrigation schemes) in Limpopo Province. Data were collected using a structured questionnaire which was administered on 200 farmers at different irrigation schemes. Stochastic frontier production function of Cobb-Douglas type was employed to analyse the data and thereby ascertain the level of technical efficiency and its determinants.

The results indicated the mean technical efficiency of 0.74, 0.72 and 0.76 for the integrated, specialised and multipurpose water management practices of the irrigation schemes respectively which implied that, there is a greater scope to increase maize, tomato, onion and spinach production with the current technology and resources available at the irrigation schemes. The most important contributors in maize, tomato, onion and spinach production efficiencies were seed, fertilizer, capital and land. Thus an appropriate amount of seed, fertilizer, capital and land could increase the productivity of maize, tomato, onion and spinach.

The results further revealed that education level of farmers, age of the farmers and land size were negatively significant toward the technical inefficiency of farmers at different irrigation schemes, which imply that an increase in any of the three variables will reduce the inefficiency and enhance the efficiency. While the family size of the farmer was positively significant, which implies that the bigger the family size, the higher the

inefficiency farmers would become for the production of maize, tomato, onion and spinach. Gender and income level of the farmers at different irrigation schemes were revealed to be insignificant toward the inefficiency. The institutional arrangements or the management practice of the irrigation schemes showed slight differences in affecting the efficiency of farmers at different irrigation schemes.

Policies designed to educate famers at different irrigation schemes through proper agricultural extension services could have a great impact in increasing the level of efficiency and hence maize, tomato, onion and spinach productivities. The Department of Agriculture should allocate more funds to strengthening the extension directorate and expanding the delivery of extension services to farmers at different irrigation schemes. Irrigation schemes were established in order to insure food security, alleviate poverty, job creation, among others. Therefore, it is of paramount importance for the government of South Africa in collaboration with the private sector to revitalise the irrigation schemes in Limpopo Province irrespective of the institutional arrangements. It is of vital concern for the policy makers to focus on the benefits of economies of scale in agricultural farming system. Therefore, land size should be increased for the farmers in integrated water management practice of the irrigation schemes to an optimum level in order for them to improve the level of technical efficiency.

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DECLARATION

I declare that the thesis hereby submitted to the University of Limpopo, for the degree of Doctor of Philosophy in Agriculture (Agricultural Economics) has not previously been submitted by me for a degree at this or any other university; that It is my own work in design and in execution, and that all material contained herein has been duly acknowledged.

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Surname and initials Date

DEDICATION

This thesis is designed and dedicated to my Late Mother (Ramadimetja Annah Pheladi Hlongwane), my wife, daughters, siblings and Reformed Apostolic Faith Mission in Africa.

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WRC	Water Research Commission
FAO	Food Agricultural Organization
IMT	Irrigation Management Transfer
ha	Hectare
US	United State
PIS	Public Irrigation Schemes
MPIS	Multipurpose Public Irrigation Schemes
GDP	Gross Domestic Products
IPTRID	International Programme for Technical and Research in Irrigation and Drainage
WUA	Water User's Association
USA	United States of America
TE	Technical Efficiency
ML	Maximum Likelihood
COLS	Corrected Ordinary Least Squares
OLS	Ordinary Least Squares
LR	Likelihood Ratio
HYV	High Yielding Variety
MLE	Maximum Likelihood Estimates
SIS	Smallholder Irrigation Schemes
R&D	Research and Development
IWMI	International Water Management Institutes
DWAF	Department of Water Affairs and Forestry

SSA	Sub-Saharan Africa
Mt	Million ton
NDA	National Department of Agriculture
PDA	Provincial Department of Agriculture
ISA	Irrigation Schemes Association
IACs	Irrigation Action Committees
CCSIS	Coordinating Committee on Small-Scale Irrigation Support
LIMDEP	Limpopo Department
CMA	Catchment Management Agency
O&M	Operation and Maintenance
EE	Economic Efficiency
AL	Allocative Efficiency
SF	Stochastic Frontier
DEA	Data Envelopment Analysis
DAFF	Department of Agriculture, Fishing and Forestry
KNP	Kruger National Park
SACG	South African Coast Guard
UNESCO	United Nations Educational Scientific and Cultural Organization
RDSN	Rural Development Services Network
MAR	Mean Annual Runoff
MAP	Mean Annual Precipitation
CWSS	California Weed Science Society
NPII	Northern Province Investment Institutes

TDS	Total Dissolved Solids
IAE	Institutes for Agricultural Engineering
LDA	Limpopo Department of Agriculture
CRIR	Centre for Research on Interdisciplinary and Readoption
HDP	Historically Disadvantage People
MAX	Maximum
MIN	Minimum
CPCs	Community Production Centres
PGDS	Provincial Growth and Development Strategy
TIL	Trade Investment Limpopo
CSO	Scientific and Cultural Organization
NWA	National Water Association
MIS	Micro Irrigation System
ARC	Agricultural Research Council
TREC	Turfloop Research Ethics Committee
SAWS	South African Weather Services
TDS	Total Dissolved Solids
OECD	Organisation for Economic Co-operation and Development
R	Rand

CHARPTER ONE

INTRODUCTION

1.1 Background of the study

Agriculture is the backbone of South African economy and will continue to be so in the foreseeable future especially in Limpopo Province. It plays an important role in uplifting the economy of the Limpopo Province. The role and significance of agriculture in the province's economy is very important to the extent that its performance can be conceptualized into productivity, investment impact, labour absorption, income distribution and stability. The South African government stated that self-sufficiency in the production of agricultural products such as maize, wheat, and vegetables is a key strategy for sound economic management and renewed growth for the country. It is widely recognized that the sustained flow and use of improved agricultural technologies is key to increased growth and agricultural productivity.

Agricultural productivity can be achieved when there is efficiency among farmers who produce various types of agricultural products. Efficiency is a way of achieving maximum benefits with limited resources. The efficiency of a firm consists of two components, which are technical and allocative efficiency. Technical efficiency is reflecting the ability of a farm to obtain maximum attainable output from a given set of inputs while allocative efficiency is reflecting the ability of a farm to use the inputs in optimal proportions given their respective prices. A farm is said to be technically efficient if it is operating at a point on an isoquant and more specifically at the least cost point rather than interior to the isoquant curve or production frontier curve (Farrell, 1957).

In the South African context, the low agricultural production of the small-scale farming sector, due to either lack of technical efficiency or allocative efficiency or both, has been a long-term concern of agricultural experts. In South Africa, the government spends a significant amount of its budget on the development of small-scale farmers. However, several factors are preventing the small-scale farmers from reaching their full potential. Some of these factors are: inefficient agronomic practices that tend to promote soil disintegration; lack of improved crop varieties; poor farm-and-water-management practices; lack of favourable pricing policy for crops and agricultural inputs; poor transportation and credit facilities; lack of appropriate technologies; and lack of proper transfer of technologies in the event technology is appropriate.

The water deficit caused by low and erratic rainfall and high evaporation demand limits dry land crop production in most of South Africa (WRC, 2011). Irrigated agriculture presents an attractive alternative under these conditions. Irrigation refers to the artificial application of water to land for the purpose of enhancing plant production. It reduces or removes water deficits as a limiting factor in plant growth and makes it possible to grow crops where the climate is too dry for this purpose and to increase crop yields where plant-available soil water is a yield-limiting factor during parts or all of the growing season (Van Averbeke *et al*., 2011).

Irrigation water can be abstracted from the source and conveyed to the field by farmers individually or in a group as an irrigation scheme. Accordingly, an irrigation scheme can be defined as an agricultural project involving multiple holdings that depend on a shared distribution system for access to irrigation water and in some cases, on a shared water storage or diversion facility. The term ‘irrigation scheme’ is also used more broadly to refer to a multitude of entities that correspond to this definition, when these entities share the same bulk conveyance system (Reinders *et al*., 2010).

Maize is a staple diet in South Africa and fluctuations in its production substantially affect food security in South Africa. Domestic production of maize, wheat, rice and other food crops is not enough to fulfil the dietary demand of people of South Africa, especially supply of maize remains a burning issue for the policy makers. Mostly, people get nutrient ingredients from rice and wheat, which is not sufficient to feed for long and also do not fulfil the dietary needs of the people.

Vegetable production could be increased through horizontal expansion, development of modern technology and vertical expansion such as efficient use of readily available resources. The approach of using available resources more efficiently is more viable since, there is no need to make extra efforts to bring new area under vegetable cultivation and or changing cropping patterns. Similarly, new investment is not needed to develop modern technology. This implies that vegetables production could be increased through boosting up productivity. This will not only increase availability of vegetables in the country but it will also increase income of vegetable growing farmers (Bakhsk *et al*., 2007).

Irrigation has played an enormous role in increasing agricultural output worldwide. As a result of increasing population, demand for water for the agricultural, industrial, and domestic sectors has grown significantly. Consequently, water allocation has undergone a significant shift since the turn of the 21st century, when almost 90% of water resources were consumed by agriculture. Recent figures indicate that irrigation worldwide now accounts for 62%, whereas industrial and municipal consumption have increased from 6% to 25% and from 2% to 9% of allocation, respectively (FAO, 2010).

As the world population and competition for land increase, agricultural production on irrigated land will become more important. Today, an estimated 55% of global output of rice and wheat are from irrigated areas, and one third of the world's food is grown on 237 x 10^6 ha, or 17% of the irrigated arable land (FAO, 2010). Growth projections suggest that by 2025, 80% of global food production will come from irrigated land (FAO, 2010).

Access to reliable irrigation can enable farmers to adopt new technologies, leading to increased productivity, overall higher productivity and greater returns from farming. This in turn opens up new opportunities; both on-farm and off-farm for job creation and poverty alleviation and can improve income, livelihoods and the quality of life in rural areas (Hussain *et al*., 2004a). Hussain *et al*. (2004a) mentioned five key interrelated dimensions of the relationship between accesses to good agricultural water, socio-economic uplifting in rural communities and poverty reduction. The dimensions are production, income/consumption, employment, vulnerability/food security and overall welfare. In general, access to good irrigation facilities allows poor people to increase their production and income, and enhances opportunities to diversify their income base, reducing vulnerability caused by the seasonality of agricultural production as well as external shocks. Thus, access to good irrigation has the potential to contribute to poverty reduction and the movement of people from ill-being to well-being (Hussain *et al*., 2008).

Increased output from irrigated agriculture may arise from improved yields, reduced crop loss, improved cropping intensity and increased cultivated area (Namara *et al*., 2010). Accordingly, reliable access to water enhances the use of complementary inputs such as high-yielding cultivars and agrochemicals which also increase output levels and thereby improve farm income and reduce poverty (Smith, 2004).

Smallholder irrigation schemes in South Africa's former homelands exhibit a glaring legacy of dependency on state support which hindered development of basic entrepreneurial skills – farm operations, water management and marketing were all in the hands of parastatals. The recent state withdrawal from the schemes and subsequent Irrigation Management Transfer (IMT) coincide with the challenges of implementing the national water act, which among others, pledges to redress inequity in access to water (Van Averbeke *et al*., 2011). For smallholder irrigation communities, although realising this goal seems a long way off, the success of irrigation management transfer remains a huge challenge especially in Limpopo Province.

The South African government has established over 160 smallholder irrigation projects in the Former Northern Province (Limpopo Province) with the objective of improving the livelihood of rural black African farmers. Under the previous government, the projects those were located in former 'homelands' were administered in a top-down manner with the objective of local food self-sufficiency. Under the new government of 1994, the provincial authorities have instituted a programme to determine the efficiency and thereby viability of these projects, rehabilitate those that are economically and environmentally viable and hand over the refurbished projects to the community.

Smallholder irrigation schemes (SIS) in South Africa have performed poorly and have not delivered on their development objectives of increasing crop production and improving rural livelihoods. Limited knowledge of irrigated crop production among farmers has been identified as one of the constraints to improved crop productivity. Irrigation application and system efficiencies were below the norm and irrigation scheduling did not take crop type and growth stage into account. According to Van Averbeke *et al*. (2011), Monitoring of 20 farmers over a three year period showed that cropping intensity averaged only 48% and that the yields of the 2 main summer crops, grain maize and butternut averaged only 2.4 and 6.0, respectively. In addition to poor water management, other main constraints to crop productivity were inadequate weed and fertiliser management and low plant populations.

Various types of management organisations in irrigation schemes exist in the various parts of the world. According to the principles delineated in literature (Lecler and Griffiths, 2003), an attempt was made to categorize irrigation schemes in terms of their management practices. The criteria used are only one way of categorizing most of the existing irrigation organizations, while other such as Tema (2005) used different criteria. The main criteria chosen to classify the organisations is whether the organisational structure covers all the activities which include water management, agricultural extension, applied research, supply of inputs, credit, marketing and basic infrastructure and social service, or a few of these activities, or only those related to water management alone. Within each of these categories, a further distinction is made depending on the degree to which management is controlled by farmers and/or government.

According to Lecler and Griffiths (2003), the following are the three types of management organizations of irrigation schemes existing in South Africa: integrated management organization, specialized water management organisation and multipurpose water management organisation. It is of paramount importance to briefly define each of the three irrigation management systems considered for this study.

i. Integrated Water Management Organisations

These organisations are characterized by an integrated organisational structure where all development activities are undertaken by specialized units which are all connected by a clear line of command and finally responsible to a single person (project manager) or committee. There are several types of integrated management organisations depending on the degree of the government and farmers in the management of the scheme (Lecler, 2000). Where an organisation is run by the farmer it usually adopts the structure of a service cooperative. Where the government officials fully control the organisation, there are two possibilities depending on the size of the production units: State farm (large production units) and Irrigation settlement projects (Small production units)

Another distinctive feature of these cooperatives is that most of the farmers involved are relatively wealthy. This is almost a precondition because of the high cost of irrigation infrastructure. Although part of the needed funds can be obtained through loans, it is apparent that such credit must be backed by the strong payment capacity of farmers. The organisation of an irrigation cooperative depends greatly on the kinds of contributions made and the services needed by project members. The organisational structure is similar to that of the irrigation association which is described later in the proposal. The rules and regulations governing the activities of the cooperative are established within the framework of the national laws for cooperatives (Lecler, 2000).

ii. **Specialized Water Management Organisations**

A specialized water management organization can be broadly defined as a social organisation aiming at an appropriate use of water for irrigation purposes among the farmers of a community. The term “appropriate” is used here to designate a timely and equitable distribution of the water. It is normally part of segregated organisational structures of irrigation schemes. The functions of specialized water management organisations are: the operation of the irrigation and drainage systems, maintenance of the systems, and assessment and collection of water charges. They are supported by certain general management services (finance, personal, planning and monitoring).

The degree of intervention by the government and the farmers in undertaking the functions described above indicates the main types of specialized water management organisations, which are: organisations mainly controlled by farmers (Irrigation Schemes Associations (ISA)); organization mainly controlled by government officials (Public Irrigation Schemes (PIS)) and organisations with mixed control by farmers and government officials (Schemes where the main irrigation system is managed by government officials while the tertiary canals are controlled by farmers associations (Lecler, 2000).

iii. Multipurpose Water Management Organizations

A multipurpose water management organisation is characterized by having responsibilities directly related to water management and some others which may include among others, irrigation extension, research, water quality management, marketing. These responsibilities should be the results of a careful examination of what is needed in the project that cannot be effectively provided by existing institutions. It represents a suitable solution since, uses the nucleus of a water management organisation and adds only those activities that are most needed and are not done by any other existing institution.

Multipurpose organisations basically take the structure of PIS where the relevant new activities are added. They have been designated here as multi-purpose public irrigation schemes (MPIS). Typical, added functions are: irrigation assistance to farmers, applied irrigation research, irrigation improvement service, water quality management and other activities. Sometimes a MPIS may also take responsibility for the establishment of some physical infrastructure aimed at improving marketing (Stores, processing plants, markets), provision of inputs (fertilizers, seeds, etc.) or credit facilities, depending on the specific needs of the project area. While the establishment of the first group of functions (formative and training nature) is strongly favoured in many instances, the second group must be restricted to very specific situations and only if they cannot be undertaken in the near future by any existing institution (Lecler, 2000).

Agricultural production efficiency generally focuses on the possibility of producing the optimal level of output from given resources, or producing a certain level of output at lowest cost. This study investigates whether sugar cane farmers are efficient in their resource utilisation and consequently how efficiency might be improved. If the farmers are operating efficiently, then only by introducing improved methods of production can farm outputs be increased. In contrast, if this is not the case production can be increased through improved management practices and transferring the experiences of the efficient farmers to the less efficient ones (Abate, 1995).

1.2 Problem statement

Irrigation schemes in Limpopo Province were initiated and funded by the South African government with the intention of achieving higher agricultural output, higher labour absorption, food security and poverty alleviation in the rural areas (Tema, 2005). After the withdrawal of government support from most of the irrigation schemes, there were some doubts with regard to the viability of those irrigation schemes.

A number of studies (such as Tema, 2005; Hlongwane, 2005 etc.) concerning efficiency of irrigation schemes have been conducted, where negative outcomes were revealed. However, the inefficiency problems associated with the institutional arrangement of the irrigation schemes were not documented and this implies that there is a high probability that a concrete research has never been conducted and no attempt was made with regard to comparative analysis of efficiency among the different management practices such as integrated, specialised and multipurpose practices of the irrigation schemes. The way in which irrigation schemes operates may have positive or negative effects on the efficiency of the irrigation schemes.

Existing low levels of food production, low technical efficiency and use of primitive technology, hinder the efforts to achieve progress in agricultural development. Traditional cereal farming e.g. maize and wheat is not only low yielding but also results in the mining of plant nutrients from the soil (Tlou *et al.,* 2006). Important objectives of small-scale irrigation scheme development and improvement are to: alleviate poverty, increase household incomes, improve nutritional status of rural communities and serve as a pole for broader agriculturally-led growth in rural areas (Sevendsen and Merrey, 2000). For these objectives to be achieved, small-scale farmers at the various irrigation schemes must be technically efficient.

The main focus of this study was, therefore, to compare the level of technical efficiency among the three different management irrigation practices taking into consideration the effects of institutional arrangement and management practices

1.3 Motivation for this study

South African governmental policies are based on the need to establish a more efficient and rational structure of farming, efficient use of land and natural resources, as well as to redress equitable access to resources in search of justice and social stability. Those policies seek to achieve optimal land utilization and increase productivity so as to deliver employment growth, improve income distribution and environmental sustainable use of natural resources. As it is evident from many researches (for example, Fuglie and Rada, 2013), South Africa is far behind in crops production despite having surplus labour in the rural areas of the country. But the question arises, how can we increase maize and vegetable production in South Africa? There are three possible ways to increase maize and vegetable production and these are: allocation of more land for maize and vegetable production; developing and adopting new technologies in maize and vegetable production to increase yield per hectare; and utilization of the available resources more efficiently (Bakhsk *et al*., 2007).

Maize and vegetable production occupy small share of total agricultural product area of South Africa as well as Limpopo Province. To increase area under maize and vegetable production is much more difficult, since it requires reallocation of cultivated area from major agricultural products to maize and vegetable demanding a change in agricultural produce pattern. Change in agricultural produce pattern requires time and investment and it is not possible in a short duration of time. Moreover, there are many agricultural, socio-economic and political factors regarding the reallocation of land resources. The other option is to bring new land area under maize and vegetable cultivation after making development on the unproductive land area. This option is not suitable in short duration of time because it demands a lot of investment in land improvement. Furthermore, water is the major constraint in bringing new area under cultivation. It is also evident that land area has reached its ultimate limit (Hussain *et al*, 2004a), so it is not possible to add more land area in maize and vegetable production.

The second way to increase maize and vegetable production is to develop and adopt the latest technologies. Development and adoption of new innovation is a long-term process and it needs more funds to be allocated for research and development. On the other hand, mostly the farmers in South Africa are illiterate, conservative and traditional. These factors hinder in diffusion and adoption of new technology at the farm level. Empirical studies indicate that the potential of new technologies has not been fully exploited due to inefficient decision making processes at the farms. Aspects relating to farm management practices are the most key factors responsible for not fully utilizing the potential of new technologies. Moreover, the introduction of new technologies is not a single time phenomenon as improvement and innovation in new technology is a continuous process. Disequilibria will result due to introduction of new technologies at the farms because introduction of technologies is a continuous process for a long period of time (Hussian *et al*., 2004b).

The third option of using available resources more efficiently becomes viable in the current situation. Maize and vegetable production can be increased by improving productivity i.e. yield per unit area. Since, additional area and development and adoption of new technology are not feasible in a short period of time, therefore the plentiful potential exists for improving productivity i.e. output per unit of area. Productivity is vital for the future of mankind to meet its basic needs of food, fibre and shelter. The greatest challenge in years to come will be to produce adequate food for the fast increasing population (Hussain and Hanjra, 2004).

It is generally thought that farmers in developing countries do not take advantage of full potential of research in agricultural sector. Here are different studies carried out in various countries (Herdt and Mandac, 1981; Kalirajan and Flinn, 1983; Kalirajan and Shand, 1989; Dawson and Lingard, 1989; Mushunje and Belete, 2005; Al-hassan; 2008; Neumann *et al*., 2010; Fanadzo *et al*., 2010) indicated that 7-50 percent inefficiency existed in rice, maize, wheat and cotton production. Technical inefficiency between 30-34 percent was reported by Bravo-Ureta and Pinheiro (1993); Taylor and Shonkwiler (1986) in Dominican Republic, Brazilian and Tanzanian agriculture respectively. Hussian *et al*. (2004b) estimated 30 percent and 57 percent technical and allocative efficiency respectively in Pakistan agriculture. Ali and Flinn (1989) concluded that improving efficiency could increase the profit of the rice farmers in Parkistan to the extent of 28 percent. Bravo-Ureta and Evenson (1994) found technical and allocative efficiency of 40 percent and 30 percent respectively in cotton production in Paraguay.

The majority of the farmers in South Africa have small landholding and they face financial constraints in growing major crops such as maize, wheat, cotton and sugarcane because major crops are long-duration crops. Small farmers could earn high income in a short duration of time by growing vegetables. Studies have showed that vegetable cultivation is more profitable compared to competing crops (Singh and Sikha, 1992; Ali and Hau, 2001). Shifting from major crops to vegetables is more viable option for small farmers.

In spite of high profitability, farmers are not shifting towards vegetable production. Those who are engaged in growing vegetables are not achieving potential yields. Studies are needed to investigate causes of lower vegetable yields and factors affecting farm management practices. Previous studies (Ahmad *et al*., 2005) have focused on the determination of cost and profitability of growing vegetables. Therefore, this study was designed to determine and compare the level of technical efficiency of farmers in integrated, specialised water and multipurpose water management organisations of irrigation schemes with emphasis to maize and some common selected vegetables such as tomatoes, onions, spinach and to identify significant socio-economic determinants of the efficiency of farmers in integrated, specialised and multipurpose water management organisations of irrigation schemes and to determine the extent to which each socio-economic determinant affect the efficiency of farmers at the different management organisations/institutional arrangement of the irrigation schemes.

1.4 Purpose of the study

1.4.1 Aim

The aim of the study was to compare the level of efficiency of maize, tomato, onion and spinach farmers in different management organisations/practices of the irrigation schemes (i.e. Integrated, Specialised and Multipurpose water management organisations) in Limpopo Province.

1.4.2 Objectives

The objectives of the study are:

i. To determine the level of technical efficiency of the maize, tomato, onion and spinach farmers in integrated, specialised water and multipurpose water management practices of irrigation schemes.
ii. To identify significant socio-economic determinants of the technical inefficiency of maize, tomato, onion and spinach farmers in integrated, specialised and multipurpose water management organisations of irrigation schemes and to determine the extent to which each socioeconomic determinant affect the technical efficiency of farmers at the different management practices/institutional arrangement of the irrigation schemes.
iii. To establish the effects of management practices/ institutional arrangements of the irrigation schemes on the technical efficiency of maize, tomato, onion and spinach farmers.
iv. To examine the production efficiency gaps in farmers operating as integrated, specialised and multipurpose water management practices of irrigation schemes with regard to efficiency.

1.4.3 Research hypotheses

The following hypotheses were formulated and tested by the study:

i. There is a low technical efficiency of the maize, tomato, onion and spinach farmers in integrated, specialised water and multipurpose water management practices of irrigation schemes.
ii. There are no significant socio-economic determinants of the technical inefficiency of maize, tomato, onion and spinach farmers in integrated, specialised and multipurpose water management practices of irrigation schemes.
iii. Management practices/ institutional arrangements of the irrigation schemes have no significant effects on the technical efficiency of maize, tomato, onion and spinach farmers.
iv. There are no known production efficiency gaps in farmers operating as integrated, specialised and multipurpose water management practices of irrigation schemes with regard to efficiency.

1.4.4 Research questions

The study was guided by the following research questions:

i. What are the levels of technical efficiency of the maize, tomato, onion and spinach farmers on the three management organisations/practices of the irrigation schemes?
ii. What are the significant socio-economic determinants of maize, tomato, onion and spinach farmers' efficiency on the three management practices of the irrigation schemes? What are the extents to which each socio-economic determinant of

farmers at different irrigation schemes affects farmer's technical efficiency in different management practices?

iii. Are there any effect(s) of management practices/institutional arrangements of the irrigation on the technical efficiency of maize, tomato, onion and spinach farmers? Are the institutional arrangements or management practices of farmers at different irrigation scheme, the major obstacle with regard to efficiency?

iv. Are there any production efficiency gaps of farmers operating in integrated, specialised and multipurpose water management practices of irrigation schemes with regard to efficiency?

1.5 Organization structure of the thesis

Since the purpose of this study was "to compare the level of efficiency of maize, tomato, onion and spinach farmers in different management practices of the irrigation schemes (i.e. Integrated, Specialised and Multipurpose water management organisations) in Limpopo province", the remainder of this thesis comprises seven chapters, including general introduction.

Chapter two provides detailed literature review whereas, chapter three is devoted to an overview of the irrigation schemes in South Africa. Chapter four presents a detailed description of the study area, chapter five deals with the analytical framework employed in the study and chapter six deals with the descriptive and empirical results of the efficiency in different management practices of irrigation schemes and thorough discussion of the results. The last chapter which is chapter seven presents the summary, conclusion and policy recommendations.

CHARPTER TWO

LITERATURE REVIEW

2.0 Introduction to literature review

The main focus of this chapter is to review the past studies conducted to determine the efficiency of farmers more especially in different irrigating schemes with emphasis on crops and some common selected vegetables. This chapter has been divided into seven sections. The first section provides a detailed description of the agricultural sector in South Africa and the second section is devoted to the operation of irrigation schemes. The third section contains the three management organisations of the irrigation schemes while section four and five present the general review of efficiency studies in Agriculture worldwide and review of studies in agriculture from South Africa. The last two sections are devoted to socio-economic factors affecting the success of smallholder farmers and summary and conclusion respectively.

2.1 Agricultural sector in South Africa

South Africa has a dual agricultural economy: a well-developed commercial sector and a predominantly subsistence sector. About 12% of the country can be used for crop production. High-potential arable land comprises only 22% of total arable land. Some 1.3 million hectares (ha) are under irrigation. Agricultural activities range from intensive crop production and mixed farming to cattle ranching in the bushveld, and sheep farming in the more arid regions (Van Averbeke *et al*., 2011).

Primary agriculture contributes about 2.5% to the gross domestic product (GDP) of South Africa and about 8% to formal employment. However, there are strong linkages into the economy, so that the agro-industrial sector comprises about 12% of GDP. Although South

Africa has the ability to be self-sufficient and produce surplus for export in virtually all major agricultural products, the rate of growth in exports has been slower than that of imports. The only increase in agricultural export volumes occurred during the period of exchange-rate depreciation in 2002 and came to about nine million tons (Mt). Major import products include wheat, rice, vegetable oils and poultry meat.

Producer prices of agricultural products increased, on average, by 24.9% from 2006 to 2007, compared to an increase of 17.9% during the previous year. In 2007, the producer prices of field crops rose by 41.9%, against an increase of 32.4% the previous year. This increase was mainly the result of a 44.7% increase in the price of summer grains and increases of 90.4% and 51.9% in the prices of winter cereals and dry beans, respectively. Producer prices of horticultural products increased by 20.6% in 2007 compared to 2006. Prices of vegetables increased, on average, by 20.6% during 2007, while the prices of fresh fruit increased by 27.7% (Fuglie and Rada, 2013).

The producer prices of animal products were 14.5% higher in 2007 than in 2006. Prices received for pastoral products increased by 29.9%. The price farmers received for milk was 33.8% higher. Prices received for poultry products rose by 13% (Fuglie and Rada, 2013).

On one hand, there is very well-developed commercial agricultural sectors characterized by a relatively small number of producers (about 60 000 commercial farmers) owning 87% of the total agricultural area and producing more than 95% of the marketed output. On the other hand a subsistence or small-scale agricultural sector characterized by a very large number of producers (3 million small-scale farmers), and majority of them are settled in the communal areas, making up about 13% of the agricultural land area (Kristen and Van Zyl, 1998).

In South Africa, the concept of small-scale farmer is usually associated with poverty, inefficient, uneducated farmer; this creates a wrong impression and is often viewed in a negative way. The reluctance and confusion of many people about small-scale farming also relates to the lack of a viable farm size. South Africans typically judge a farm‘s viability on its land size without necessarily considering other attributes, like specific farming enterprise or managerial ability.

It is stated that there is a problem in the exact definition of a small-scale farmer, and argued that it should be based on agricultural activity in whatever form. Small-scale is often equated with a backward, non-productive, non-commercial subsistence agriculture that is found in parts of the former homeland areas. Their production levels are generally low due to a traditional land tenure system, lack of physical infrastructure, a lack of credit facilities and lack of extension services (Cornia, 1985).

The smallholder sector is divided into three categories: net food buyers, intermediate farmers and net food sellers. Net food buyers are those farmers with less than 0.7 hectare who cannot produce food to satisfy their subsistence needs given the technology they use and who thus remain dependent on off-farm activities. Intermediate smallholder farmers are those with land holding between 0.7 and 1.5 hectares who produce just enough for their survival but have very little for sale. Net food sellers are those farmers with land holdings of more than 1.5 hectares who produce more than their subsistence needs for survival during the year (Alwang and Siegel, 1999).

Agricultural sector performance can be conceptualised into productivity, investment impact, labour absorption, income distribution, and stability (Roth and Haase, 1998). It produces a diversity of crops and animals ranging from maize, groundnuts, cowpea, coffee, soybeans, sunflowers, barley, wheat and cotton to cattle, sheep, goats, pigs and chickens (Rukuni *et al*., 1994). Horticultural crops like flowers, fruits, citrus, and vegetables are also produced to earn foreign currency. The recent performance of South African agriculture has declined in such a way that it only contributes 3% to gross domestic product (DAFF, 2010).

2.2 Operation of the irrigation schemes

In line with the global irrigation development that occurred mainly during the 20th century (Turral *et al*., 2010), the area under irrigation in South Africa increased from 0.23×10^{6} ha in 1909 (Scotney and Van der Merwe, 1995) to 1.2×10^{6} ha in 1991(Bruwer and Van Heerden, 1997), About 30% of irrigated land was located in state irrigation schemes, 30% in schemes controlled by irrigation boards and 40% in private irrigation farms (Vaughan, 1997). The South African Government has rendered considerable support to irrigation development by providing subsidies to state irrigation schemes and irrigation board schemes. Several large state schemes were developed during the 1930s when South Africa was affected by severe drought and economic depression.

State irrigation schemes were created to increase food production, insure agriculture against drought, establish new owner-operators in the farming sector, provide rural employment opportunities and develop new settlements (Backeberg and Groenewald, 1995). Public funds were used to pay for the full capital development of state schemes and also for partial payment of the operation expenditure (Backeberg and Groenewald, 1995), whilst irrigation board schemes received one third of the capital cost as a state subsidy (Vaughan, 1997).

During most of the 20th century, South African social policies of racial segregation and separation benefitted whites (Beinart, 2001). Irrigation development was no exception and the lion's share of irrigation schemes was established for the settlement of white farmers (Bruwer and Van Heerden, 1997; Backeberg and Groenewald, 1995). Moreover, irrigated holding of White farmers, which ranged between 8 to 20 ha (Van Averbeke, 2008), were on average about 10 times larger than the 1.5 ha plots allocated to black farmers explains why in South Africa, the term 'smallholder irrigation scheme' is commonly used to refer to irrigation schemes in which the land is held by Black people (Machete *et al*., 2004).

According to Van der Stoep (2006), smallholder irrigation schemes in South Africa are of secondary importance in terms of land area and farmer participation. In 2010, smallholder irrigation schemes covered 47 667 ha, compared to the 1 675 822 ha of registered irrigated annually ((Van Averbeke *et al*., 2011). The total population of 34 158 plot-holders on smallholder irrigation schemes in 2010 was also relatively small compared to the 1.3 million Black homesteads that had access to land for cultivation (WRC, 2011). In these areas, irrigated farming has the potential to contribute significantly to food security and income of participating homesteads (Lipton *et al*., 1996; Bembridge, 2000; Van der Stoep, 2006) and to create employment both directly and through forward and backward linkages to primary production.

According to WRC (2011), irrigation schemes are failing to provide high yields and are affected by a whole range of problems such as technical, management, training, agricultural policy and lack of finance. Yet in South Africa, the increase in food output can partially be achieved by a rise in the number of irrigation schemes and the rehabilitation of abandoned ones. It is imperative, therefore, to develop a strategy for improvement of schemes which encompasses not only the technical and economic aspects but also the participation and training of the farmers involved.

In 1992, the WRC commissioned a second study aimed at providing a comprehensive overview of smallholder irrigation in South Africa. This investigation, conducted by De Lange (1994), indicated that there were probably about 150 000 Black irrigators in the country, comprising three broad groups, namely:

i. Independent irrigation farmers, who privately accessed and applied water to their farms
ii. Holders of allotments on irrigated community gardens
iii. Plot-holders on smallholder irrigation schemes.

Du Plessis *et al*. (2002) added a fourth group comprising backyard or home-garden irrigators, who watered crops on parts of their residential sites. There was general agreement that, when combining the groups, Black irrigators farmed on about 100 000 ha and that half of this irrigated area was located on smallholder irrigation schemes (Backeberg and Sanewe, 2010; Bembridge, 1997; Vink and Van Rooyen, 2009). This made smallholder irrigation schemes the most important in terms of irrigated area. International Programme for Technology and Research in Irrigation and Drainage (IPTRID) (2000) reported that in 1999, the combined area covered by the 2 635 irrigated community gardens in KwaZulu-Natal amounted to 2055 ha. Extrapolating this figure to the nine provinces would suggest that nationally, irrigated community gardens covered between 10 000 ha and 20 000 ha. By implication, the area farmed by independent irrigation farmers and home garden irrigators would be of the order of 30 000 ha to 40 000 ha.

IPTRID (2000) reported that on average, irrigated community gardens in KwaZulu-Natal had a membership of 19 gardeners, small irrigation projects. This lends support to

Backeberg (2006), who indicated that the total population of Black irrigators in South Africa could be as high as 250 000.

For nearly 20 years, smallholder irrigation schemes have been one of the focal points of agricultural water research initiated, funded and management by the WRC. Not all research on South African smallholder schemes has been conducted under the auspices of the WRC. Universities (Bembridge, 1984; Rossouw, 1989) and other organisations such as the International Water Management Institute (Shah *et al*., 2002), also made important contributions however, the body of knowledge produced by the WRC stands out for its coverage, depth and attention to practical application.

Water, food, poverty and urbanisation have strong impacts on food security. Urbanisation leads to tightening competition over scare water resources. Growing cities and industries demand more water and as they can also pay more for water, agriculture is losing its share of water resources in the competition. In order to secure water and food for the future's population, agriculture must use water more efficiently that is producing more crops per litre of water (Karkkainen, 2002). The challenge of making irrigation more efficient cannot be answered on the basis of the Green Revolution (Postel, 1999) as cited by Ntsonto, 2005).

Now, after the Green Revolution decades, some 50 - 70% of the world's irrigation schemes are in need of repair (Postel, 1999; Karkkainen, 2002). The large-scale schemes are often also badly maintained and managed (World Bank, 2005). The Green Revolution development was not sustainable because the principle of the Green Revolution was to increase the production per unit area whilst regarding water as a public good (Karkkainen, 2002).

A new concept of ‘Blue Revolution ‘has emerged and according to Karkkainen (2002), Blue Revolution will be more difficult than the Green Revolution of the past because, there is no obvious, off-the-shelf package available to raise water productivity. This new challenge will require a more diverse and creative mixes of strategies that make agriculture more information intensive and less resources intensive by substituting technology and better management for water. It will require thinking systematically because water performs many different functions as it flows through the landscape toward the sea.

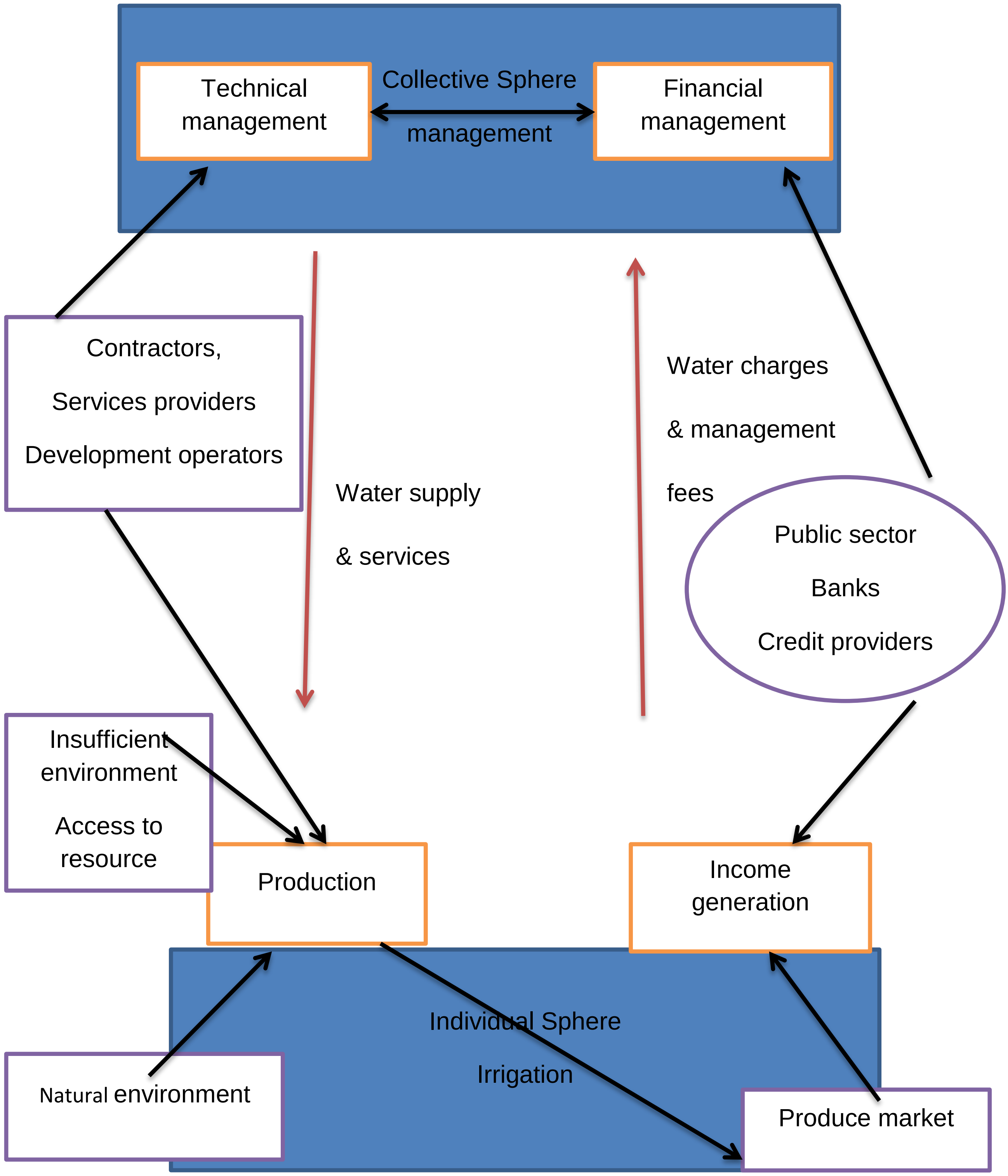


Figure 2.1: Operation of an irrigation framework

Source: Perret (2002) as cited by Ntsonto (2005).

Figure 2.1 represents the framework for irrigation scheme's operation. This framework attempts to integrate the different dimensions, stakeholders and functions that take place in a scheme's operation.

It is a conceptual framework and an analytical framework as well as providing guidelines for multidisciplinary and comparative analysis and stimulates participation among different stakeholders (Ntsonto, 2005). The management of a scheme involves three types of stakeholders: the individual farmers, the management entity and external role players. These can be the public sector (government, provincial authorities), contractors and service providers, banks and the marketing or food-processing sector. All provide financial or technical support to the management entity and/or to the farmers at different irrigation schemes.

Farmers manage production at farm level; possibly market the products, which in turn generates income. The natural environment influences the production process (e.g. climate, soils, weeds, pests and hail). The institutional context also impacts on production, especially the rules on accessing resources such as land tenure, inner water-sharing features and water rights). Farm income influences production, since it defines the level of intensification. Finally, contractors and service providers, the public sector (extension) also influence the production process (Ntsonto, 2005).

According to Ntsongo (2005), the management entity (a corporation or an irrigation board in the past, a water users' association nowadays) provides irrigation water and related-services to the farmers, for them to produce (see figure2.2). It technically manages, operates and maintains the scheme as a whole. There are costs incurred by such management. This supposes a financial management. Funds are collected from the farmers and managed at the scheme level. Four major functions may be identified within a scheme: production (farmers), water supply and Water Users Association (WUA), finance (WUA) and commercialisation/ input supply (farmers and possibly WUA). These functions generate a number of flows and transfer: water (between WUA and farmers), money (between farmers and WUA, between markets and farmers), products (between farmers and markets), services (between providers and the scheme, between WUA and farmers). Such transfers are conditioned by proper information circulation between all parties. The whole process is illustrated in figure 2.2 from land use to economic viability at farm and scheme level.

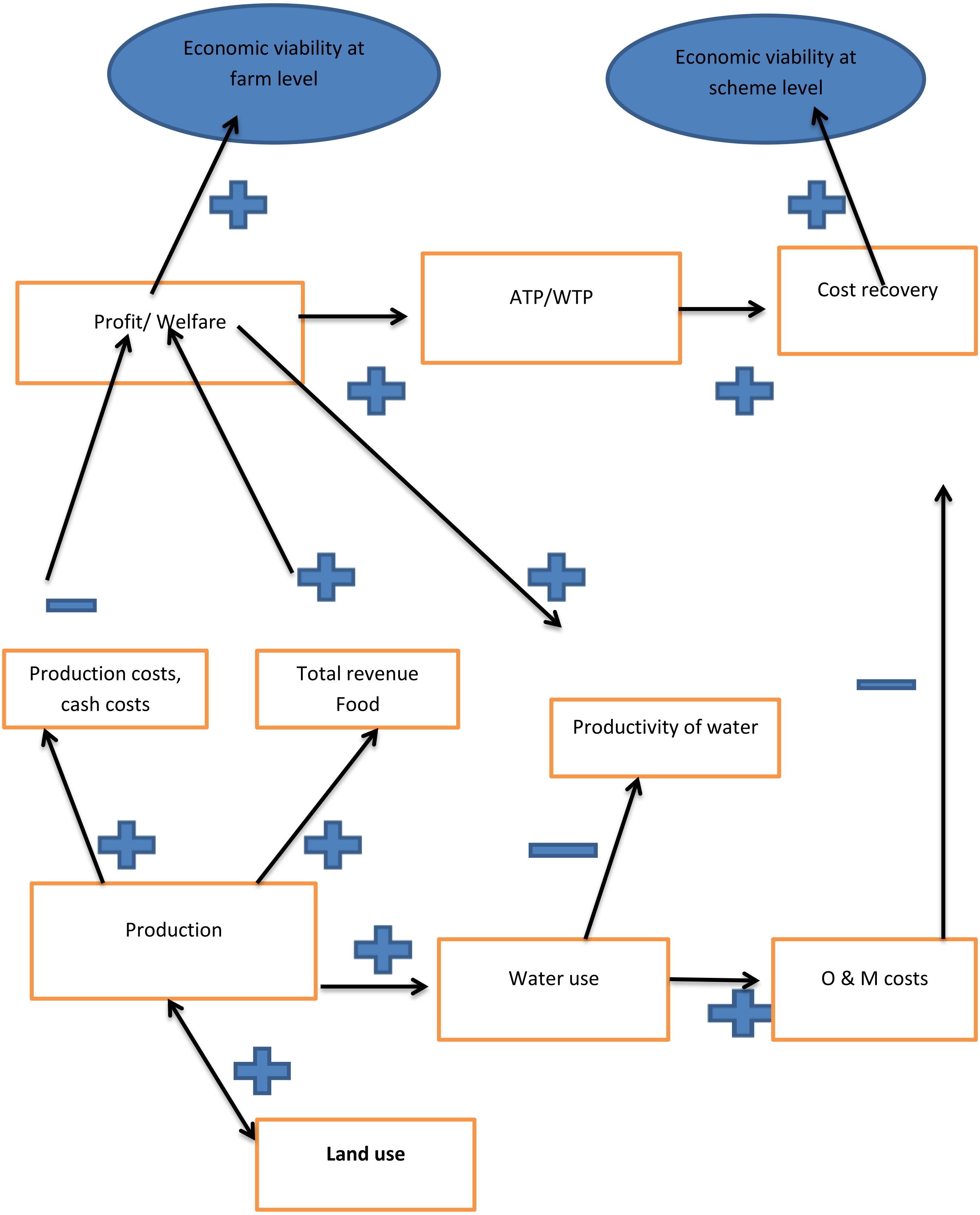


Figure 2.2: The smile approach

Source: Perret (2004)

The economic and social output from irrigation projects is often lower than estimated at the planning stage (Da Silva *et al*., 2001). In the report which evaluated more than 200 irrigation schemes subsidized by the World Bank, for example 23% were rated unsatisfactory (Jones, 1995). Freeman and Lowdermilk (1991) argued that many accounts of irrigation projects reported failure to meet estimated agricultural production targets, poor maintenance and disappointing economic returns on investments.

The future alternative water supplies for irrigation will have to be carefully developed and managed (Smith and Maheshwari, 2002). Another related issue is that the way farmers manage water affects the long-term sustainability of their farms. There is now greater demand to share water resources with the environment. As a result landholders need to consider the options available to them to meet their irrigation water needs (Smith and Maheshwari, 2002).

The significant changes in water policies are being implemented in South Africa (Perret, 2002). These changes will lead to increased contribution by farmers to costs and reduced availability of water for irrigation (Smith and Maheshwari, 2002). In general, the changes will require irrigators to improve water use efficiency and look for alternative water supplies. In the case of South Africa water reform (Act 36 of 1998) will play a large role in driving this.

Among the key outcomes of the Earth Summit were the recommendations that water should be treated as an economic good (with a property right attached to it), that water management should be decentralised and that farmers and stakeholders should play an important role in the management of natural resources including water (Vermillion, 1997 as cited by Ntsonto, 2005). Early efforts to IMT from the government to farmer's organisation occurred in the USA, France, Colombia and Taiwan from 1950s through the

1970s (Vermillion, 1997). Irrigation Management Transfer became a national strategy in most developing countries only in the 1980s and 1990s.

According to Ntsonto (2005), It has remained to be seen whether (IMT) can simultaneously save money for the government, bring about more cost-efficient management for the farmers and achieve financial and infrastructure sustainability (Vermillion, 1997). In developing countries, most post-transfer organisations tend to be water users' associations that take over O&M (Operation and Maintenance) responsibility directly, at relatively small-scales (see figure 2.2). But policy encourages farmers to defer maintenance. Neither post-transfer management entities nor individual farmers have clear or measurable water rights. This uncertainty may inhibit farmers from investing more fully in the long-term maintenance and improvement of their irrigation systems (Vermillion, 1997).

There are some clear common trends in most of countries. In those countries where IMT has not been initiated, it is one of the main objectives of development policies for the coming years along with modernisation or rehabilitation of the schemes (FAO, 2007). Besides, there is a tendency to consolidate the existing users associations through institutional strengthening programmes aiming at financial sustainability, technical assistance, training and extension for users and technicians. Additionally, work is being done to determine irrigation water charges and collection. In most arid and semi-arid zones, increase in irrigated land will require efficiency improvement in conveyance, distribution and application as well as more efficient use of water by plants (Byerlee and Murgai, 2001).

Despite the success of irrigation in supporting the green revolution, irrigation schemes have often under-performed in economic terms and field research has highlighted substantial shortcomings in management (Operation and maintenance), equity, cost-recovery and agricultural production (Johnson *et al*., 2002). Public investment in irrigation development tailed off during 1980s as fiscal constraints set in, internal and external funders become disillusioned with the economic performance of previous investments. Further, growing environmental concern over the impacts and costs of large water development projects has stimulated more interest in the careful use of water than in simply increasing its supply.

Disappointing performance of state-owned and operated irrigation systems have compelled a number of countries to transfer rights and responsibilities for management of irrigation systems from government agencies to private or local persons or organisations (Wijayaratna and Vermillion, 1994; Svendsen, 1992). Transferring responsibilities has come to be seen as a way to reduce pressures on thinly stretched government finances, while at the same time improving irrigated agricultural production and ensuring the long-term sustainability of irrigation systems (Lipper, 2001). The intention is to encourage efforts by individuals to take responsibility for the management of resources in the belief that individuals have greater stake and better information for making efficient resource allocations (Bruwer and Van Heerden, 1997). Irrigation officials insist that the primary concern behind encouraging irrigation management transfer is to improve water use efficiency. Irrigation must provide a wide range of users with on-time, adequate and equitable supply of water at least cost. To achieve this goal, irrigation institutions need to adopt a service orientation and improve their performance in different areas. At global level there is a need to produce more food with the same amount of water, improve water resources management and contribute to the well-being of rural inhabitants that constitute most of the poor people in developing countries.

2.3 The three management organisations of the irrigation schemes considered for this study

It is of paramount importance to briefly define each of the three irrigation management organisations of the irrigation schemes considered for this study. Integrated Water Management Organisations are characterized by an integrated organisational structure where all development activities are undertaken by specialized units which are all connected by a clear line of command and finally responsible to a single person (project manager) or committee. There are several types of integrated management organisations depending on degree of the control by government and farmers in the management of the schemes (Lecler, 2003). In cases where project is run by the farmer it usually adopts the structure of a service cooperative, whereas in case where government officials fully control the organisation there are two possibilities depending on the size of the production units: State farm (large production units) and Irrigation settlement projects (Small production units).

Another distinctive feature of these irrigation projects is that most of the farmers involved are relatively wealthy. This is almost a precondition because of the high cost of irrigation infrastructure. Although part of the needed funds can be obtained through loans, it is apparent that such credit must be backed by the strong payment capacity of farmers. The organization of an irrigation cooperative depends greatly on the kinds of contributions made and the services needed by project members. The organisational structure is similar to that of the irrigation association which is described later in the proposal. The rules and regulations governing the activities of the cooperative are established within the framework of the South African laws for cooperatives (Lecler, 2000).

A specialized water management organisation can be broadly defined as a social organisation aiming at an appropriate use of water for irrigation purposes among the farmers in the community. The term “appropriate” is used here to designate a timely and equitable distribution of water. It is normally part of segregated organisational structures of irrigation schemes. The functions of specialized water management organisations are: the operation of the irrigation and drainage systems, maintenance of the systems, assessment and collection of water charges. They are supported by certain general management services (finance, personal, planning and monitoring).

The degree of intervention by the government and the farmers in undertaking the functions described above indicates the main types of specialized water management organisations, which are: Organisations mainly controlled by farmers (Irrigation Schemes Associations), Organisation mainly controlled by government officials (Public Irrigation Schemes) and Organisations with mixed control by farmers and government officials i.e. schemes where the main irrigation system is managed by government officials while the tertiary canals are controlled by farmers’ associations (Lecler, 2000).

A multipurpose water management organisation is characterized by having responsibilities directly related to water management and some others which may include irrigation extension, research, water quality management, marketing (Lecler, 2003). These responsibilities should be the results of a careful examination of what is needed in the project that cannot be effectively provided by existing institutions. It represents a suitable solution since is using the nucleus of a water management organisation and adds only those activities that are most needed and are not done by any other existing institution.

Multipurpose organisations basically take the structure of public irrigation schemes, where the relevant new activities are added. They have been designated here as multi-purpose public irrigation schemes (MPIS). Typical added functions are: irrigation assistance to farmers, applied irrigation research, irrigation improvement service and water quality management. Sometimes a MPIS may also take responsibility for the establishment of some physical infrastructure aimed at improving marketing (stores, processing plants, and markets), provision of inputs (fertilizers, seeds, etc.) or credit facilities, depending on the specific needs of the project area. While the establishment of the first group of functions (formative and training nature) is strongly favoured in many instances, the second group must be restricted to very specific situations and only if they cannot be undertaken in the near future by any existing institution (Lecler, 2000).

The literature on this section is very limited since the criteria chosen to classify the institutional arrangement of the irrigation vary from literature to literature. The above three types of management practices of the irrigation schemes i.e. integrated, specialised and multipurpose water management practices are not popularly known and the documentation of those concepts are very limited.

2.4 General review of efficiency studies on Agriculture worldwide

Adesina and Djato (1997) used profit function to estimate relative efficiency of women as farm managers in African agriculture. Results showed that the relative degree of efficiency of women was similar to that of men. The results provided support for efforts to eliminate bias against women farmers in African agriculture.

Ahmad *et al*. (2002) estimated technical efficiency of rice farmers in Pakistan Punjab using Cobb Douglas stochastic frontier production function. An average technical efficiency of farms of 85% was estimated and it was also found that extension services and the availability of agricultural credit could improve technical efficiency.

Ahmad *et al*. (2002) adopted a stochastic production frontier analysis to estimate wheat productivity, efficiency and sustainability in Pakistan. The results showed that the average technical efficiency was about 68% showing that an average farmer could increase wheat production by 32% with available resources. Farm size, credit and location of market were found to be negatively related to technical inefficiency.

Ahmad (2002) estimated different input elasticities of production for poor and non-poor farms using the stochastic frontier production function. The average cost of the existence of technical inefficiencies was about 43% in terms of loss in output, ranging from 17 to 62%. The salinity problem and the tail end location of the plot adversely affected farm productivity and efficiency.

Ajibefun *et al.* (1996) investigated the factors that influenced the technical efficiency (TE) of smallholder croppers in Nigeria. They used the translog stochastic frontier production function instead of the Cobb-Douglas frontier function because the latter was not an adequate representation of their data. The estimated technical efficiency of the sample farmers varied widely, ranging from about 19% to 95%. The results from the same study also indicate that the technical inefficiency of production of farmers is significantly related to age and farming experience of the farmers, farm size and the ratio of hired-labour to total labour used. The inefficiency of these smallholder farmers was not significantly related to the size of farming operations for the farmers involved.

Ali and Flinn (1989) used a stochastic profit frontier of modified translog type for basmati rice farmers in Pakistan's Punjab. Factors significantly contributing towards profit losses included level of education, off-farm employment, unavailability of credit and various constraints associated with irrigation and fertilizer application.

Ali and Byerlee (1991) compared agricultural production efficiency in four irrigated cropping regions of the Punjab province of Pakistan using probabilistic frontier production function using whole farm survey data for the year 1984 -1985. They found that the gross income of farmers could be increased by 13% at the current levels of resource use, thus increasing profits by up-to 40%. This highlighted the need for strengthening the existing extension services to exploit the potential of the available farm technology.

Alimi (2000) determined important factors affecting economics of mono-cropping okra under tropical conditions during the rainy and dry seasons in Nigeria. Results showed that okra producers were similar in socio-economic characteristics in both areas. However, farmland and entry level capital requirements were higher in dry area as compared to rainy areas and profits were also higher in dry areas. Low output prices and high perishable nature of vegetables in rainy season were the highest ranked constraints in okra production.

Alvarez *et al*. (2004) proposed a procedure to incorporate cross-sectional information in the estimation of technical efficiency indexes obtained from panel data. According to Alverez *et al*. (2004), conventional index of technical efficiency was estimated in a first stage using panel data on inputs and outputs. The individual effects from the first stage were then adjusted using cross-sectional information, obtaining a corrected technical efficiency index. The model was applied to a panel of eighty-two Spanish dairy farms, where only cross-sectional information about input quality was available. Analysis of variance was performed between some variables and both the corrected and the uncorrected indexes. The findings that the conclusions derived from the two analyses were different.

Alvarez *et al*. (2004) explored the relationship between milk quota values and economic efficiency in order to analyse government interventions in quota allocations among producers. For this purpose, they estimated quota values using a panel of Spanish dairy farms. They found that efficiency was important in explaining quota values but was uncorrelated with observable farm characteristics.

Amara *et al*. (1999) used a deterministic statistical frontier production function to estimate the Quebec potato farmers' technical efficiency. Results showed that the average potato farm was 80% efficiency, implying that potato production could be improved to some extent. Farming experience and the adoption of conservation technologies were both significant variables for increasing technical efficiency.

Ashraf *et al*. (2006) reported data on total costs per acre of various vegetables using a small sample of 150 farmers. However, this study did not provide much detail on individual cost items, such as seed, fertilizer, irrigation, plant protection measures and labour.

Bailey *et al*. (1989) used a stochastic frontier production to estimate technical, allocative and scale inefficiencies for cross-sectional data on 68 Ecuadorian dairy farms. The technical inefficiencies of individual farms were about 88%. However, little variation in technical efficiency was found among individual farms.

Bakhsh (2002) worked out economics of growing winter vegetables in Multan district of Punjab, Pakistan. Vegetables included carrot, radish and turnip. Results showed that labour was important constituent of total cost in vegetable cultivation. Higher share of labour in total cost was reported in cauliflower, followed by carrot and turnip. Average gross income was higher in cauliflower (R35 592.75) as compared to carrot (R17 633.20) and turnip (R15 732.03). Net income per kilogram was estimated to be R0.96, R0.43 and R0.38 for cauliflower, turnip and carrot, respectively. Cost of production per kilogram in growing vegetables was worked out to be R1.30, R1.29 and R0.81 for cauliflower (R1.74) followed by turnip (R1.53) and carrot (R1.29).

Bakhshoodeh and Thomson (2001) determined input and output technical efficiencies of wheat production in Kerman, Iran. For that study, they used a Cobb-Douglas frontier production function to establish a simple relationship between a farm-level output-based technical efficiency measure and an input-based measure. The respective average efficiencies were estimated at 0.93 and 0.91, implying that there was limited scope to increase the profitability of Iranian wheat production either by increasing the product, given input levels or by decreasing inputs for the current level of wheat production.

Battese and Tessema (1993) adopted two models of technical inefficiency with stochastic production frontier to wheat crop using data of four districts of Pakistan. The results indicated that frontier was shifting out over time. It was also found that technical inefficiency was declining in the districts of Faisalabad and Badin. Adoption of new technology and better extension services to wheat producers were the important factors in improving the efficiency.

Battese (1992) adopted a stochastic frontier production function model to estimate technical efficiency of paddy farmers in India. They found that the stochastic frontier was not significantly different from the traditional average response function.

Battese and Coelli (1995) used a single stage stochastic frontier production function to estimate technical inefficiency and its determinants in wheat production in Pakistan. Only the coefficient of labour was found statistically insignificant and it was estimated that the older farmers with better education were less technically inefficient.

Battese and Broca (1997) adopted translog and Cobb Douglas production function to determine technical efficiency for wheat farmers in four districts of Pakistan. Different hypotheses were tested and the Cobb Douglas was preferred over translog model. The mean technical efficiency ranged from 50 to 100%.

Battese (1998) investigated the efficiency of cotton farmers in Vehari district of Punjab, Pakistan. The data was analysed using a stochastic frontier production function model, in which technical efficiency effects are assumed to be a function of other observable variables related to the operation. A questionnaire was used to collect details about operation of the farms especially varieties grown, yields obtained, the use of inputs like fertilizers, seeds and pesticides. The sample size was 45 and the predicted technical efficiency of those cotton farmers ranged from 0.699 to 0.991, with the mean technical efficiency estimated to be 0.930. This implies that on average they were producing cotton to about 93% of the technology being used. The empirical results also indicated an increase in land area under cotton would results in greater productivity of cotton for the farmers.

Battese and Hassan (1999) estimated technical efficiency of cotton growers using a stochastic frontier production function model. Technical inefficiency of cotton production tended to decrease for farmers who first irrigated their crops later and who performed rogging, but inefficiencies tended to increase with more inter-culture operations.

Binam *et al*. (2004) examined factors influencing technical efficiency of groundnut and maize farmers in Cameroon. They used Cobb-Douglas production function to find mean technical efficiencies to be in the region of 73% and 77%. They also concluded that access to credit, social capital, and distance from the road and extension services are important factors explaining the variations in technical efficiencies.

Brada and King (1993) estimated technical efficiency of private and state farms in Poland using a frontier production function. Results indicated that on average, the technical efficiency of state and private agriculture was not different. They concluded that the internal organisation of socialised farm units did not make them inherently less technically efficient than private farms. It was found that state farms were allocatively inefficient, with oversupplied fertilizer and machinery.

Bravo-Ureta and Rieger (1990) used deterministic and stochastic frontier production functions for a large sample of dairy farms in the North-eastern State of the United States of America for the year 1982 and 1983. The appropriate functional form was found to be Cobb Douglas functional form. The parameters of the deterministic frontiers were estimated by linear programming, corrected ordinary least squares regression and maximum likelihood techniques. The estimated technical efficiencies of farms obtained from the three different methods used for the deterministic model were generally less than those obtained by use of the stochastic frontier model.

Bravo-Ureta and Rieger (1991) adopted a stochastic model to estimate technical, economic and allocative efficiency. Data from a sample of New England dairy farms was used for the purpose of this study. The results depicted that mean economic efficiency for the farmers in the sample was about 70%. On average, little difference was found between technical (83%) and allocative (84%) efficiency. Farm size, education, extension and experience were significantly related to the level of efficiency.

Bravo-Ureta and Evenson (1994) acknowledged that most studies on efficiency do not go beyond the measurement of technical efficiency in the developing country's agriculture. In their study they used the stochastic efficiency decomposition methodology to derive technical, allocative and economic efficiency measures separately for cotton and cassava for peasant farmers in eastern Paraguay. They found an average economic efficiency of 40.1% for cotton and 52% for cassava, which shows that there is considerable room for improvement in the productivity of the farms sampled.

According to Brinkman (1998), due to imperfect markets and policy distortion in some countries in Africa, the evidence of inverse relationship between farm-size and productivity is more mixed than elsewhere in the world. Brinkman (1998) argues that large farms have often been more profitable, particularly in Eastern and Southern Africa.

Burki and Shah (1998) determined technical efficiency of farms in irrigated areas of Pakistan’s Punjab using stochastic frontier production approach. Translog variable cost frontier was estimated and it was found that technical inefficiency raised the cost of average sample farms by 24%. Farm efficiency was found to be positively related to formal schooling of farmers, abundance of canal water and head reaches of mogha while negatively related to farm size.

Burki and Terrel (1998) determined technical and scale efficiencies of small manufacturing firms in Pakistan using Data Envelopment Analysis (DEA). It was estimated that output could be increased by 6 to 29% by improving technical efficiency. Education and experience were found to be positively affecting technical efficiency.

According to Byiringiro and Reardon (1996), smaller farms were found to have greater average and marginal land productivity than the large farms. The smaller farms were less allocatively inefficient. They also revealed that, the marginal value product for land on smaller farms to be well above the rental land price.

Chavas *et al*. (2005) investigated the economic efficiency of farm households at the household level, with an application to the Gambia. Technical efficiency, allocative efficiency and scale efficiency were estimated using non-parametric measurements. Results revealed that the mean technical efficiency measure at the household level ranged from 0.895 to 0.995. Tobit model was used to determine technical inefficiency model and results showed that incidence of herding, food security, loans/withdrawals and land tenure security were significantly negatively relate with technical efficiency.

Coelli (1995) used Monte Carlo experimentation to investigate the finite sample properties of the maximum likelihood (ML) and corrected ordinary least squares (COLS) estimators of the half-normal stochastic frontier production function. He suggested that ML should be used in preference to COLS. A one-sided likelihood ratio (LR) test and a test of the significance of the third moment of the OLS residuals were suggested and were found to have the correct size with the one-sided LR test.

Coelli *et al*. (2002) estimated technical, allocative, cost and scale efficiencies in Bangladesh rice cultivation using a nonparametric approach. For the dry season, mean technical efficiency was 69.4%, allocative efficiency was 81.3%, cost efficiency was 56.2% and scale efficiency was 94.9%. The wet season results were similar with a few points lower. Inefficiency effects model results showed that large families were more inefficient, whereas farmers with better access to input markets and doing less off-farm work were more efficient.

Dawson and Lingard (1989) adopted a Cobb Douglas stochastic frontier production function to estimate technical efficiency of Philippine rice farmers using four years of data. Comparison was made between estimates of stochastic frontier method and deterministic method. The individual technical efficiencies were in the range of 10 to 99% with the means between 60% and 70% for the four years involved. The four stochastic frontiers estimated were significantly different from the corresponding deterministic frontier.

Dawson *et al*. (1991) calculated farm-specific technical efficiency over time for rice farms in Central Luzon, the Philippines and using stochastic frontier production function. Results showed that technical efficiency ranged from 84% to 95% with little variation across the twenty-two farms, so limited scope existed for increasing output by resource allocation.

Demir and Mahmud (2002) estimated the technical inefficiency model for Turkey using a translog frontier production function with agro-climatic variables such as rainfall and land quality and it was found that the agro-climatic variables were statistically significant and their omission substantially affected mean output elasticities and relative technical efficiencies.

Dev and Hossian (1995) estimated the farm specific technical efficiency of rice farmers. Technical efficiency estimation showed that technology had significant positive contribution to technical efficiency in rice production while farmers' education had no significant contribution.

Dhungana *et al*. (2004) studied the economic, technical, pure technical, scale and allocative inefficiencies of Nepalese rice farms. Data envelopment analysis approach was adopted to estimate these efficiencies. Results indicated that average economic, allocative, technical, pure technical and scale inefficiencies were 34, 13, 24, 18 and 7% respectively. Seed, labour, fertilizers and mechanical power contributed towards the significant variations in the level of inefficiency across sample farms. Inefficiency model was determined using a second stage Tobit regression model. Results revealed that farm-specific attributes such as the farmers' level of risk attitude, the farm manager's gender, age, education and family labour endowment were associated with the variation in the efficiency.

Dorward (1999), found a positive relationship between farms size and farm productivity in both labour-scarce and land-scarce smallholder farming in Malawi. The study established that the absence of an inverse relationship can be explained in terms of failures in capital and produce markets with acute capital constraints, which affect both capital and labour inputs on smaller farms.

Ekanayake and Jayasuriya (1987) used Cobb Douglas type production function to determine technical efficiency in an irrigated area in Sri Lanka. Both deterministic and stochastic frontier production functions were used. Maximum likelihood and corrected ordinary least squares methods were adopted to estimate the parameters of the two frontiers. In only the 'tail reach' irrigated area, the stochastic frontier appeared to be significantly different from the deterministic model. Nevertheless, the estimates obtained for the farms in the 'head reach' area were vastly different for the two different stochastic frontiers.

Fare *et al*. (1985) investigated the improved production technology and efficiency of small holder farmers in Ethiopia. The study indicated a positive impact of improved maize technology on maize production efficiency; the results of the study indicated that there are inefficiencies of maize production under both traditional and improved technology. Production efficiency in traditional maize production is attributed to more technical efficiency. Improvements in technical efficiency provide greater opportunity to increase maize production. Production inefficiency is equally attributed to both technical and allocative inefficiencies. Both technical and allocative efficiencies must be raised to increase maize production under improved technology.

Fraser and Hone (2001) determined farm-level efficiency and productivity estimates of Victorian wool producers using an eighty year balanced panel data. DEA and Malmquist estimates of total factor productivity were used. It was found that farms changed their relative rank in terms of efficiency across years.

Gorton and Davidova (2004) studied farm efficiency in six Central and East European countries. They estimated productivity and efficiency of farms managed by family setting and corporate structures and the nature of the relationship between size and farm efficiency. Results showed that there was no clear indication that corporate farms were inherently less efficient for all farming activities than family farms. Significant differences had been found in favour of family farms against the average corporate farms. It was also found that the best corporate farms tended to perform as well as the best family farms. As far as size was concerned, corporate farms were less inefficient compared to larger cohorts as against countries where small family farms were a relatively new phenomenon.

Hadri and Whittaker (1999) used stochastic frontier production functions to ascertain the relationship between farm size, technical efficiency and the use of agrochemicals potentially contaminating environment, using farm data from the South West of England for the year 1987 to 1991. They estimated a positive relationship between technical efficiency and use of contaminants and between technical efficiency and farm size. It was observed that the more efficient farms were larger farms and used a higher volume of environmental contaminants.

Hailu *et al*. 2005) used two non-homothetic translog stochastic meta-frontier cost functions using a non-linear maximum likelihood estimation procedure to compare the cost efficiency of Alberta and Ontario dairy farms for the period 1984 to 1996. Average cost efficiency for the pooled sample was approximately 89% indicating that there existed some potential for improvement in dairy farms.

Hassan (2004) estimated technical efficiency of wheat farmers in the mixed farming system of the Punjab, Pakistan using stochastic frontier production function incorporating technical inefficiency effects model. The Cobb Douglas production function was found to be an adequate representation of the data, given the specification of the corresponding translog frontier model. The mean predicted technical efficiency of wheat farmers was 94% and it was estimated that the wheat growing farmers were operating at constant return to scale. Area under wheat crop, weedicide cost, number of cultivation and fertilizer were found to be responsible for increased wheat production, whereas the results of the inefficiency model depicted that the technical inefficiency could be reduced by sowing the crop in time, increasing education of the farmers, providing credit to the farmers and sowing the crop by drill method. However, shortage of canal water was found increasing technical inefficiency in the mixed farming system of Punjab.

Hazarika and Alwang (2003) used data from the Malawi financial markets and household food security survey to examine the effects of access to credit from formal sources and tobacco plot size, on cost inefficiency among Malawian smallholder tobacco cultivators. Farm-specific cost efficiency was estimated using stochastic frontier model. It was found that tobacco cultivation was significantly less cost inefficient per acre on larger plots. While access to credit by itself had no statistically apparent effect on cost inefficiency and it reduced the gain in cost efficiency from a larger plot size.

Helfand and Levine (2004) explored the determinants of technical efficiency and the relationship between farm size and efficiency in the Centre-West of Brazil. Technical efficiency was studied with DEA. Non-linear relationship was estimated between farm size and efficiency, with efficiency first falling and then rising with size. Type of land tenure, access to institutions and markets and modern inputs were found to be important factors causing differences in efficiency across farms.

Heshmati and Mulugeta (1996) estimated the technical efficiency of Uganda matoke producing farms and found that they face decreasing returns to scale with mean technical efficiency of 65%. On the other hand, they found no significant variation in technical efficiency with respect to farm sizes.

Himayatullah (1995) estimated relative technical efficiency in Barani agriculture by farm size and tenancy status. He found that large farms were technically more efficient than small farms. Nevertheless, medium farms were relatively technically more efficient than both small and large farms. The then study further concluded that owner-operated farms were more efficient than both tenant and owner-cum-tenant operated farms.

Huang *et al*. (1986) used a stochastic profit function approach to investigate the economic efficiency in two states in India. Efficiency of small and large farms was estimated. Results indicated that individual farm economic efficiencies were greater for large farms than small farms. The average economic efficiencies were 84% and 80% for large and small farms respectively, indicating plentiful scope to increase profit of both large and small farms with available resources and technology.

Hussain (1999) estimated the technical, allocative and cost efficiencies of the cotton growing farmers in four districts of Punjab. Both parametric approaches were employed. The mean values of technical, allocative and cost efficiencies for stochastic frontier production function and DEA were approximately similar. Farmers' education, extension service and credit facilities were found to decrease technical inefficiency in cotton production.

Johnson *et al*. (1994) estimated production efficiency in Ukraine using farm level panel data and found decreasing technical efficiency in crop production. Factors such as management structure resource base and different policies on capital and other input allocation were contributing towards wide variability in the technical efficiency of farms.

Jaforrullah and Whiteman (1999) measured the scale efficiency of the New Zealand dairy industry. DEA was applied to a sample of 264 dairy farms. Overall technical efficiency was 83% with a minimum of 39%.

Kalaitzandonakes and Dunn (1995) argued that conflicting empirical results on the relationship between technical efficiency and education would be in part attributable to difficulties in the measurement of key variables. Calculation of technical efficiency with three alternative frontier methods (COLS, ML and DEA) for a sample of Guatemalan corn farms was made. Results showed significant differences both in the average technical efficiency of the sample and the efficiency rankings of individual farms. Furthermore, following two-step procedures, it was shown that the choice of efficiency measurement technique could alter the importance of education as a contributing factor to increased technical efficiency.

Kalirajan and Shand (1986) studied the technical efficiency of rice farmers within and without the Kemubu irrigation project in Malaysia during 1980. Maximum likelihood methods were used for estimation of the parameters of the models and it was found that the frontiers for the two groups of farmers were significantly different. Given the specifications of a translog stochastic frontier production functions for the output of the rice farmers, the Cobb Douglas model was found inappropriate model for the given data. Results showed that the individual technical efficiencies changed from 40 to 90%. Results indicated that the effect of introduction of new technology had not increased technical efficiencies significantly compared to those using traditional technologies. Results of the study revealed that introduction of new technology is a continuous process and it takes time to give expected returns.

Kalirajan (1989) estimated technical efficiencies of individual farmers engaged in rice production in two regions in the Philippines in 1984 - 85. A Cobb-Douglas stochastic frontier model was found to be more appropriate. The predicted technical efficiencies were regressed on several farm and farmers-specific variable to determine the extent of effects of variable in the variation of technical efficiencies.

Kalirajan (1990) used translog frontier production function to estimate economic efficiency of rice farmers in the Philippines. The study adopted a system consisting of a production frontier and factor share equations to estimate firm specific technical efficiency and input-specific efficiency and input specific allocative efficiency simultaneously. The technical efficiency estimates ranged from 64% to 92%. It was found that the sample participants were allocatively inefficient with respect to all the inputs whereas theoretically acceptable signs for all production elasticities were estimated.

Kebede (2001) assessed various distributional assumptions made on the estimation of stochastic frontier models and compared estimation results for technical efficiency. According to the author, maximum likelihood estimates of technical efficiency were obtained from the half-normal stochastic frontier model. Results showed that the average paddy farm in Nepal was 71% efficient, implying that improvements in technical efficiency were still possible. Large elasticity of labour with high statistical significance showed that labour was an important variable for improving technical efficiency. In addition, credit was found to be a very important variable that should be taken into account in trying to measure the level of efficiency.

Kirkley *et al*. (1995) estimated technical efficiency in fisheries. According to the authors, Vessel efficiency was estimated using a stochastic production frontier based on a sample of sea scalp of vessels operating in the Mid-Atlantic between 1987 and 1990. Estimates of technical efficiency were computed and computed with input usage, resource conditions, economic performance and recently imposed regulations. The analysis suggested that owners and captains only partially compensated for changes in resource conditions through the use of labour and fishing effort and recent regulations would improve overall technical efficiency in the short while.

Khan and Maki (1980) determined relative efficiency by farm size and after Green revolution in Pakistan using the unit output price profit function. It was found that high-yielding seeds were more efficient than seeds of old varieties. However, farm size had no effect on efficiency.

Kumbhakar and Heshmati (1995) introduced a new specification of technical inefficiency in panel data models. The model was used to examine technical efficiency in Swedish dairy farms during the period 1996 to 1988. Results showed that the mean persistent technical inefficiency was about 10.27% and the mean residual inefficiency was 3.90%. The persistent inefficiency component varied across farms ranging from 0.00 to 39.11%, whereas the residual inefficiency component ranged from 1.20 to 17.05%.

Kumbhakar *et al*. (1989) estimated technical, allocative and scale inefficiencies for Utah dairy farmers. They used stochastic frontier production function containing endogenous and exogenous variables. Both types of explanatory variables were found to have significant effects on the variation of farm production. Technical efficiency and farm size were positively related, implying that improvement in technical efficiency could be made with increased farm size.

Kumbhakar *et al*. (1991) investigated farm-level technical and allocative efficiency of U.S. dairy farmers. Results showed that levels of education of the farmers were important factors determining technical inefficiency. Moreover, large farms were more efficient than small and medium sized farms.

Kumbhakar (2001) used augmented translog profit function, incorporating both technical and allocative inefficiencies. Four models were estimated using a panel of 60 salmon farms from Norway. The homogeneity hypothesis of the underlying production function was rejected in all four models, so translog profit function was preferred. Estimates of elasticities from models which failed to include either technical inefficiency or allocative inefficiency or both were found to be quite different from the models, which included both technical and allocative inefficiencies.

Kwon and Lee (2004) adopted parametric and non-parametric production frontiers and compared with estimated productivity using panel data on Korean rice production. It was estimated that parametric estimations were found to produce higher technical efficiency scores as compared to the non-parametric approach and productivity measures differed considerably between these approaches. Both approaches revealed that the main sources of growth in Korean rice farming had been technical change and productivity improvements in regions of the country that had been associated with low efficiency.

Lass and Gempesaw (1992) used random coefficients regression methods to determine firm-varying production technologies for a sample of Massachusetts's dairy farms. Results showed that hired labour, land and machinery inputs were used in excess of efficient levels. All farms underutilized livestock supplies. Although estimated means were closer to optimal levels, efficiencies of feed, crop material, fuels and utilities varied.

Latruffe *et al*. (2005) analysed the technical and scale efficiency of Polish farms using data envelopment analysis. Results showed that livestock farms were on an average, more technically and scale efficient than crop farms. Technical inefficiency was due to pure technical rather than scale inefficiency. This evidence showed that the low educational attainment of people engaged in agriculture was the more important reason for these inefficient practices and 64% of livestock.

Llewelyn and Williams (1996) adopted non-parametric analysis of technical efficiency for irrigated farms in the Madium regency in the west-central part of East Java, Indonesia. Farmer age, the level of diversification of cropping activities and high school education were related to technical efficiency in the rainy season under irrigated conditions. It was also estimated that inefficient farms were using excessive levels of inputs particularly nitrogen fertilizer.

Mochebelele and Winter-Nelson (2000) assessed the impact of labour migration on the technical efficiency performance of farms in the economy of Lesotho. Using the stochastic production function (translog and Cobb-Douglas), the study found that households that sent migrant labour to South African mines are efficient than those that do not, with mean inefficiencies of 0.36 and 0.24, respectively. In addition there is no statistical evidence that the size of the farm or the gender of the household head affects the efficiency of farmers.

Mushunje and Belete (2005) established that maize and cotton production and producers experience in Zimbabwe increasing returns to scale. On the other hand, they discovered that one percent increase in quantity of land resulted in 0.81% and 1.11% increase in maize and cotton output, respectively. Elasticity of maize production for maize was however found to be negative. This means that increasing quantities of cotton production would decrease the volume of production of maize. This perhaps indicates that maize and cotton are competitive products. The authors inferred that small-scale communal farmers interviewed were either under or over-utilising resources.

Nsanzugwanko *et al.* (1996) analysed the technical efficiency (TE) of small agricultural producers of central Ethiopia. They estimated the technical efficiency of individual peasant farmers in the Ethiopian agricultural sector and used the stochastic frontier production functions to estimate the technical efficiency of production. The multi-stage sampling method was used to sample the 843 respondents. The variables used include the gross value of crop and livestock output, the dependent variable, with land, fertilizer, farming equipment and cattle numbers used as the independent variables. Despite its importance the labour variable was left out.

O'Donnell *et al*. (1999) used Markov Chain Monte Carlo methods to estimate a seemingly unrelated regression system on input demand functions for U.S. agriculture. According to O'Donnell *et al*. (1999), input demand functions allowed for input technical inefficiency and Bayesian approach ensured that measures of relative technical efficiency had distributions which were confined to the unit interval. Bayesian estimates of relative technical efficiency suggested that the Mountain states were the most technically efficient and the states in the Southeast were least efficient but still 95% efficient relative to states in the mountains.

O'Donnell and Griffiths (2006) used fixed and random effects state-contingent production frontiers to estimate technical efficiency for the Philippine rice farmers. It was found that estimating production frontiers in a stage-contingent framework gave significantly different estimates of technical efficiency, elasticities and other quantities of economic interest than those of conventional stochastic frontier models.

Osbome and Trueblood (2006) examined economic efficiency of crop production of Russian corporate farms for 1993 to 1998. Results revealed that declines in both technical and allocative efficiency caused decline in economic efficiency. Technical efficiency results indicated that output levels could have been maintained while reducing overall input use by an average of 29% to 31% in 1998, depending on the method used.

Paul *et al*. (2004) used an input distance function approach to evaluate scale and technical efficiency and productive effects of contracting for small as compared to large farming operations. Higher value of marketing and production contracts by crop and livestock species and manure nitrogen production per cultivated acre was associated with greater productivity, scale economies and technical efficiency. They found that smaller operations and those with lower contracting levels were less efficient overall than larger-scale and contract-intensive entities.

Parikh *et al.* (1995) measured economic efficiency in Pakistani agriculture and used the cost function approach and combined the concepts of technical and allocative efficiency in the cost relationship. They argued that any errors in the production decision translated into higher costs for the producer. The derived measure of inefficiency was then related to socio-economic, demographic and farms size variables. They found that land fragmentation had a negative effect on efficiency, thus disproving the inverse relationship between farm size and efficiency.

Rauf (1991) estimated the relationship between education and technical efficiency during Green Revolution in the entire irrigated areas of Pakistan. Cobb Douglas production function was used to investigate this relationship. It was found that the effect of education on technical efficiency was substantial. But the effect of higher education on technical efficiency was more compared to that of primary education.

Reddy (2002) investigated productivity differences between tenant and owner operated sugarcane farms in Fiji using stochastic frontier production function. A significant difference was found between two types with respect to input usage, productivity and technical efficiency. Mean technical efficiency estimates for tenant operated farms and owner-operated farms were 0.82 and 0.90 respectively.

Reinhard *et al*. (1999) estimated the technical and environmental efficiency of a panel of Dutch dairy farms. Nitrogen surplus was assumed as an environmentally detrimental input. A stochastic translog production frontier was specified to estimate the output-oriented technical efficiency. Environmental efficiency was estimated as the input-oriented technical efficiency of a single input, the nitrogen surplus of each farm. The mean output-oriented technical efficiency was as high as 89%. Contrariwise, the mean input-oriented environmental efficiency was only 44%.

Reinhard *et al*. (1999) developed and implemented a methodology for analysing the source of variation in environmental efficiency across producers. It was found that environmental efficiency could be improved through a number of policy options, including the provision of farmers with more insight into the nutrient balance of their farms.

Seyoum *et al*. (1998) consider the technical efficiency and productivity of maize producers in Ethiopia and compare the performance of farmers within and outside the programme of technology demonstration. Using Cobb-Douglas stochastic production function, their empirical results shows that farmers who participate in the programme are more technically efficient with a mean technical efficiency equal to 94% compared with those outside the project whose mean efficiency equal to 79%.

Shafiq and Rehman (2000) applied data envelopment analysis (DEA) to study the relative technical and allocative efficiencies of individual farms in cotton production in Pakistan Punjab. The analysis pointed out the existence of a significant extent of resource use inefficiency. In many instances, it was found that farmers were using the quantities of inputs unjustifiably higher than what would be required to achieve their present levels of crop output.

Sharif and Dar (1996a) estimated technical efficiency of farmers in the cultivation of traditional and high-yielding variety (HYV) rice using production frontiers in Bangladesh. Lower technical efficiency and much greater variability in technical efficiency were in high-yielding variety cultivation. It was found that small farmers with the least education and growing experience were least technically efficient.

Sharif and Dar (1996b) used stochastic frontier production function and corrected ordinary least square to estimate technical efficiency of rice farmers in Bangladesh. Results indicated that farmers growing high yielding varieties rice were technically more efficient compared to traditional ones. Education and farm size were found to have a positive but diminishing impact on technical efficiency.

According to Shapiro and Muller (1977), the average technical efficiency of smallholder farmers reported in their studies range between 0.49 among maize farmers in Kenya to 0.79 among Tanzania sugarcane farmers. This shows smallholder farmers have low and highly variable levels of efficiency especially in developing countries. Farmers age, education, access to extension, access to credit, family size, tenancy, land holding size and farmers access to fertilizer, agrochemicals, tractors and improved seeds variables are reported by many studies as having a positive effect on technical efficiency.

Sherlund *et al*. (2002) investigated the efficiency of smallholder rice farmers in Cote d'Ivoire and controlling for environmental factors that affect the production process. Apart from identifying factors that influence technical efficiencies, the study found that the inclusion of environmental variables in the production function significantly changes the results: the estimated mean technical efficiencies increase from 36% to 0.76%.

Stefanou and Saxena (1988) found that education and experience were substitutes and played a prominent role in the level of allocative efficiency in Pennsylvania dairy farms. Dairy operators were allocating their variable inputs in an absolutely inefficient manner. Furthermore, the estimates of the efficiency measures suggested that these operators were maximizing production rather than short run profits.

Tadesse and Krishnamoorthy (1997) examined the level of technical efficiency across ecological zones and farm size groups in paddy farms of the Southern Indian State of Tamil Nadu. Their study shows that 90% of the variation in output among paddy farms in the state was due to differences in technical efficiency. The level of technical efficiency among paddy farms in the state differs significantly across agro-ecological zones and size groups as well. Small size and medium size farms showed relatively higher technical efficiency.

Tadesse and Krishnamoorthy (1997) used the two-way ANOVA to analyse Paddy production in India and found significant difference in the average technical efficiency across small, medium, and large farms. The Tobit model was also used on the same data and the authors established that paddy farms on small and medium holdings operate at a higher level of technical efficiency than the large sized farms. The study showed that most efficient farms employed 150.94 man-days of labour as per hectare compared to large farms.

Thiam *et al*. (2001) adopted a meta-analysis to review empirical estimates of technical efficiency in developing country agriculture. Results using two-limit Tobit model showed that primal versus dual, number of field inputs and number of variable inputs increased average technical efficiency estimates. On the other hand, they found that Cobb Douglas functional form and cross-sectional data yielded a lower level of technical efficiency. It was also estimated that the number of variables in the model, crop type, stochastic versus deterministic frontiers and sample size were not affecting significantly estimates of technical efficiency across studies.

According to Townsend *et al*. (1998), regional differences exist in the strength of the farm size productivity relationship, with the Olifants River experiencing the most significant relationship. They found an inverse relationship between farm size and both land and total productivity being weak and not consistent. In some cases, although not significant, the relationship was considered positive. They assert that the results suggest that it is misleading to generalize about the existence of the inverse relationship between farm size and productivity across all farming systems and regions. Townsend *et al.* (1998), consider an efficient farm as farm using fewer resources to produce a given output than other farms. Superior performance is manifested in higher efficiency ratio and lower cost per unit of production.

Udoh (2005) applied the stochastic production frontier function to estimate output-oriented technical inefficiency of urban women cultivating waterleaf vegetable. Using MLE, asymptotically consistent and efficient ML estimates were obtained together with inefficiency determinants. Empirical result revealed that the mean level of technical efficiency was 65%, showing that there existed potential to increase crop production by 35% with the present technology.

Udoh and Etim (2006) estimated farm-level, output-oriented technical efficiency indices using stochastic frontier production for waterleaf producers in Ethiopia. Labour, organic manure and irrigation were the most important production factors. The mean efficiency of 65% showed that output could be increased with available technology and resources.

Van Zyl *et al.* (1996), in studies done in Poland found that small farms are more efficient than large farms. Their studies showed that small farms have a larger labour/machinery ratio than large farms. These results indicate that small farms are more labour intensive than large farms. They further stated that there will be no efficiency loss if large mechanized farms can be reduced to small farms, as this will lead to more labour intensive process that will be beneficial in terms of employment.

Wang *et al*. (1996a) analysed production efficiency of Chinese farms using households' date. Results indicated that farmers' resource endowment and education influenced their allocative efficiency. Family, per capita net income and family members operating as village leaders were positively related to households' production efficiency. It was suggested that reducing market distortions could increase farm households' production efficiency.

Wang *et al*. (1996b) developed a shadow-price profit frontier model to estimate production efficiency of Chinese rural households in farming operations. Data from China's Rural Household Survey for 1991 were used in that study. The estimated efficiency index ranged from 6% to 93% with a sample average of 62%. Households' educational level, family and per capita net income were found positively affecting production efficiency. They concluded that decreasing market intervention, giving right of use of farm land to be transferred among households, encouraging migration of excess farm labour and promoting farmers' education would improve rural households' efficiency in agricultural production.

Weir (1999) investigated the effects of education on farmer productivity of cereal crops using average and stochastic production functions. The study found substantial internal benefits of schooling for farmer productivity in terms of efficiency gains but finds a threshold effect that implies that at least four years of schooling are required to lead to significant effects on farm level technical efficiency. Using different specifications, average technical efficiencies range between 0.44 and 0.56, and raising education from zero to four years in the household leads to a 15% increase in technical efficiency. Moreover the study found evidence that average schooling in the villages (external benefits of schooling) improved technical efficiency.

Weir and Knight (2000), they found evidence that the source of externalities to schooling was in the adoption and spread of innovations that shifted out the production frontier. Mean technical efficiencies of cereal crop farmers are 0.55. A unit increase in years of schooling increases technical efficiency by 2.1% points.

2.5 Review of efficiency studies on South African agriculture

Armour and Viljoen (2007) applied a simulation based approach to show significant losses to irrigation farmers in the Lower Vaal and Riet catchments of South Africa due to salinity problems. Furthermore these authors argued that if salinization is incorrectly managed or left unattended, salinization can lead to financial, social and environmental degradation and threaten the major contribution that irrigation in arid areas makes to national food security. Irrigation farmers can mitigate the effect of salinity on net income through the cultivation of more salt tolerant crops and if water supplies are adequate water can be applied in excess of the crops water requirements to leach salts from the root zone (Armour and Viljoen, 2007).

Baloyi *et al*. (2011) used a Cobb-Douglas production function to determine the technical efficiency of small-scale maize farmers in Ga-Mothiba rural community, Limpopo Province of South Africa. The results revealed that the small-scale maize producers in Ga-Mothiba are experiencing decreasing return to scale of 0.398. Variables such as land use and fertilizers were found to be positively significant while capital was found to be negatively significant toward the technical efficiency. Seed was found to be positively insignificant whereas labour was negatively insignificant towards technical efficiency.

Matthews *et al*. (2008) conducted the study aimed at developing a robust non-linear optimisation model that was able to endogenously determine the impact of declining irrigation water quality on the economic efficiency or irrigation farming in Free State Province, South Africa. The data was integrated into a data envelopment analysis framework to model the non-parametric salinity crop yield function. The model was applied to determine the impact of deteriorating irrigation water quality on the value of irrigation water under limited water supply conditions. Results showed both increasing and decreasing marginal values as irrigation water salinity increases. The specific relationship was explained by the trade-off that exists between using irrigation water to increase area planted and using it to leach excess salts from the soil. The study concluded that if leaching was seen as a beneficial water use and water allocations were increased, irrigation farming profitability might be increased at the expense of the environment.

Ngwenya *et al*. (1997) used farm level data for the 1988/89 agricultural years from a sample survey of wheat farmers in Eastern Free State Province, South Africa. Stochastic frontier production functions were estimated. It was estimated that the Cobb Douglas function was not an adequate representation of the data, given the specifications of the translog stochastic frontier production function for the given sample. The technical inefficiency effects were negatively and significantly related to the size of the farms. The mean efficiency of wheat farmers was around 67%.

2.6 Socio-economic factors affecting the success of farmers worldwide

The constraints and problems that have been discussed above are some of the main causes slowing down the progress of smallholder farmers towards success, mainly determined by how the initiative is implemented. However, there are other factors that have been found in other studies.

2.6.1 Age

According to Dlova *et al*. (2004), age is one of the factors that can affect the probability of a farmer being successful in farming. Results from the study concluded that older farmers are less capable of carrying out physical activities while younger ones are capable. In this study, Dlova *et al* (2004), concluded that younger farmers are more ready to adopt modern technology. Thus because younger people may be more adaptive and more willing than older people to try new methods, age is expected to be an influencing factor. Bembridge (1984) also concluded that as farmers get older, they often become more conservative and reluctant to accept risk, they work fewer hours and have fewer non-farm employment opportunities.

2.6.2 Gender

According to Bembridge (1984), a profile of best farmer characteristics was found and significantly more of the best farmer heads of households were men who were managing the farm. This is also true according to Dlova *et al.* (2004), who found that it was expected because males are physically capable of coping with the manual demands of farming practices. Women are also expected to perform domestic chores in the household. The exclusion of married women from decision-making activities of the farm even though their husbands were not farmers had an impact on the ability of the females to be successful

(Dlova *et al*., 2004). This means that males would be more likely to succeed compared to females.

2.6.3 Education and training

The best farmers were the educated and most of them had some vocational training (Bembridge, 1984). To be an entrepreneur with parameters that determine the scope of an enterprise in rural situations, the smallholder farmers must be familiarized with the principles of business economics, record keeping and they should become proficient in managerial skills (Nompozolo, 2000). Thus, Dlova *et al* (2004) found that the higher the level of education, the more successful the farmer was. A sound educational background can reinforce natural talent; it can provide a theoretical foundation for informed decisions. Entrepreneurial success requires formalised knowledge of functional aspects like marketing, purchasing, supply chain management and finance (Rwigema and Venter, 2004).

Therefore, education is likely to improve managerial ability in terms of better formulation and execution of farm plans and acquiring better information to improve marketing ability. However, Nompozolo (2000) suggests that education and training should go hand in hand; education being the primary motivator and initiator. Thus, Dlova *et al* (2004) conclude that the probability of a farmer becoming successful improved when the farmer had some type of vocational training. Doni (1997) states that any agricultural development initiative should start with training of the targeted farmers before other support services are provided. Such training should continue through extension support as part of the project implementation.

2.6.4 Access to off-farm income

Access to income can affect the probability of a farmer becoming successful (Dlova *et al.,* 2004). The probability of success in farming should be directly related to access for other sources of income. According to Dlova *et al.* (2004), those farmers who have access to other sources of incomes made better use of all existing factors of production while farmers who have access to little alternative income under-utilized some of their factors of production due to inadequate operating capital. Bembridge (1984) found out that even though the best farmers derived ten times the income from farming as did average farmers, they were still dependent on outside income for 37% of their gross earnings compared to the 90% in the case of average farmers.

2.6.5 Household size

Normally, the larger the family size, the more likely the farmer is to become successful as the household has more labour to work on the farm. However, this would only work if all family members are old enough to perform the farm work, otherwise if the household size consists of a majority of young children who cannot be used as family labour, it will not work. However, according to Dlova *et al.* (2004), farmers with bigger families were less successful than those with smaller family sizes. This situation is explained by the fact that the increased use of the family income to feed, clothe and educate a larger number of children may leave limited funds for meeting farming expenditures because of the high household expenditures.

2.6.6 Information sources

With the exception of farming publications that are not readily available, Bembridge
(1984) found that the best farmers had significantly greater contact with all sources of information, which confirms the importance of knowledge, and information in improving farming efficiency. Nompozolo (2000) suggests that for good performance, a reasonable amount of information is necessary to back up agricultural productivity. He also recommends that extension officers must be trained in indigenous knowledge relevant to

the farming communities they serve. Whether an individual farmer has contact with the extension service or not mainly depends on his perceptions of the service.

2.7 Summary

Review of literature demonstrated that all of the studies were conducted on major agricultural enterprises, such as dairy, rice, wheat, cotton and sorghum except few studies on maize and vegetables, to estimate technical efficiency and factors causing technical inefficiency. Mostly DEA and the econometric frontier approaches were adopted in the above-mentioned studies. Nevertheless, stochastic frontier production function approach is noted in most of the studies. In the present study, the stochastic frontier production function approach has been adopted in the efficiency and productivity analysis.

A closer look on the above-mentioned studies points out that the frontier approach has been used for measuring efficiency of agricultural sector. There are very limited if not few studies conducted to measure technical efficiency in maize, tomato, onion and spinach production, not to mention in different management organisation of the irrigation schemes (integrated, specialised water and multipurpose water management organisations of irrigation schemes). These concepts are used in this study to distinguish the three institutional arrangements of the irrigation schemes in South Africa. Based on the knowledge, the study of this magnitude has never been conducted in South Africa.

The studies reviewed in this chapter revealed that technical and allocative inefficiencies were serious problems compared to other efficiencies and it is therefore of prime importance to measure the technical and the allocative efficiencies of farmers at different management practices or institutional arrangements of the irrigations scheme with emphasis on the maize, spinach, tomato and onion production. The study assumes that main causes of technical and allocative inefficiencies include poor managerial qualities of the producers. Agricultural productivity could be enhanced by improving managerial abilities (technical skill and knowledge) of the farmers.

It seems that institutional arrangement of the irrigation schemes affect the technical and allocative efficiency of farmers. Since the above literature identified a number of socio-economic factors affecting the successfulness of the smallholder farmers, e.g. age, gender, education and income of farmers. Therefore, this study determined the level of technical efficiency of maize, spinach, tomato and onion farmers at different management practices of the irrigation schemes. The study further identified the socio-economic determinants of the efficiency of farmers in integrated, specialised and multipurpose water management organisations of irrigation schemes in Limpopo Province and to determine the extent to which each socio-economic determinant affect the efficiency of farmers at the different management organisations/institutional arrangement of the irrigation schemes. The next chapter is devoted to the overview of the irrigation schemes in South Africa.

CHARPTER THREE

AN OVERVIEW OF THE IRRIGATION SCHEMES IN SOUTH AFRICA

3.0 Introduction

This chapter presents an overview of the irrigation schemes in South Africa with emphasis on the establishment/origin of the irrigation schemes, water sector institutions, environmental policies in relation to irrigation, current status of irrigation schemes, socioeconomic impacts of irrigation schemes, transaction costs of irrigation water management and the challenges faced by farmers at different irrigation schemes.

Irrigation agriculture plays a key role in water resources management, conservation and food supply. Historically, the irrigation sector was managed by governments, and it was proved to be inefficient in most cases. Water, food, poverty and urbanisation have strong impacts on food security. Urbanisation leads to tightening competition over scarce water resources. Growing cities and industries demand more water and as they can also pay more for water, agriculture is losing its share of water resources in the competition. In order to secure water and food for future's population, agriculture must use water more efficiently; make more crops per drop (Karkkainen, 2002). The challenge of making irrigation more efficient cannot be answered on the basis of the Green Revolution (Postel, 1999 as cited by Karkkainen, 2002).

3.1 Establishment of the irrigation schemes in South Africa

South Africa has about 1.3 million ha of land under irrigation' of which about 0.1 million hectares are in the hands of smallholder farmers (Backeberg, 2006; Van Averbeke, 2008). In order to describe the smallholder irrigation sector, one needs to have a good understanding of who the smallholder farmer is. The main criteria often used to classify farmers as smallholders by various analysts include land size, purpose of production (subsistence or commercial), income level (whether poor or rich), and ethnic group in South Africa. Various definitions have been used to describe smallholder farmers in South Africa (Machethe *et al*., 2004; Botha and Treurnich, 1997; Catling and Saaiman, 1996; Van Zyl *et al*., 1996). Terms used to describe smallholder farmers include small-scale farmers, resource-poor farmers, peasant farmers, food deficit farmers, household food security farmers, land reform beneficiaries and emerging farmers (Machethe *et al*., 2004).

In the South African context, smallholder farmers are defined as black farmers most of whom reside in the former homelands. It is also noted that not every black farmer is a smallholder farmer and smallholder farmers are not a homogenous group (Machethe *et al*., 2004). Smallholder irrigators in South Africa have been categorised into four groups namely farmers on government initiative irrigation schemes, independent irrigation farmers, community gardeners and home gardeners (Crosby *et al*., 2000; Du Plessis *et al*., 2002; Van Averbeke, 2008). According to Backeberg (2006), there were 200 000 to 250 000 smallholder irrigators contained in these four groups. This review is concerned with one group of smallholder irrigators, namely those operating on irrigation schemes.

South African smallholder irrigation scheme (SIS) can be defined as multi-farmer irrigation projects larger than 5 ha in size that were established in the former homelands or in the resource poor areas by black people or agencies assisting their development (Van Averbeke, 2008). These schemes are under local responsibility, controlled and operated by the local people in response to their felt needs, and using a level of technology which they can operate and maintain effectively (Underhill, 1984). Such schemes vary in size, both in terms of the number of farmers supported by a particular scheme and the size of the scheme.

Over the years, many SIS have been established in South Africa in order to gain accessibility to productive land and increase production in the different regions of the country. Available evidence indicates that in 2010 there were 302 SIS in South Africa, with a command area of 47 667 ha (Van Averbeke *et al*., 2011). Not all 302 SIS were operational in 2010 and not all operational schemes were fully functional (Van Averbeke *et al*., 2011). Most of the schemes have collapsed or are utilised well below their potential. About 79% of the SIS are located in the Eastern Cape, KwaZulu-Natal and Limpopo Provinces.

The primary goal of establishing these schemes was to improve rural livelihoods through sustainable crop production for food security and poverty alleviation (FAO, 2001). However, because of poor performance, the development objectives of SIS remain largely unfulfilled (Yokwe, 2009; Fanadzo *et al*., 2010). As such, the benefits of irrigation have not been realised in the smallholder sector of South Africa.

Government smallholder irrigation schemes were developed in former homeland areas of South Africa during the apartheid era. Although experiencing serious financial, technical, and institutional problems, most of them are now earmarked for rehabilitation and transfer to water users' associations. Transfer operators find it difficult to evaluate the potential for viability, then to organize the transfer accordingly.

Now the government aim is to revitalise smallholder irrigation and curtail the financial burden of their maintenance and operation costs. Most schemes are earmarked for rehabilitation and transfer to water user’s association (WUAs) in South Africa. Water Users Associations form the third tier of water management and operate at local level. These WUAs are in effect co-operative associations of individual water users wishing to undertake water-related activities for their mutual benefit. By law, (Ntsonto, 2005), farmers have to form water users association and farmers should pay for water use and water-related services and for the resource. Since the late 1990s, government have set up rehabilitation and management transfer programme throughout the country but it is taking place in Limpopo Province and is still in the planning phase in the Eastern Cape Province (Perret, 2002).

3.2 Operational status of South African smallholder irrigation schemes per province and irrigation system.

The available evidence indicates that in 2010 there were 306 (see table 3.1 below) smallholder irrigation schemes with a combined command area of 47 667b ha in South Africa (WRC, 2011). According to Van Averbeke *et al.* (2011), the plot-holder population on these schemes totalled 34 158b ha. Rivers are the principal source of water. A total of 46 114b ha (96.7%) obtained its water from rivers, either pumped directly, diverted by means of weirs or through dam storage.

Not all 306 smallholder irrigation schemes were operational in 2010 and not all operational irrigation schemes were fully operational but the data available on provinces other than Limpopo Province did not allow for estimates of the extent to which operational irrigation schemes were functioning. Table 3.1 shows operational status of the irrigation schemes by province in relation to irrigation method or system (WRC, 2011).

According to WRC (2011), in 2010, 216 irrigation schemes were operational and 90 were not. The status of one gravity-fed canal scheme in KwaZulu-Natal and 5 overhead irrigation schemes in the Eastern Cape could not be established. Significant was that the likelihood of irrigation schemes to be operational was 81% for gravity-fed canal irrigation schemes, 70% for pumped surface irrigation schemes, 65% for overhead irrigation schemes and 56% for micro-irrigation schemes.

Among the primary constraints identified by extension staff on 164 of the 306 smallholder irrigation schemes, poor management topped the list (50% of the cases); followed by infrastructural problems (15%); water inadequacies (13%); conflict (12%) and theft (7%). This suggested that human (capacity) and social (institutional) resource problems were at the heart of the below-expected performance of smallholder irrigation schemes in South Africa identified by nearly all assessments that were made (Bembridge, 1997; Bembridge, 2000; Kamara *et al*., 2002; Shah *et al*., 2002; Machethe *et al*., 2004; Tlou *et al*., 2006;; Yokwe, 2009; as all cited by WRC, 2011).

Table 3.1 Operational status of South African smallholder irrigation schemes by province and irrigation system.

Province	Number of operational schemes by irrigation system				Number of non-operational schemes by irrigation system				Total
	Gravity-fed surface	Pumped surface	Overhead	Micro	Gravity-fed surface	Pumped surface	Overhead	Micro	
Limpopo	49	9	30	13	12	5	41	11	**170**
Mpumalanga	3	0	4	0	1	0	11	0	**19**
North-West	0	2	0	0	0	0	0	0	**2**
Kwazulu-Natal	5	0	30	0	0	0	0	0	**35**
Free State	0	1	0	0	1	0	0	0	**2**
Northern Cape	0	2	0	0	0	1	0	0	**3**
Eastern Cape	4	0	46	1	0	0	16	0	**67**
Western Cape	6	0	1	0	0	0	1	0	**8**
Total	**67**	**14**	**111**	**14**	**14**	**6**	**69**	**11**	306

Source: Van Averbeke *et al.* (2011)

The operational status of six irrigation schemes, five in the Eastern Cape and one in Kwazulu-Natal was not known bringing the total to 306 (Van Averbeke *et al*., 2011).

According to Van Averbeke *et al*. (2011), Ground water was used on 1 405.5 ha (3.0%), municipal water on 110 ha (0.2%) and spring water on 37.6 ha (0.1%). Water was pumped on 23 111.8 ha (48.5%), gravitated on 16 497.2 ha (34.6%) and on 8 058.5 ha (16.9%) gravity and pumping occurred in combination. On all existing schemes, the irrigation system was constructed after 1950. Smallholder irrigation scheme development in South Africa has a much longer history (Van Averbeke, 2008), but in 2010 schemes that were constructed before 1950 no longer existed in their original form while the original canal irrigation system has been replaced with an overhead system (Van Averbeke *et al*., 2011).

Figure 3.1 Example of overhead irrigation system

Source: Griffiths and Lecler (2002)

Figure 3.2 Example of canal irrigation system

Source: Griffiths and Lecler (2002)

Figure 3.3 Example of the gravity-fed surface irrigation system

Source: Griffiths and Lecler (2002)

Figure 3.4 Example of Pumped surface irrigation system

Source**:** Griffiths and Lecler (2002)

According to Union of South Africa (1955) In 1952, when the Commission for the Socio-Economic Development of the Bantu Areas completed its data collection, it identified 122 smallholder irrigation schemes, which covered a total of 11 406 ha (WRC, 2011). This irrigated area was held by 7 538 plot-holders, each holing a plot with an average size of 1.5 ha. All of these were river-diversion schemes and it would appear that in most cases their water conveyance and distribution systems had no linings at that time (De Lange *et al*., 2000). After 1950, the state upgraded existing smallholder canal schemes by constructing permanent weirs or dams and by lining canals and furrows with concrete. Several new smallholder canals irrigation schemes were also built and all of those had concrete linings (Van Averbeke, 2008).

At the time, the commission for the Socio-Economic Development of the Bantu Area within the Union of South Africa (1955) predicted that these lined canal schemes would have a 20 to 40 year lifespan. However, some of them have now been in operation for more than 50 years, although most are presently in need of repairs (Van Averbeke, 2008). The construction of canal schemes came to an end around 1975. In the Vhembe District, for example the last canal schemes that were built were Morgan and Klein Tshipise in 1974. Of the total command area covered by smallholder irrigation schemes in 2010, 12 802 ha (26.9%) was located on gravity-fed canal schemes. Invariably, surface irrigation was practised on such schemes, almost always by means of the short-furrow method (De Lange, 1994; Crosby *et al*., 2000; Van Averbeke, 2008). Surface irrigation occurred on an additional 3 278 ha (6.9%) located on pumped schemes, where short-furrow or border-strip irrigation was practised (Van Averbeke, 2008).

Considerable smallholder irrigation development occurred between 1975 and 1985, particularly in the Eastern Cape (Van Averbeke *et al*., 1998). Overhead irrigation systems replaced canal irrigation in the design of these schemes, in line with the global trend of modernisation (Faure *et al*., 2007). Some of the large smallholder schemes that were developed during this period in South Africa included Ncora, Keiskammahoek, Tyefu, Shiloh and Zanyokwe in the Eastern Cape (WRC, 2011). All of these projects were capital-intensive (Bembridge, 1997; Van Averbeke *et al*., 1998). For example, the cost of construction of the 473 ha pilot phase of the Tyefu scheme in 1976 amounted to R12 000 per ha (Ross, 2012), equivalent to R282 189 per ha if adjusted to 2010 South African Rand values.

In most cases, construction of these large schemes involved the building of dams and use was made of modern water distribution and application systems (Van Averbeke *et al*., 1998; Denison and Monona, 2007). The mechanised farming systems that prevailed on these schemes carried high operational and maintenance costs and required sophisticated management systems (Laker, 2004). All costs were expected to be carried by the projects but financial viability was never achieved. As a result, these projects remained dependent on state subsidies for continued operation (Van Averbeke *et al*., 1998; Laker, 2004).

In 2010, various forms of overhead irrigation were found on the largest part of the existing command area of smallholder irrigation schemes. A total of 27 758 ha (58%) was involved, all on schemes that were built after 1975 or on schemes where the canal systems were replaced with overhead systems. The extent of micro-irrigation systems on smallholder schemes was limited to 3 830 ha, which represented 8% of the total command area.

3.3 Description of the irrigation systems employed by farmers at different irrigation schemes

3.3.1 Micro irrigation system

Micro-Irrigation is a co-ordinated water management system where water is made to flow under pressure through a network of pipes of varying diameters, the mainline, the submain lines and the lateral lines with appropriately placed emitters along the length of the latter through which water is discharged to the root zone (WRC, 2011).

i. Need for micro-irrigation

- To achieve required food production with increasing population, India has to enhance the current irrigation potential of 91 million ha to 160 million ha.
- But the total water resources estimated at 230 MHM will have to cater to the non-agricultural uses also.
- The country will be water stressed in the coming years.
- Therefore hand in hand with technologies for water harvesting and storage, technologies for precision water application methods need to be adopted.
- Micro-irrigation technology is the most efficient irrigation method available as of present

ii. Kothari's contribution

- Recognized the importance of MIS for a country like India with its shrinking water resources and expanding Agriculture.
- Establishing R&D centre for adapting and developing MIS components to suit Indian and other arid and semi-arid farming conditions.
- Established higher class production facilities for all the components of MIS.

- Established strict quality control systems to ensure MIS components of highest quality.
- Recognized the special nature of requirements of small land holders of the country.
- Developed an integrated approach in extending MIS for Developing Countries; the study of the land, soil and weather, preparation of tailor made design, supply of irrigation system and provision for support services are factored into this approach.

iii. Benefits

- Saves water up to 70%. More land can be irrigated with the available water
- Crop grows consistently, healthier and mature fast
- Early maturity results in higher and faster returns on investment
- Increase in yield up to 50%
- Fertilizer use efficiency increases by 30%
- Undulating and hilly lands can be brought under cultivation

3.3.2 Overhead irrigation system

An overhead irrigation system is a lot like a lawn sprinkler -- the basic principle is the same. Water is pumped in under pressure and sprayed down onto the plants from flat spray nozzles. These may be mounted on an overhead network of aluminum pipes or even simply mounted on the top of a stake. Because it can be difficult to produce an even coverage, some more expensive systems may feature a moving overhead boom. This mechanism, which moves across the length of the whole crop, can then disperse the water in a much more even manner. Another overhead irrigation device is the water gun**,** which, as its name suggests, shoots water into the air and out over a field. A large water gun can cover several acres of land without needing to be moved (Ross, 2012).

According to Ross (2012), overhead systems are particularly useful when covering large areas of land, and some can even be dismantled and moved from field to field with little trouble. As overhead irrigation systems need a plentiful supply of water at a relatively high pressure, they vary greatly in complexity and cost depending on the acreage, one is covering. Another important thing to keep in mind is that, with overhead irrigation, the foliage of a crop does get wet. If the leaves remain wet for an extended period of time, anywhere from as little as 10 and up to 24 hours, this can cause problems with fungi and bacterial disease.

3.3.3 Gravity fed irrigation system

A gravity fed irrigation system is a cheap effective way to provide water for a smaller sized crop area. It would be especially cost effective if the climate of the area can provide enough precipitation to consistently keep a reservoir filled using rain water harvesting techniques. According to Ross (2012), the basic system is very simple consisting of an elevated reservoir with a pipe coming out the bottom that feeds water into a basic drip irrigation system that is all controlled either by hand or with a very efficient battery powered timer that controls the rate at which the crop is watered. The components needed include:

i. **A water reservoir**

- It must be able to contain at least one days' worth of water
- The greater capacity of the reservoir is proportional to how often it must be refilled
- The complication of having a very large container is that you must elevate it above the crop and refilling a very high container is more work
- The reason to elevate the tank is that it adds pressure which needs to be kept consistent at the point where the drip lines are fed so that the water is distributed equally

ii. **A structure to support the water reservoir**

- Can be constructed of anything that can support the weight of the container when it is filled with water
- It must also be able to withstand outside forces such as the wind
- An 880 gal container full weighs 4 tons

iii. **Piping**

- There must be a pipe at the base of the reservoir that lets water flow out and having a shut off valve at this connection point is a good idea if the reservoir is larger than one days' worth of water
- The piping if using the timer method then feeds the water through a filter
- Different sized piping should be used to increase the pressure
- This is done by gradually decreasing the size of the lines being used such as starting with a 2ft line at the base of the reservoir then decreasing the size every 1-4ft so that it would then be a 1ft, 6in, 3in, 1in, 1/2in, down to the 1/8in emitters in the drip lines

iv. **Timer and filter**

- There are many models of battery powered timers that can be set up and run for a whole season
- These timers control the frequency that water is emitted into the drip lines
- A filter must be installed in the water line before the timer valves
- This prevents the smaller lines from becoming clogged

v. **Valves and drip lines**

- Shut off valves should be placed between the reservoir pipes and the irrigation pipes and before the timer valves

- Drip lines are the average lines and emitters that can be purchased at any garden supply store

The Construction: If you are using a small system that can be refilled daily with no timer it can be created for about R200. If you use the large system the price will vary greatly depending on what is bought at what price, so for safety one can round off on the average price of materials.

3.3.4 Pumped surface irrigation system

Pumped surface has evolved into an extensive array of configurations which can be broadly classified as: (1) basin irrigation; (2) border irrigation; (3) furrow irrigation; and (4) uncontrolled flooding. As noted previously, there are two features that distinguish a surface irrigation system: (a) the flow has a free surface responding to the gravitational gradient; and (b) the on-field means of conveyance and distribution is the field surface itself (Ross, 2012).

A surface irrigation event is composed of four phases as illustrated graphically in Figure 3.4. When water is applied to the field, it 'advances' across the surface until the water extends over the entire area. It may or may not directly wet the entire surface, but all of the flow paths have been completed. Then the irrigation water either runs off the field or begins to pond on its surface. The interval between the end of the advance and when the inflow is cut off is called the wetting or ponding phase. The volume of water on the surface begins to decline after the water is no longer being applied. It either drains from the surface (runoff) or infiltrates into the soil. For the purposes of describing the hydraulics of the surface flows, the drainage period is segregated into the depletion phase (vertical recession) and the recession phase (horizontal recession). Depletion is the interval between cut off and the appearance of the first bare soil under the water. Recession begins at that point and continues until the surface is drained (Ross, 2012).

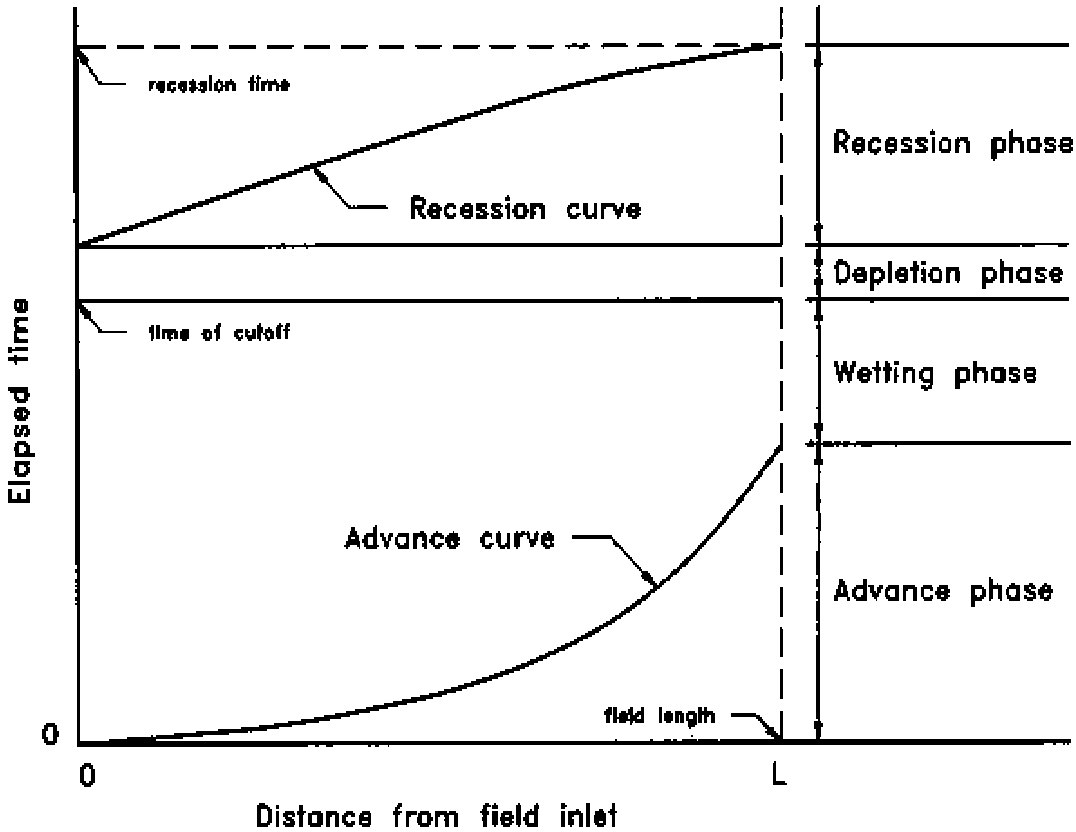


Figure 3.5: Time-space trajectory of water during a surface irrigation showing its advance, wetting, depletion and recession phases.

Source: Ross (2012)

The time and space references shown in Figure 3.5 are relatively standard. Time is cumulative since the beginning of the irrigation, distance is referenced to the point water enters the field. The advance and recession curves are therefore trajectories of the leading and receding edges of the surface flows and the period defined between the two curves at any distance is the time water on the surface and therefore also the time water is infiltrating into the soil.

It is useful to note here that in observing surface irrigation one may not always observe a ponding, depletion or recession phase. In basins, for example, the post-cut off period may only involve a depletion phase as the water infiltrates vertically over the entire field. Likewise, in the irrigation of paddy rice, irrigation very often adds to the ponded water in the basin so there is neither advance nor recession - only wetting or ponding phase and part of the depletion phase. In furrow systems, the volume of water in the furrow is very often a small part of the total supply for the field and it drains rapidly. For practical purposes, there may not be a depletion phase and recession can be ignored. Thus, surface irrigation may appear in several configurations and operate under several regimes.

According to Ross (2010), the surface irrigation system is one component of a much larger network of facilities diverting and delivering water to farmlands. It may be divided into the following four component systems: (1) water supply; (2) water conveyance or delivery; (3) water use; and (4) drainage. For the complete system to work well, each must work conjunctively toward the common goal of promoting maximum on-farm production. Historically, the elements of an irrigation system have not functioned well as a system and the result has too often been very low project irrigation efficiencies. The focus of surface irrigation engineering is at the water use level, the individual irrigated field. For design and evaluation purposes, these guidelines will note elements of the conveyance and distribution system, especially those near the field such as flow measurement and control, but will leave detailed treatment to other technical sources.

Although surface irrigation is thousands of years old, the most significant advances have been made within the last decade. In the developed and industrialized countries, land holdings have become as much as 10 - 20 times as large, and the number of farm families has dropped sharply. Very large mechanized farming equipment has replaced animal-powered planting, cultivating and harvesting operations. The precision of preparing the field for planting has improved by an order of magnitude with the advent of the laser-controlled land grading equipment. Similarly, the irrigation works themselves are better constructed because of the application of high technology equipment.

The changes in the lesser-developed and developing countries are less dramatic. In the lesser-developed countries, trends toward land consolidation, mechanization, and more elaborate system design and operation are much less apparent. Most of these farmers own and operate farms of 1- 10 hectares, irrigate with 20 - 40 litres per second and rely on either small mechanized equipment or animal-powered farming implements.

Probably the most interesting evolution in surface irrigation so far as this guide is concerned is the development and application of micro-computers and programmable calculators to the design and operation of surface irrigation systems. In the late 1970s, a high-speed micro-computer technology began to emerge that could solve the basic equations describing the overland flow of water quickly and inexpensively. At about the same time, researchers like WRC (2011) made major contributions with efficient and accurate numerical solutions to these equations. Today in the graduate and undergraduate study of surface irrigation engineering, micro-computer and programmable calculator utilization is, or should be, common practice.

Micro-computers and programmable calculators provide several features for today's irrigation engineers and technicians. They allow a much more comprehensive treatment of the vital hydraulic processes occurring both on the surface and beneath it. One can find optimal designs and management practices for a multitude of conditions because designs historically requiring days of effort are now made in seconds. The effectiveness of existing practices or proposed ones can be predicted, even to the extent that control systems operating, sensing and adjusting on a real-time basis are possible.

The classification of surface methods is perhaps somewhat arbitrary in technical literature. This has been compounded by the fact that a single method is often referred to with different names. In this guide, surface methods are classified by the slope, the size and shape of the field, the end conditions, and how water flows into and over the field. Each surface system has unique advantages and disadvantages depending on such factors as were listed earlier like: (1) initial cost (2) size and shape of fields (3) soil characteristics (4) nature and availability of the water supply (5) climate (6) cropping patterns (7) social preferences and structures (8) historical experiences and (9) influences external to the surface irrigation system (WRC, 2011).

Basin irrigation is the most common form of surface irrigation, particularly in regions with layouts of small fields. If a field is level in all directions, it is encompassed by a dyke to prevent runoff, and provides an undirected flow of water onto the field; it is herein called a basin. A basin is typically square in shape but exists in all sorts of irregular and rectangular configurations. It may be furrowed or corrugated, has raised beds for the benefit of certain crops, but as long as the inflow is undirected and uncontrolled into these field modifications, it remains a basin. Two typical examples are shown in Figure 3, which illustrate the most common basin irrigation concept: water is added to the basin through a gap in the perimeter dyke or adjacent ditch.

There are few crops and soils not amenable to basin irrigation, but it is generally favoured by moderate to slow intake soils, deep-rooted and closely spaced crops. Crops which are sensitive to flooding and soils which form a hard crust following an irrigation can be basin irrigated by adding furrowing or using raised bed planting. Reclamation of salt-affected soils is easily accomplished with basin irrigation and provision for drainage of surface run-off is unnecessary. Of course it is always possible to encounter a heavy rainfall or mistake the cut-off time thereby having too much water in the basin. Consequently, some means of emergency surface drainage is good design practice. Basins can be served with less command area and field watercourses than can border and furrow systems because their level nature allows water applications from anywhere along the basin perimeter. Automation is easily applied (WRC, 2011).

Basin irrigation has a number of limitations, two of which, already mentioned, are associated with soil crusting and crops that cannot accommodate inundation. Precision land levelling is very important to achieving high uniformities and efficiencies. Many basins are so small that precision equipment cannot work effectively. The perimeter dykes need to be well-maintained to eliminate breaching and waste, and must be higher for basins than other surface irrigation methods. To reach maximum levels of efficiency, the flow per unit width must be as high as possible without causing erosion of the soil. When an irrigation project has been designed for either small basins or furrows and borders, the capacity of control and outlet structures may not be large enough to improve basins.

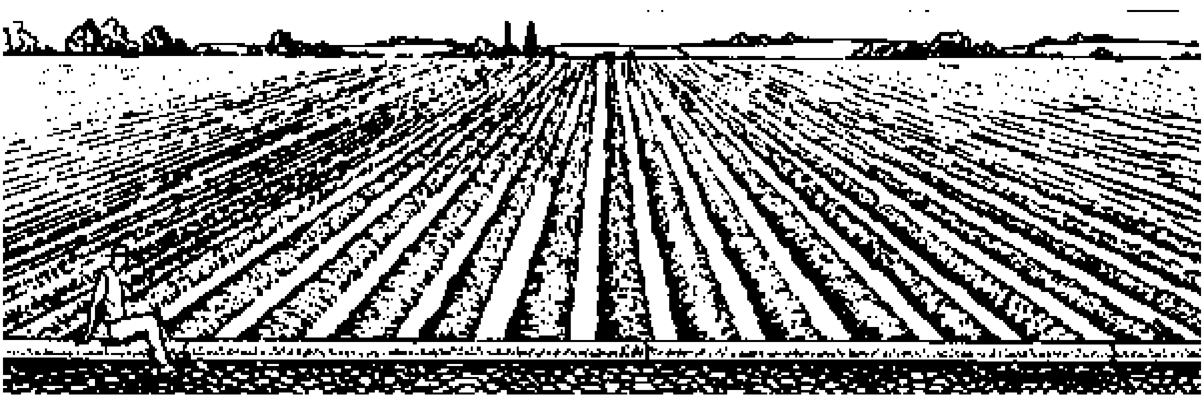
Border irrigation can be viewed as an extension of basin irrigation to sloping, long rectangular or contoured field shapes, with free draining conditions at the lower end. Water is applied to individual borders from small hand-dug checks, from the field head ditch. When the water is shut off, it recedes from the upper end to the lower end. Sloping borders are suitable for nearly any crop except those that require prolonged ponding. Soils can be efficiently irrigated which have moderately low to moderately high intake rates but, as with basins, should not form dense crusts unless provisions are made to furrow or construct raised borders for the crops. The stream size per unit width must be large, particularly following a major tillage operation, although not so large for basins owing to the effects of slope. The precision of the field topography is also critical, but the extended lengths permit (WRC, 2011).

Furrow irrigation avoids flooding the entire field surface by channelling the flow along the primary direction of the field using 'furrows,' 'creases,' or 'corrugations'. Water infiltrates through the wetted perimeter and spreads vertically and horizontally to refill the soil reservoir. Furrows are often employed in basins and borders to reduce the effects of topographical variation and crusting. The distinctive feature of furrow irrigation is that the flow into each furrow is independently set and controlled as opposed to furrowed borders and basins where the flow is set and controlled on a border by border or basin by basin basis.

Furrows provide better on-farm water management flexibility under many surface irrigation conditions. The discharge per unit width of the field is substantially reduced and topographical variations can be more severe. A smaller wetted area reduces evaporation losses. Furrows provide the irrigator more opportunity to manage irrigations toward higher efficiencies as field conditions change for each irrigation throughout a season. This is not to say, however, that furrow irrigation enjoys higher application efficiencies than borders and basins (WRC, 2011).

There are several disadvantages with furrow irrigation. These may include: (1) an accumulation of salinity between furrows (2) an increased level of tail water losses (3) the difficulty of moving farm equipment across the furrows (4) the added expense and time to make extra tillage practice (furrow construction) (5) an increase in the erosive potential of the flow (6) a higher commitment of labour to operate efficiently and (7) generally furrow systems are more difficult to automate, particularly with regard to regulating an equal discharge in each furrow.

(a) Graded furrow irrigation system



(b) Contour furrows

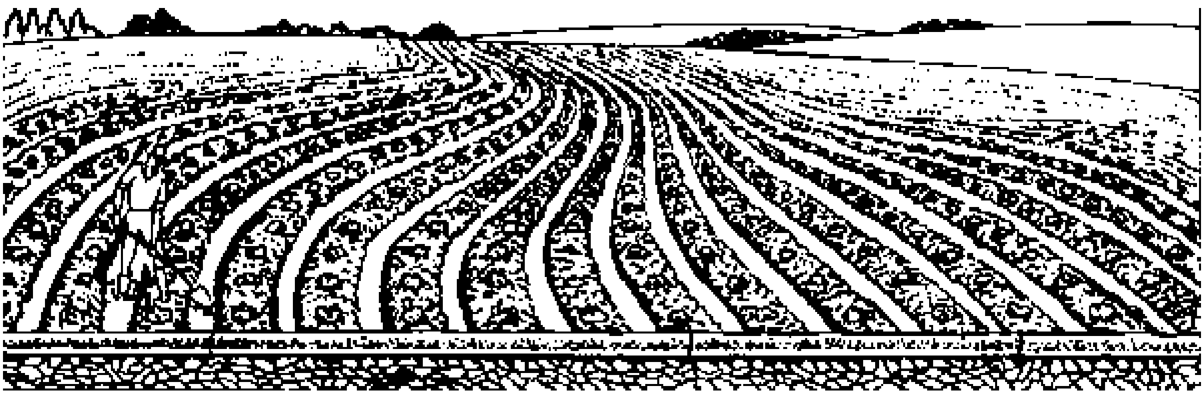


Figure 3.6 Two typical furrow irrigated conditions

Source: Laker (2004)

There are many cases where croplands are irrigated without regard to efficiency or uniformity. These are generally situations where the value of the crop is very small or the field is used for grazing or recreation purposes. Small land holdings are generally not subject to the array of surface irrigation practices of the large commercial farming systems. Also in this category are the surface irrigation systems like check-basins which irrigate individual trees in an orchard, for example. While these systems represent significant percentages in some areas, they will not be discussed in detail in this paper. The evaluation methods can be applied if desired, but the design techniques are not generally applicable nor need them be since the irrigation practices tend to be minimally managed (Laker, 2004).

There is substantial field evidence that surface irrigation systems can apply water to croplands uniformly and efficiently, but it is the general observation that most such systems operate well below their potential. A very large number of causes of poor surface irrigation performance have been outlined in the technical literature. They range from inadequate design and management at the farm level to inadequate operation of the upstream water supply facilities. However, in looking for a root cause, one most often retreats to the fact that infiltration changes a great deal from irrigation to irrigation, from soil to soil, and is neither predictable nor effectively manageable. The infiltration rates are an unknown variable in irrigation practice.

In those cases where high levels of uniformity and efficiency are being achieved, irrigators utilize one or more of the following practices (1) precise and careful field preparation (2) irrigation scheduling (3) regulation of inflow discharges and (4) tail water run-off restrictions, reduction, or reuse. Land preparation is largely a land grading problem which will be discussed in Section 5. Irrigation scheduling is a theme covered separately by several publications such as the FAO Irrigation and Drainage Paper 24 (Rev) by Doorenbos and Pruitt (FAO, 2010). The attention here then is focused on inflow regulation and tailwater control.

Surface irrigation systems have two principal sources of inefficiency, deep percolation and surface run-off or tail water. The remedies are competitive. To minimize deep percolation the advance phase should be completed as quickly as possible so that the intake opportunity time over the field will be uniform and then cut the inflow off when enough water has been added to refill the root zone. This can be accomplished with a high, but non-erosive, discharge onto the field. However, this practice increases the tailwater problem because the flow at the downstream end must be maintained until a sufficient depth has infiltrated. The higher inflow reaches the end of the field sooner but it increases both the duration and the magnitude of the run-off.

3.4 Development issues related to irrigation schemes in South Africa

According to Ministry for Agriculture and Land Affairs (1998) “Ensuring that we manage our inheritance of natural resources with care, so that it provides livelihoods for present and future generations, is the responsibility of all. Those who use land and water must have the incentives, resources and knowledge to use them wisely”.

Many governments have found it increasingly difficult to finance the costs of irrigation operation and management and to be effective providers of water services to large numbers of small farmers (WRC, 2011). Government is attempting to transfer management responsibility for irrigation systems from government agencies to farmers organised into Water Users Associations (WUAs). Government is seeking technical and economic options for the smallholders and rural community members to improve their standards of living, especially in smallholder irrigation schemes in which the authorities are urging the emergence of commercial farming systems, in a context of rehabilitation and ownership transfer (Ntsonto, 2005). Backeberg and Groenewald (1995) argued that irrigation development in South Africa shows success or failure in the past as related to marketing potential of agricultural products and the level profitability of farming.

In South Africa, smallholder black farmers are subsistence and lack organisation which is not favourable to sustainable self-management and cost recovery (Ntsonto, 2005). Without proper support measures, smallholder farmers are not likely to take over immediately the management that governments and parastatals used to carry out for them, to shift directly from subsistence farming to commercial farming and lastly to take direct charge of operating and maintenance costs within the schemes. Conversely to most situations elsewhere in the world, black farmers are not used to paying for irrigation water related services (DWAF, 2000).

Irrigation Management Transfer (IMT) is a new solution in this regard, whereby farmers should manage their own scheme and activities and contribute to cover water fees and resource fees. The reliance of farmers on irrigation schemes may be weak in many instances; on-farm diversification livelihood system is widely spread in SIS (Ntsonto, 2005). Shah *et al*. (2001), emphasise that viability after irrigation management transfer depends on the cost of sustainable self-management and reliance on the farmers of irrigation. The authors stressed that for the process of IMT to succeed the following requirements should be satisfied:

i. Hold out a promise of improvement in the life situations of significant proportion of farmers involved in the process.
ii. Irrigation must be central to creating such improvements (large proportion of income of the farmers must come from irrigation).
iii. The cost of sustainable self-management must be an acceptable proportion of the improved income.

3.5 Socioeconomic impact of small-scale irrigation schemes

Irrigation has played an enormous role in increasing agricultural output worldwide. As the population increases, demand for water for the agricultural, industrial, and domestic sectors has grown significantly. Consequently, water allocation has undergone a significant shift since the turn of the century, when almost 90% of water resources were consumed by agriculture. Recent figures indicate that irrigation worldwide now accounts for 62%, whereas industrial and municipal consumption have increased from 6 to 25% and from 2 to 9% of allocation, respectively (FAO, 2001).

As the world population and competition for land increase, agricultural production on irrigated land will become more important. Today, an estimated 55% of global output of rice and wheat are from irrigated areas, and one third of the world's food is grown on 237 x 10^6 ha, or 17% of the irrigated arable land (Carruthers and Morrison 1994; FAO, 2001). Growth projections suggest that by 2025, 80% of global food production will come from irrigated land (FAO, 2001).

Impact studies differ in terms of geographical coverage, scale of analyses and approach adopted in measuring impacts (Hussain and Hanjira, 2004). Accordingly, the scale of analyses vary among different studies, ranging from household to village, region, national to international levels. The approaches adopted to study the socio-economic impacts of irrigation in various studies can be classified into three major categories:

a. Before and after comparisons
b. With and without comparisons
c. More and less comparisons

Small-scale irrigation schemes as compared with other irrigation strategies used in Africa, if properly implemented with appropriate technologies, may have a considerable potential in improving rural livelihoods. However, the viability of such systems becomes questionable when the financial responsibility rests entirely on the community in the absence of institutional support services that enhance market orientation (Kamara *et al*., 2002). Literature on smallholder irrigation in SSA gives conflicting conclusions on the viability and sustainability of smallholder schemes (Kamara *et al*., 2010).

The sustainability of the irrigation sector in South Africa has been an issue of debate because of its disappointing performance in many cases. As a result of the complex set of constraints facing smallholder producers, providing access to irrigation water by itself is not enough. Smallholders also require a broad range of support services (access to inputs, credit and output markets), knowledge of farming and secure land tenure. To achieve economic viability in small-scale irrigation schemes on a market-oriented basis requires access to support services and opportunities for producing high value crops.

There are strong direct and indirect linkage between irrigation and poverty (Hussain and Hanjira, 2004). Direct linkages operate through localized and household level effects, whereas indirect linkages operate through aggregate or sub-national level impacts. Irrigation benefits the poor though higher production, higher income and lower risk of crop failure. Irrigation enables smallholders to adopt more diversified cropping patterns and to switch from low-value staple production to high-value market-oriented production. Increased production makes food available and affordable for the poor. Since irrigation investments lead to production and supply shifts, indirect linkages operate through regional and national level and have strong positive effects on the national economy.

Past interventions in irrigated agriculture have yielded immense benefits, for example, cereal production in Asia has more than doubled between 1970 and 1995, from 300 million tons to 650 million tons (Hussain and Hanjira, 2004). Many SSA countries have recognized the contribution of irrigation to food production despite all the constraints identified (FAO, 2001). Also in Africa there are examples of success. For example, in Zimbabwe farmers could secure food production thanks to irrigation and the use of high-yielding varieties and fertilizers (FAO, 2010).

Hussain and Hanjra (2004) identified five interrelated linkages of how access to good irrigation water contributes to socio-economic uplift of rural communities and poverty alleviation. These are production, income, and consumption, employment, food security and other social impacts contributing to overall improved welfare. The access to good irrigation facilities helps smallholders to increase their production and income, creates employment opportunities for the local people, an increases the opportunity of smallholder to diversify their income base and to decrease their vulnerability to drought due to short and erratic rain fall conditions.

3.6 Water management, policies and legislation related to water use in agriculture.

3.6.1 Institutional issues

Three ministries are involved in water management and irrigation development:

a) The Ministry of Water Affairs and Forestry, through the Department of Water Affairs and Forestry (DWAF), monitors surface water and groundwater resources, formulates the national water strategy and is responsible for the implementation of the Water Act;

b) The Ministry of Agriculture, through the National and Provincial Departments of Agriculture (NDA and PDA), promotes irrigation engineering concepts and is responsible for agricultural extension with the aim of improving irrigation efficiency;
c) The Ministry of Land Affairs is responsible for the settlement of new farmers.

The development of new irrigation schemes and the upgrading of existing schemes for commercial agriculture are coordinated between the relevant departments by provincial liaison committees, known as the Irrigation Action Committees (IACs). Development and upgrading of irrigation schemes for non-commercial agriculture are coordinated by the Coordinating Committee on Small-Scale Irrigation Support (CCSIS).

According to WRC (2005), Most of the research on the various aspects of water use is promoted, funded and coordinated by the Water Research Commission (WRC), whose funds are generated by a levy on water use. Various institutes of the Agricultural Research Council (ARC) are to a greater or lesser degree involved in irrigation related research, as are some of the universities. Very little irrigation-related research and extension is done by the departments of agriculture. This is offset by one private organization, the South African Sugar Association, which does some irrigation related research and extension work.

3.6.2 Water management issues

The Water Act of 1998 stipulates water management by Water User Associations (WUA) at the local level. Each WUA will have all water users in an area as members, and the local management should eventually be the total responsibility of the WUA. Each WUA will have an elected management body, with all sectors of water users represented on the committee. Several WUAs will fall under an umbrella organization, the Catchment Management Agency (CMA). Each CMA will have an area of responsibility, which could be a catchment, a portion of a large catchment or a combination of small catchments. Nineteen such water management areas have been identified (DWAF, 2002).

The administrative procedures for converting irrigation board areas, private schemes and government water schemes into WUAs are currently in progress. Until the CMAs are in place, the DWAF will carry out their function. The conditions for the use of water that the CMAs and WUAs must oversee include: i) equal access to water by all interested parties; ii) safeguards against water wastage and low efficiencies of water use; and iii) safeguards against pollution. Construction of private reservoirs is restricted to a maximum capacity of 250 000 m^3 and diversion of discharge must not exceed 110 litres/sec. Specifications on dam safety are also set (DWAF, 2002).

3.6.3 Policies and legislation issues

According to FAO (2009), no definite policy is in place regarding natural disasters such as floods and droughts in South Africa. Each case is judged on merit but experience has shown that in most cases none or very little government aid is given. The baseline message seems to be that the prevalence of disasters should be part of the irrigator's risk management strategy and that the irrigator should be as self-reliant as possible under all circumstances.

Major changes in policy are the shift from the previous practice of selling irrigation water on an area basis to selling it on a volumetric basis, and the initiation of a water market. This has opened the potential for efficient irrigators to save on their irrigation expense account and also for irrigators to sell surplus water to more efficient and productive irrigators (Thompson *et al*., 2001). One unfortunate result of changes in policy is that the agricultural extension services that were available to the commercial irrigation sector have been scaled down in favour of services for the previously disadvantaged communities where very little irrigation takes place. The result is that a large sector of the irrigation community is no longer advised on the latest developments in irrigation technology because those farmers cannot afford irrigation consultants and, except for innovators and early adopters, are also not necessarily people who will actively and independently seek out and apply new irrigation technology (Thompson *et al*., 2001).

The Water Act of 1998 determines that all water use, with the exception of reasonable domestic use, home garden use and stock water requirements, must be licensed. This ends the era of a distinction between government irrigation schemes, irrigation boards, private irrigation schemes, as well as public and private water with all that it entailed. The Act also provides for stiff penalties if non-effective use of water can be proved. The Water Act is the result of various discussion papers that have been circulated and widely discussed. To ensure the involvement of all potential irrigators, these discussion papers were included as parts of discussion papers on other, but related, fields such as a discussion paper on an agricultural policy and discussions on a white paper on a national water policy.

3.7 Environment and health issues

The DWAF acts of 1998 against polluters, if they can be identified. Some cases have been taken to court, amongst others for herbicide pollution by some farmers and for pollution by industry. There is a general tendency that the salt content of rivers increase as one moves downstream, mainly through industrial, irrigation and drainage return flows. Research on the negative effect of this on crop production is being funded by WRC, but to date no concerted extension programme to minimize this problem have been launched by the various departments of agriculture.

The Water Act of 1998 specifies that a specific amount of water be kept earmarked to satisfy ecological requirements. All future water balance calculations must include a provision for this ecological reserve, although the application of this principle has not yet been described in full detail.

An estimated 260 000 ha of irrigated land in South Africa is affected by waterlogging and/or salinization. The salinization of about 15 000 ha is serious enough to limit the choice of crops to salt-tolerant species only and would require costly rehabilitation programmes. On balance, salinity would suppress production levels of salt-sensitive crops, but the choice of crops is not seriously limited and treatment with ameliorants and leaching will usually suffice. Government extension personnel and consultants on remedial actions are on hand to advise farmers who experience salinization and/or waterlogging problems and ask for advice.

Rapid urbanization results in informal shanty towns that spring up near cities. In most of these cases waste management is at a very low level or absent. Pollution of water resources happens and the local population becomes threatened by waterborne diseases. Surveys are currently under way to identify high-risk areas and the number of high-risk inhabitants with the aim of launching information and other programmes to reduce pollution. The shifting of water management to the local level through WUAs also transfers the responsibility for the following advisory services to that level:

a) Effective water use and measures to prevent misuse;
b) Environmentally friendly production practices;
c) Prevention of salinization and reclaiming salinized areas;
d) The management of water-borne diseases.

Sedimentation of dams is a problem, especially in the dams that impound parts of the Central Plateau that are covered by the very old rock of the Karoo (Karroo) System and its sediments. As a general rule the soils that develop from this material are prone to erosion and hence some dams in the central parts of the country have lost a substantial amount of their capacity. The exact dimensions of this problem have not been determined but some exceptional cases are known where dams have lost more than 25 percent of their capacity over the last 80 years.

3.8 Prospects for agricultural water management

Provisional estimates are that South Africa will run out of surplus usable water by 2025, or soon thereafter. Inter-basin transfers are in place and more are planned, but due to the high cost of this development, such water is seen as being used for industrial and public needs only and not for irrigation. It is foreseen that in the future the irrigation sector must sacrifice some of its water for public and industrial usage.

The DWAF has three pilot studies in progress to determine what steps WUAs could take to ensure more effective water use in the future. These include an increase in irrigation efficiency according to the benchmarks of crop irrigation requirements and more efficient dam and canal management.

New large-scale irrigation development is not possible because of the limited water availability and the shortage of good irrigable soils within economic distance of water sources. Irrigation development with government and donor funding is mainly limited to the development of community gardens and the revitalization of irrigation schemes in the previously black homelands.

Water demand projections indicated an annual growth of 1.5 percent between 1990 and 2010, ranging from 3.5 percent for urban and industrial use to 1 percent for irrigation. The moderate predicted growth for irrigation is caused by low economic returns on irrigation water and, since 1984, the sharp increase in costs of irrigation equipment compared with a modest increase in agricultural produce prices.

3.9 Transaction costs of irrigation water management

Transaction costs are costs associated with searching (information), negotiation and decision-making and monitoring and enforcement. The most important public transaction costs are related to administration (Falconera and Saunders, 2002). Transaction costs increase as the diversity and number of parties involved increases (Williamson, 2000). Transaction costs explain alternative forms of economic organisations and contractual arrangements.

In many developing countries the management of irrigation schemes is transferred from the government to WUAs to reduce the transaction cost associated with their management (Easter and Zekri, 2003). According to them the same argument can be made for reforming the institutional and organisational arrangements for irrigation systems and water agencies. In empirical studies, a direct measurement of transaction is the economic value of resources used in locating trading partners and executing transactions. The aggregate value of transaction costs in the economy is the total value of resources used in the transaction sector (Wallis and North, 1986). The associations are supposed to have full control over the irrigation infrastructure in the territory they serve. However, problems with under financial of O&M and investments are observed due to incomplete decentralisation processes (Penov, 2004).

The major problems for many irrigation systems are: free riding, rent seeking and corruption (Penov, 2004). Free ridding evokes lack of trust between the actors. Potential rents stimulate efforts to influence public decision-making and evoke corruption. Free ridding can be overcome when farmers are convinced that the benefits exceed cost as well as well as by improvement of communication among them. Establishing institution that do not allow single official to have full control over the resources can help to reduce corruption (Penov, 2004).

Improvement of communication between farmers, irrigation schemes and state institutions could make the parties more aware of the problems and reduce both rent seeking and corruption (Penov, 2004). To reduce the transaction costs of changing government policy, one of the key steps is to reduce the expenses of organisation and involve the stakeholders in specific water management reforms (Penov, 2004). Some specific tasks that will be added to the transaction costs of water reform included designing regulations for allocating water in an open and transparent manner, developing water delivery schedules in conjunction with stakeholders, enacting water-use rights and procedures and resolving disputes over water allocation (Penov, 2004).

3.10 Summary

The review of research on the irrigation schemes in South Africa has provided evidence of considerable knowledge base that has been generated by a number of literature reviews in this chapter. Gaps in knowledge on human, economic and social aspects of irrigation were identified. Filling these gaps is of paramount importance to contribute to improved performance and greater sustainability of various irrigation projects. Generally, the picture of irrigation schemes painted by researchers has been rather bleak, but there has also been evidence of success (WRC, 2011).

It seems that most researchers have concluded that the impact of irrigation schemes to the livelihoods and well-being of irrigators has been limited, despite the substantial public investments that have been made to construct, maintain and revitalise these projects. Against a backdrop of water scarcity, the social and economic value of using irrigation schemes as an option for rural development in South Africa has been questioned, resulting in calls for development focus to shift from irrigation agriculture to dry land agriculture because dry land farming has been proved to be hydrologically neutral (Inocencio *et al*., 2003) Thus, this study attempted to validate the claims and outcomes of the researchers from their studies using Limpopo Province as the case study. Based on literature, it is confirmed that most of the operational irrigation schemes are situated in Limpopo Province.

CHAPTER FOUR

DETAILED DESCRIPTION OF STUDY AREA

4.0 Introduction

This chapter present an overview of the study area (i.e. Limpopo Province), with it districts, economic activities, climatic conditions such as temperature, rainfall and evaporations, catchments, water users associations and general uses of water.

Spedding (1988) as quoted by Backeberg (2006) defines agriculture as an activity of people, which is primarily undertaken for the purposeful production of food and fibre by means of crop cultivation and animal husbandry within constraints of available resources. Some of these available resources include land (soil), water, climate, people and finance. In this section, greater attention was only being paid to climate and water resources. Secondary source of information was used in this chapter.

The Food and Agricultural Marketing Series aims to explore these issues in a rigorous and yet very applied manner and from the perspective of food and agribusiness communicators, brand managers, policy makers, or members of the media reporting. The series brings together the best original research from around the world and offers commentary and practical advice on its implications and applications. The objective is to provide readers with the understanding of the opportunities and risks associated with the industry and the confidence to communicate with and engage consumers and others in the food supply chain in an authoritative, ethical and effective way (NDA, 2011).

4.1 Location of Limpopo Province

Limpopo Province is one of South Africa's richest agricultural areas. It is a major producer of vegetables. The subtropical climate enjoyed by much of the province gives rise to the cultivation of tea, coffee and fruits, especially tropical fruits. Forestry makes a major contribution to the economy, as do tobacco, sunflower, wheat, cotton, maize, and groundnuts. Livestock farming includes cattle ranching and game. The abundance of orchards with various sub-tropical fruits and nuts form the basis of a thriving agro-industrial sector (M'Marete, 2003).

Limpopo is situated at the North Eastern corner of the Republic of South Africa. A unique feature of this province is that it shares international borders with three other countries: Botswana to the west and north-west, Zimbabwe to the north, and Mozambique to the east. Limpopo is the link between South Africa and countries further afield in sub-Saharan Africa. On its Southern flank, the province shares borders with Gauteng, with its Johannesburg-Pretoria axis, the most industrious metropol on the continent. It is divided into the following districts

4.1.1 Capricorn District

The name "Capricorn" is derived from the tropic of capricorn, the bottom of which crosses Limpopo and the northern section of this region. The region of Capricorn stretches from Ysterberg, all along the foothills of the lush Wolkberg, to the tropic of Capricorn in the north. The region's position makes it a perfect stopover between Gauteng and the northern areas of the province and between the country's North-Western areas and the world-renowned Kruger National Park. It is also in close proximity to the neighbouring countries of Botswana, Zimbabwe, Mozambique and Swaziland.

4.1.2 Waterberg District

Situated in the magnificent Waterberg Mountain Range of Limpopo, the Waterberg District is the ideal getaway where the weary traveller can relax and revel in the great natural beauty of the bushveld savannah and its rich wildlife heritage. The Waterberg Mountains stretch along more than 5 000 km2 of spectacular vistas and scenic valleys - the ideal destination off the beaten tourism track. The area is steeped in a history and some artifacts found here date back to Stone Age times. The area is a mosaic of culture and tradition as is reflected by the different rural tribes such as the Bapedi, Tswana and Basotho, while the Voortrekkers also left their distinctive mark on the area.

Commercial agriculture is an integral part of this province, and cattle ranching and maize farming are regional institutions - the water-rich valleys of the Limpopo River on the Botswana border provide sweet bushveld grazing, while the plains of the Springbok Flats near the towns of Bela-Bela and Mokopane are covered with a colourful quilt of carefully cultivated fields of maize and sunflowers (NDA, 2011). Otherwise, the bushveld landscape, interspersed with sandstone buttresses and baobab, marula and fever trees, supports a number of towns that make up one of the country's fastest-growing industrial and agricultural districts.

This is one of the most mineralised regions in the world and numerous towns form part of the Bushveld Igneous Complex - a 50 000km2 treasure trove yielding massive amounts of minerals such as vanadium, platinum, nickel and chromium. The Waterberg District offers the tourist a bit of both worlds - an infrastructure of excellent facilities and modern conveniences found in the many game reserves and conservation areas, coupled with the opportunity to experience the African wilderness in its pristine stat (NDA, 2011).

4.1.3 Vhembe District

Flowing across from the northwest and framing the northern border of this province lays the Vhembe area - a fertile region where baobabs guard the varied countryside and where rock art and caves entice the visitor to uncover its romantic and historical past. One of the main geographical features of this region is the Limpopo, the country's third most important river, which forms South Africa's northern border. This life-giving river provides sustenance to the predominantly hot, dry lands through which it meanders and its many tributaries support several small, thriving farming villages in the region's northern areas.

In this region tourists will find the former independent homelands of Lebowa and Venda where traditional African cultures thrive. In fact, this fertile valley has been home to cultures dating back to the Iron Age. The western section of the region is framed by the rocky spine of the awe-inspiring Soutpansberg (salt pan mountain) range. The range, with a width in some parts over 30km, features a fertile, well-watered plateau receiving high rainfall and supporting a wide range of crops and cultivated lands (M'Marete, 2003).

4.1.4 Mopani District

Driving from Limpopo River across Vhembe District towards East-western side, one comes to the beautiful district of Mopani. Its strategically positioning makes it easily accessible by people from all sides of the province. On the West it borders Sekhukhune while like an Island; Bohlabela spreads through the Eastern side. On the West is Capricorn District. The beautiful towns of Tzaneen, Modjadji's skloof, BaPhalaborwa and Giyani are key to the economy of Mopani. The district consists by the following local municipalities: Greater Letaba, Greater Giyani, Greater Tzaneen and Ba-Phalaborwa (M'Marete, 2003).

4.1.5 Sekhukhune District

Sekhukhune District Municipality is a cross-border municipality between Limpopo and Mpumalanga Province. The district shares borders with Waterberg, Capricorn districts in Limpopo; Nkangala, Highveld District Council, Lowveld Escarpment district in Mpumalanga Province. During the transition period some portions of the Municipality was formerly administered by the Northern District Council, Bosveld District Council, Lowveld Escarpment District Council and Highveld District Council, The Municipality was established as per section 12 of the municipal structures Act 117 of 1998 as a cross boarder District Municipality. It comprises of five municipalities namely: Fetakgomo Municipality, Makhuduthamaga Municipality, Grater Marble Hall Municipality, Greater Groblersdal Municipality and Greater Tubatse Municipality.

According to M'Marete (2003) agriculture contributes 8% to the total value of provincial economic production. However, agriculture together with forestry and fishing contribute 11% to the GDP of the Limpopo Province M'Marete (2003). Many of the rural people practise subsistence agriculture. The most limiting factor to South African agriculture is water. As such, Limpopo Province is no exception. If one considers three soil suitability classes namely: (a) arable, (b) marginal, and (c) non-arable, only the arable land is suitable for irrigation. Even though the total arable land in the province is estimated at 2 3592147 ha (see Table 4.1 below), according to M'Marete (2003) only 181 000 ha is irrigated. This represents only a small portion of 7.7% of the total arable land.

Table 4.1: Soil suitability for the five district municipalities of the Limpopo Province

Soil suitability	Area for various district municipalities			Limpopo Province (13948418 ha)
	Capricorn (1697030 ha)	Mopani (1109798 ha)	Sekhukhune (1338159 ha)	
Arable	283 826 ha	189 651 ha	291 434 ha	2 359 147 ha
Marginal	909 134 ha	536 741 ha	327 960 ha	6 996 713 ha
Non-arable	503 869 ha	380 690 ha	718 538 ha	4 582 786 ha
Total	1 696 829 ha	1 107 082 ha	1 337 932 ha	13 938 646 ha

Soil suitability	Area for various district municipalities		Limpopo Province (13 948 418 ha)
	Vhembe (2 140 708 ha)	Waterberg (4 951 881 ha)	
Arable	249 757 ha	1 220 900 ha	2 359 147 ha
Marginal	1 227 079 ha	2 557 273 ha	6 996 713 ha
Non-arable	661 859 ha	1 171 853 ha	4 582 786 ha
Total	**2 138 695 ha**	**4 950 026 ha**	**13 938 646 ha**

Soil suitability	Area for various district municipalities			Limpopo Province (13948418 ha)
	Capricorn (1697030 ha)	Mopani (1109798 ha)	Sekhukhune (1338159 ha)	
Arable	16.7%	17.1%	21.8%	16.9%
Marginal	53.6%	48.5%	24.5%	50.2%
Non-arable	29.7%	34.4%	53.7%	32.9%
Total	**100%**	**100%**	**100%**	**100%**

Soil suitability	Area for various district municipalities		Limpopo Province (13 948 418 ha)
	Vhembe (2 140 708 ha)	Waterberg (4 951 881 ha)	
Arable	11.7%	24.7%	16.9%
Marginal	57.4%	51.6%	50.2%
Non-arable	30.9%	23.7%	32.9%
Total	**100%**	**100%**	**100%**

Source: ARC (2011) – Institute for Soils and Climate

4.2 Climatic conditions of Limpopo Province

Limpopo Province is situated in a dry savannah sub-region, characterized by open grasslands with scattered trees and bushes. Elevation varies between 600 m and about 900 m above mean sea level (amsl). Broadly, the province has a sub-tropical type of climate. Generally summers have a high number of sunshine hours with the occasional afternoon thunderstorms. Winters throughout the province are dry, mild and mostly frost-free. Hence, winters are usually characterised by pleasant weather during the day although early mornings and nights can be cool to chilly. The province receives 90% of its total annual rainfall during the summer period i.e. from October to March. Hail occurs periodically, rarely more than three days per year (M'Marete, 2003).

Table 4.2 Climatic elements of a few Agro meteorological stations from different districts in the Limpopo Province

Station	Rainfall (mm)	Evaporation (mm)	Temperature (OC)		Humidity (%)	
			MAX	MIN	MAX	MIN
Waterberg District Municipality						
Vaalwater: Elandskloof	606.3	1 854.6	26.5	11.1	82.1	28.3
Towoomba: Warmbad	630.4	2 102.0	25.2	11.3	73.8	26.1
Settlers: Landbouskool	633.3	1 915.9	27.4	10.6	78.9	30.4
Ellisras	413.1	2 183.2	29.1	14.5	-	-
Thabazimbi	601.9	2 443.6	28.0	11.9	-	-
Vhembe District Municipality						
Messina: Proefplaas	347.3	2 761.1	29.8	15.5	76.7	30.8
Levubu: Citimba	1 329.4	1 234.5	25.5	15.1	81.2	45.5
Mara: Agri-Soutpansberg	453.4	1 965.8	25.2	12.5	83.7	33.5
Louis Trichardt: Levubu	925.4	1 633.4	26.4	15.2	81.9	37.6
Sigonde	382.9	2 443.8	30.0	16.0	82.0	40.6
Capricorn District Municipality						
Polokwane: U of Limpopo	471.4	1 974.4	24.8	10.3	86.0	32.1
Bochum	379.2	-	-	-	-	-
Sekhukhune District Municipality						
Zebediela	497.9	-	-	-	-	-
Mopani District Municipality						
Letaba Letsitele	800.7	1 678.9	27.6	14.8	86.2	36.2
Bavaria Fruit Estate (Palaborwa)	517.5	1 463.1	28.3	15.7	91.1	41.7

Source: M'Marete (2003)

4.2.1 Temperature

Daily temperatures vary from mid-20's to mid-30's with an average range of between 17° and 27°C in the summer and 4° to 20°C in the winter. Temperatures range from a high average of 21°C in the upper catchments, to a very high average of 25°C in the Kruger National Park (KNP) as shown in table 4.2. Frost rarely occurs. Certain areas can be extremely hot with maximum daily temperatures at times reaching as high as 45ºC (M'Marete, 2003).

According to Koegelenburg and Breedt (2003), various methods have been evolved for evaluating the effect of temperature on crop distribution. One simple method is determining the length of the growing season. In areas where water is not a limiting factor, the average length of the period between the first killing frost in winter or early spring and the first killing frost in autumn is a useful means of defining the growing season. In most parts of Limpopo Province, frost rarely occurs and as such the boundary between these seasons is almost not there. Therefore, temperatures are suitable for most crops in the province. However, due to variation in relief, various crops are grown where the weather and climate are most suitable45ºC (M'Marete, 2003).

4.2.2 Rainfall

Most of the rain falls in the summer months between October and March. Table 4.2 shows that the average annual rainfall in the province ranges between 300 - 400 and 600 mm. However, the mountain zone has an annual rainfall of about 2 000 mm and the dry lowveld in the Kruger National Park about 400 mm. About 90% of the rain falls during the summer months. The Soutpansberg Mountains and the Drakensberg receive quite high amounts of rainfall. For example Levubu - Citimba station records an average rainfall of about 1 329 mm (M'Marete, 2003).

Around the Waterberg mountain ranges near Thabazimbi, summers are hot but the area does not suffer from the stifling humidity so typical of the eastern Lowveld. The area is situated in the summer rainfall region and rainfall occurs in the form of heavy thunderstorms or soft rain. Winter is moderate with frost occurring in the low-lying regions only. Mornings and nights can be cold, but day temperatures are pleasant. The rainfall in this area is between 500 and 700 mm per annum.

4.2.3 Evaporation

According to Koegelenburg and Breedt (2003), annual evaporation increases gradually from 1 400 mm in the west to 1 900 mm in the east. About 60% of the evaporation occurs during the six months from October to March. The average annual potential evaporation in the Province is higher than the rainfall in almost all areas. However, the rates differ from place to place depending on the topography. One of the areas with the highest rate of evaporation is around Musina. The annual rate of evaporation in Musina exceeds 2 700 mm. The average for the province is about 1800 mm per annum 45ºC (M'Marete, 2003). Since the average potential evaporation is well in excess of the annual rainfall, this appreciably affects surface runoff from rainfall and causes high evaporation losses of water from storage dams (see table 4.2 above).

4.3 Water resources

The Department of Water Affairs and Forestry (DWAF) classifies Limpopo Province as a water-stressed country, prone to erratic and unpredictable extremes such as floods and droughts that reduce land to a dry and arid wasteland (M'Marete, 2003).

The management of water resources in South Africa is based on the concept of "Catchment Management Areas". This is a departure from the past when water was managed based on Political boundaries. In Limpopo Province, there are 4 (four) Management Areas namely: Limpopo; Luvubu and Letaba; Crocodile Wee and Merico and Oliphants. These four management areas are shown in Figure 4.1.

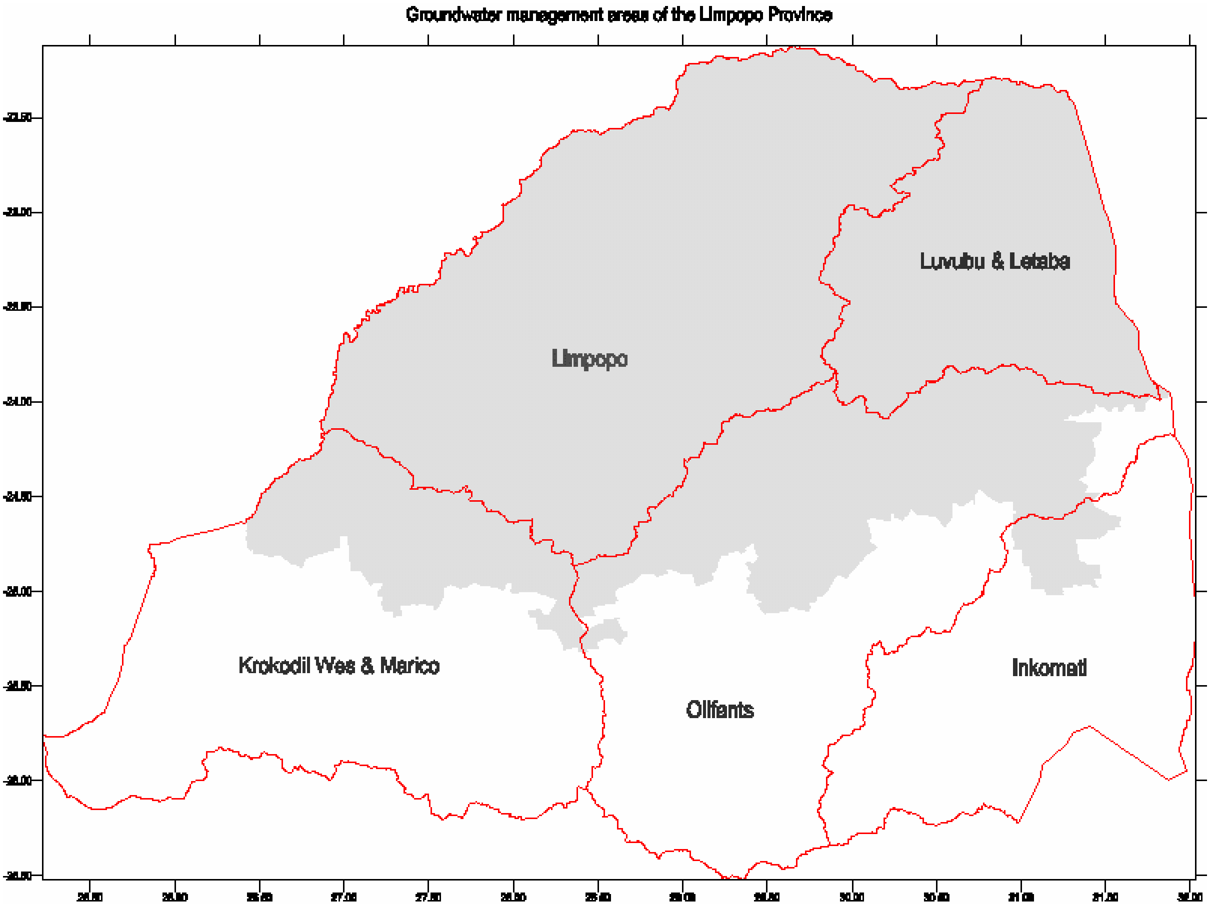


Figure 4.1 Water management areas in the Limpopo Province

Source: M'Marete (2003)

4.4 Surface water

Limpopo Province is a particularly dry province and is unable to meet its water needs from its local supplies. There is currently a critical demand for water and sanitation delivery in the Limpopo Province, which demands a significant response and level of intervention. The majority of the historically disadvantaged population is without clean running water. However, the government is trying to address these problems by developing and managing water resources efficiently. For this purpose, various dams have been proposed in different places and some are already under construction (e.g. the Nandoni Dam in Vhembe District Municipality). When completed, it will supply water for both domestic and irrigation purposes in the neighbouring areas.

The Limpopo catchment covers the largest part of the province and it drains the western part of the province. The main tributaries include Matlabas, Mokolo, Palala, Mogalakwane, Sand, Nzhelele, Nwanedi, Levuvhu, and Matale. The tributaries mainly flow in the northerly direction into the Limpopo River (M'Marete, 2003).

The Oliphant's river system drains the province to the east of the escarpment. Major rivers in the Oliphant management area include the Elands, Wilge, Steelpoort and Oliphant River. The water management area stretches from Delmans in Gauteng, though Mpumalanga and the Northern Province to the Limpopo River in Mozambique. The Oliphant's water management area is divided into five sub-catchment – the upper, upper middle, lower middle, mountain and lower catchment. Even though the Oliphant is a perennial river, it has been known to have zero flow during short period as it enters Kruger Park (M'Marete, 2003).

The Luvuvhu River and all its tributaries rising in the Soutpansberg are perennial. The Luvuvhu River and the Sterkstroom rise on the southern side of the Soutpansberg Mountains east of Louis Trichardt between 1 000 and 1 400 m above mean sea level (amsl). Further eastwards, the Latonyanda, Dzindi, Mutshindudi and Mutale tributaries joins the Luvuvhu, all originating from within the mountain ranges east of the Entabeni and Vondo forestry areas. The Luvuvhu River traverses the Kruger National Park and joins the Limpopo River at Crook's Corner on the Mozambique border. Dams in the Luvuvhu River catchment include the Albasini Dam and the smaller Mambedi, Tshakhuma, Damani, Vondo, and Phiphidi Dams, of which the latter two lie in the Mutshindudi River. The Nandoni Dam is currently being constructed in the middle section of the Luvuvhu River east of the confluence with the Dzindi tributary and east of the town of Thohoyandou (See Table 4.3).

The Groot Letaba, Politsi, Debengeni, Thabina and Letsitele rivers in the Northern Drakensberg Mountains between 1 100 and 1 800m above mean sea level (amsl) and cascade down the steep slopes in a north easterly direction IWMI (2002) as cited by (M'Marete, 2003). The undulating plains of the lowveld catchment are drained by the Groot Letaba River and its major tributaries, the Klein Letaba, the middle Letaba, Nsami and Molototsi rivers. The Letaba River flows eastward across the Kruger National Park (KNP), where it joins the Oliphant's River a short distance upstream of the Mozambique border. More than 20 major dams have been constructed in the Groot Letaba River catchment. The Tzaneen Dam on the Groot Letaba River and the Middel Letaba Dam are the two largest dams in the Limpopo Province. Some of the hydrological characteristics of these two catchments are presented in Table 4.3 while Table 4.4 shows some of the dams in the Limpopo Province.

Table 4.3: Hydrological characteristics of Luvuvhu catchments

Catchment	**Area (km^2)**	**Mean annual precipitation – MAP (mm)**	**Mean annual evaporation (mm)**	**Annual runoff**	
				Range	**Mean (MAR)**
Luvuvhu	5 941	608	1678	85 - 1900	519
Letaba	13 670	612	1669	100 - 2700	574
Oliphant's	54 475	631	1700	500 - 3700	1 992

Source: International Water Management Institutes (IWMI), (2002) Mean annual runoff (MAR) in the Letaba Catchment varies from more than 10% of the mean annual precipitation (MAP) in the wet mountainous zone to less than 2% in the drier parts of catchment. More than 60% of the MAR in this catchment derives from only 6% of the area (IWMI, 2002).

Limpopo Province benefits from the Limpopo-Oliphant's river system, encompassing 77 dams constructed to maximise the use of surface water (IWMI, 2002). Some of the main dams in the Limpopo Province are presented in table 4.4.

Table 4.4 Main dams in Limpopo Province

Limpopo Catchment		**Olifants Catchment**		**Komati Catchment**	
Name of Dam	**Area (10^6**	**Name of Dam**	**Area (10^6**	**Name of Dam**	**Area (10^6**
Mokolo	148.7	Shingwedzi	1.3	Orinonco	1.8
Doorndraai	47.3	Arabie	104.0	Edinburg	3.2
Glen Alpine	21.9	Piet Gouws	7.4	Casteel	62.1
Donkerpoort	3.4	Tours	5.5	Zoeknog	7.4
Welgevonden	0.7	Middle Letaba	184.0	Cross	-
Nzhelele	57.3	Nsami	24.0	Tshekhuma	-
Nwanedi	5.6	Tzaneen	160.2	Mbwedi	-
Luphephe	15.0	Ebenezer	68.9	Mutshedzi	-
Bgross	1.8	Magoebaskloof	5.6		
Albasini	25.2				
Vondo	5.3				
Nadoni	-				
Tshakhuma	-				

Source: M'Marete (2003)

The Levuvhu Water Scheme was inaugurated by the Minister of Water Affairs and Forestry on 18 April 1999. It will provide nine million people in Limpopo Province with drinking water. The scheme was established so as to stabilise the water supply for irrigation and alleviate water shortages in the Kruger National Park. The scheme will be run through the Department of Water Affairs and Forestry's CWSS programme while municipalities gain the experience and capacity needed to handle the provision of services. According to

M'Marete (2003), construction of the Nandoni Dam stated in May 1998 and it stated to store water from January 2003. The total cost of the project was R750 million.

4.5 Groundwater Resources

Groundwater, despite its relatively small contribution to bulk water supply (13%), represents an important and strategic water resource in South Africa. Owing to the lack of perennial streams in the semi-desert parts, two thirds of South Africa's surface area is largely dependent on groundwater. Although irrigation is the largest user, the supply to more than 300 towns and smaller settlements is also extremely important. On the irrigable land in South Africa, 24% is irrigated using groundwater supplies while surface water irrigates 76% (Dennis and Nell, 2002). Statistics from the Directorate of Water Services and Forestry (DWAF) reports that 52.6 percent of the population of the Limpopo Province is totally reliant on groundwater for domestic use. Table 4.5 shows the uses of groundwater in the four water management areas of Limpopo Province while table 4.8 shows the area irrigated using groundwater. A graphical presentation of data presented in table 4.5 is shown in figure 4.2.

Table 4.5 Groundwater use in the four catchment management areas of Limpopo Province

USE	Water Management Areas								LIMPOPO PROVINCE	
	Limpopo		Letaba/levub		Oliphant's		Crocodile			
	M m^3	%	M m^3	%	M m^3	%	M m^3	%	M m^3	%
Irrigation	131.0	63.0	9.0	15.7	79.0	69.3	56.0	67.5	**275.0**	59.5
Livestock	3.0	1.4	0.2	0.3	2.0	1.8	3.0	3.6	**8.2**	1.8
Rural communities	53.0	25.5	38.0	66.4	20.0	17.5	6.0	7.2	**117.0**	25.3
Municipaliti es	12.0	5.8	8.0	14.0	2.0	1.8	8.0	9.6	**30.0**	6.5
Mining	9.0	4.3	2.0	3.5	11.0	9.6	10.0	12.0	**32.0**	6.9
TOTAL	**208.0**	**100.0**	**57.2**	**100.0**	**114.0**	**100.0**	**83.0**	**100.0**	**462.2**	**100**

Source: Du Toit (2002)

4.6 Utilization of water resources in Limpopo Province

4.6.1 Irrigation

It has already been noted that Limpopo Province is relatively a dry area, with average annual rainfall in the region of 400 mm. However, the rivers that run through the province plus the inter-basin transfer provide water for irrigation for about 200 irrigation schemes that have been established. One of the greatest problems affecting agriculture in South Africa is the scarcity of water. Nevertheless, the demand for water is increasing all the time and there is competition for water from other sectors of the economy. Table 4.6 shows the water consumption of different sectors over time for the whole country. It can be seen that irrigation consumes by far most of the water. Therefore, irrigation will have to be more efficient to be able to meet the demand.

A close look at Table 4.6 shows that even though the demand for irrigation water has been increasing, the percentage water use against the total consumption has been falling with time from 52.2% in 1980 to a projected value of 45.9% in 2010. But since the population is increasing, it means that a unit quantity of water will have to produce more food than before so as to feed the increasing population. Either new technologies will have to be developed that can save water or the irrigation efficiency of the existing projects will have to be improved one way or another. This applies to all irrigation projects in South Africa and especially the small-scale irrigation projects. As ARC (2011) puts it, 5% increase irrigation efficiency could result in water saving of 550 million m^3 per year which was enough to supply the domestic demand for the Durban-Pietermaritzburg area in the year 2000.

Table 4.6 Expected volume and percentage of water use against its total availability

Sector	**1998**		**1990**		**2000**		**2010**	
	(10^6m	(%)	(10^6m^3/a	(%)	(10^6m^3/	(%)	(10^6m^3/a	(%)
Direct consumption								
Domestic	1,5	9.3	2,281	12.0	3,220	14.4	4,477	17.3
Industry	1,0	6.3	1,448	7.6	2,043	9.1	2,961	11.4
Mining	4	2.9	511	2.7	582	2.6	649	2.5
Power Plants	2	1.7	444	2.3	779	3.5	900	3.5
Irrigation	8,5	52.2	9,695	50.9	10,974	48.9	11,885	45.9
Stock watering	2	1.6	288	1.5	316	1.4	368	1.4
Nature Conservation	1	1.1	182	1.0	187	0.8	191	0.7
Indirect consumption								
Decreased runoff	1,2	7.9	1,427	7.5	1,570	7.0	1,700	6.6
Ecological demand:	2,7	17.0	2,767	14.5	2,787	12.3	2,767	10.7
TOTAL	16,2	100	19,043		22,458	100	25,898	100

Source: Institute for Agricultural Engineering (2011) – Agricultural Research Council (2011).

4.6.2 Domestic water supply

According to projections presented in Table 4.6, domestic water supply is the second largest consumer of water after irrigation. According to ARC (2011) by the year 2010, domestic water supply will be using over 17% of the total available water nationally. Considering that Limpopo Province has the highest percentage of rural population in South Africa, many of them do not have access to tap water, it means that by the time the government supplies water to all these people, there will be severe competition for water with other users like irrigation and industries.

4.6.3 Forestry

Country wide, water requirements for afforestation are estimated at 1 604 million m^3 per annum or 8% of total requirements (Backeburg, 2006). The Limpopo Province has a big share of forested area compared to other parts of the country. This means that a substantial amount of water is used in forestry in Limpopo Province.

4.6.4 Mining and other industries

Mining activities consume substantial amount of water. However the most serious effect of mining on water resources is pollution. If mining waste is not disposed of properly, it can lead to serious water quality problem. There are different mining operations in the province contributing to over 20 per cent of value of Limpopo's economic production (M'Marete, 2003). This makes mining the primary driver of economic activity after government services. Substantial mineral reserves include platinum, diamonds, coal, chrome, vanadium, nickel, iron ore, copper, titanium, gold, asbestos and phosphates. The largest copper and coalfields are found in this province. The feldspar copper mine, at

Naboomspruit in Phalaborwa, on the Kruger National Park border, is repute to be the world's largest open-cast copper mine; Thabazimbi is also an important iron mining centre. Nationally, mining consumes about 2.7% of the total water (see Table 4.6). In the second phase of this work, an attempt will be made to establish how the mining industries are using water in the Province and the state of effluents from these industries. Electricity generation is another user of water in the Province – for example the Matimba Power Station in Ellisras. In addition, Limpopo Province has a busting light engineering sector. However, these do not consume much water.

4.7 Formation of Water User Associations

Various government departments give grants (subsidies) to farmers. One qualifies to benefit from the grant administered by DWAF if one is a member of a registered Water User Association (WUA), this requirements makes it almost impossible for the emerging farmers to benefits from these grant schemes, as many of them do not belong to registered WUAs.

The resource poor agricultural sector (subsistence farmers, small-scale farmers and emerging farmers) need to be assisted in organising themselves into a WUAs. The whole process of forming a WUA is lengthy, tedious, and not easily understood by the rural folks the majority of which are not even literate. Where the resource poor farmer and the commercial farmers share the same water source, they need to talk to each other before they can form a WUA. Examining these two groups of farmers shows that the resource poor farmers are mainly black women while the commercial farmers are mainly white males. Getting these two groups of farmers with very few common interests to sit down and talk about the formation of a WUA is not an easy task (M'Marete, 2003).

The LDA should take concrete steps in order to assist the resource poor farmers in forming WUAs if they are to benefit from the various grants given by the government. Once the WUAs have been registered, there would be a need to train the elected office bearers because some of them may lack managerial ability. Therefore, the training should be directed at the WUA management committee. The training should focus on things such as scheme water supply management and institutional aspect.

4.8 Summary

For the study in irrigation schemes, it is of paramount importance to review the geographical and climatic conditions of the study area. Geographical location is important because it determines what water sources are available and land with steep slopes cannot be used for annual crops. Climatic conditions are important because plants are accustomed to particular climate ranges, and will not thrive in the wrong climate and climate determines the length of the growing season. Limpopo has wide climatic variations. Polokwane, reflective of the province, offers a pleasant climate for most of the year. Blessed with year-round sunshine, it can get really hot in the summer months (October-March), averaging 27 degrees Celsius. Winter is a sunny season of chilly mornings, warm mid-days, dry afternoons and cool to cold nights. The Lowveld, i.e. the Phalaborwa area, can be as hot as 45 degrees Celsius during summer.

CHARPTER FIVE

RESEARCH METHODOLOGY

5.0 Introduction

This chapter presents a detailed description of the analytical technique employed in the sampling activities, type of data and methods of data collections used in this study. Also in this chapter, an effort has been made to explain some definitions, historical development of approaches used to measure technical efficiency with special emphasis on the stochastic frontier production function.

5.1 Data set

Limpopo Province is divided into five districts wherein, each district having a number of small-scale farmers at different irrigation schemes. Capricorn, Waterberg, Sekhukhune, Mopani and Vhembe are five districts of Limpopo Province. The farmers at different irrigation schemes in all the five districts of Limpopo Province were selected for this study.

One crop and three selected vegetables were chosen and these are maize, tomato, spinach and onions. Maize was chosen because in Limpopo Province as a whole, it is regarded as the main staple food and the major cash crop among the small-scale farmers, occupying more than 50% of all land cropped and providing more than 65% of gross farm income (NDA, 2011). Selected vegetables such as tomato, spinach and onions were selected for the purpose of the study since they also serve as the stable food and they are occupying more than 50% of the entire irrigation schemes in Limpopo Province.

5.1.1 Information sources

Primary data were collected in two stages. In the first stage verbal discussions were held with the leaders of the irrigation schemes. In the second stage farm level data were obtained from a cross-sectional survey of farmers at different irrigation schemes in Limpopo Province. Data on household composition, farm production, and inputs were collected via a structured questionnaire (See Appendix two) which was administered to 200 farmers at different irrigation schemes.

The institutional arrangements of the irrigation schemes in Limpopo Province were identified by the study to be integrated water management organisation, specialised water management organisation and multipurpose water management organisation. A composition of farmers operating as integrated (80), specialised (60) and multipurpose (60) management practices of the irrigation schemes were selected respectively in 2010 for the purpose of this study. Table 5.1 below presents the name of the irrigation schemes, district and management practices of the irrigation schemes from which farmers were sampled.

Table 5.1: Irrigation schemes sampled for the purpose of study.

Name of the irrigation scheme	District	Management practice
Elandskraal irrigation scheme - Krokodile - Petwane - Mogalatsane - Setlaboswana Strydkraal irrigation scheme - Ikageng - Kgoshi Masha - Mabokotswane - Mooiplaas	Sekhukhune	Integrated water management Specialised water management Multipurpose water management
Kalkfontein irrigation scheme Paprika irrigation scheme Mthikana irrigation scheme Rameeetse irrigation scheme Welgevenden irrigation scheme	Waterberg	Integrated water management Specialised water management Multipurpose water management
Sundays river irrigation scheme Calais selati irrigation scheme Blyde irrigation scheme Klein Letaba irrigation scheme	Mopani	Integrated water management Specialised water management Multipurpose water management
Sepitsi irrigation scheme Ramakgopa irrigation scheme Emang ka maoto irrigation scheme Faith farming irrigation scheme Mapps irrigation scheme	Capricorn	Integrated water management Specialised water management Multipurpose water management
Mamvuka irrigation scheme Mamuhohi irrigation scheme Tshiombo irrigation scheme Mandiwana irrigation scheme Luvhada irrigation scheme Cordon irrigation scheme	Vhembe	Integrated water management Specialised water management Multipurpose water management

Source: Field Survey

5.1.2 Design of the questionnaire

The survey is designed to capture information on the performance of farmers at different irrigation schemes. Therefore, the questionnaire was designed in such a way that reasonably accurate data/information is obtained to test the hypotheses of the study and the general evaluation of the performance of these farmers.

The questionnaire was organised in such a way that it covers inputs and outputs plus some households' information. It was administered during a single interview. The questionnaire had some open-ended questions to allow the respondents to give more information. The questionnaire is shown in Appendix one.

5.1.3 Sampling Procedure

The study clustered the five districts according to the three irrigation management practices and a sample of farmers (at least 60) from each management practices of the irrigation scheme was taken into consideration for this study. Stratified random sampling, snow ball and clustered techniques were all employed for the identification of various irrigation schemes and isolation of the irrigation schemes that were not falling within the three different management practices. The remaining farmers were randomly sampled and clustered according to their types of management organisation of their irrigation schemes. The overall sample size for this study was 200 farmers at different irrigation schemes.

5.1.4 Interview Procedure

Interviews in each irrigation scheme were conducted with the help of enumerators. Most of the selected enumerators are university students and employees of the Department of Agriculture at the local level. Two Agricultural extension officers offered their assistance in data collection wherein one was in Vhembe district and the other was in Mopani district. In the other three districts tribal authorities’ process were followed in collecting data by the identified enumerators. Representatives of the various irrigation schemes were consulted a week before the real interview took place.

To each and every farmer sampled, the research objectives and questionnaire were first discussed and explained. Permission was then granted. When granted, the interviews commenced. In all cases participants were very willing to respond. The enumerators helped to interpret questions from English to the local languages in some of the irrigation schemes. At times the interview had to digress from the questions on the questionnaire and this was found to be helpful as it gave more insights into the characteristics of the farmers and also established a good rapport between the enumerator and the respondents.

During the data collection, farmers at different irrigation schemes were not aware as whether their irrigation schemes were falling in any of the management practices of the irrigation schemes. Nevertheless, it was the competencies of the enumerators and the researcher to classify farmers according to the management practices of the irrigation schemes.

5.2 Ethical consideration

The issue of ethics is very important when dealing with the living organisms. The study dealt with human beings (farmers in different irrigation schemes). The main objective behind the ethics clearance was to make sure that the nature of the dissertation does not embarrass, harm, impose or even negatively affect the livelihood of farmers who served as the survey respondents.

The researcher clearly informed the respondents about the aim, procedure and risk involved in the study where, the consent of the participant was seriously considered. The respondents were guaranteed confidentiality of the information provided during the interview and was allowed to withdraw at any-time if uncomfortable due to some questions. The respondents were promised that the outcomes of this study would be presented to the concerned farmers as a form of recognition and to maintain a good future relationship. The researcher followed all the necessary procedures to make sure that the clearance application forms, consent forms and all accompanying documents are legally obtained from the Turfloop Research Ethics Committee (TREC), completed and attached to the thesis as appendix three.

5.3 Analytical techniques and historical background of the model

5.3.1 Concept of production function

In this study production function means a technical relationship that transform factors of production such as land, labour, capital and entrepreneur that are combined together into outputs. Factors of production have derived demand because factor of production alone provide no utility to human being. According to Beattie and Taylor (1985) as cited by Chavas *et al.* (2005), production function is the maximum output that a firm can produce from a given set of inputs with a given state of technology. According to Doll and Orazem (1984), a production function in algebraic form is expressed as

$$Y = f(X_1, X_2, X_3, X_4 / X_5, X_6 ... X_n) \ , \qquad (1)$$

where, Y denotes output of a firm or farm, X_1 to X_4 shows a vector of variable inputs, X_5 to X_n are the bundle of fixed inputs and f represents the suitable functional form.

The above function implies that the inputs used in the production process are of a different nature. Quantity of some inputs is varied during the production process while quantity of other inputs remains fixed. Therefore, the inputs used in the production process are divided into variable inputs and fixed inputs (Doll and Orazem, 1984). The variable inputs are those whose quantity could be wide-ranging during a specified period of time or the inputs that the farmer has control of or inputs that the producer can alter its quantity during the production process. Fixed inputs refer to those inputs whose quantity remains constant in the production process for a specified period. Thus two time periods, namely short-run and long-run periods are involved. In the long-run, all inputs used in the production process are considered as variable inputs, while one input is considered fixed and all other inputs are assumed to be variable inputs in the short-run.

The following assumptions are made for production functions (Mohr, 2012):

i. The first assumption is mono-periodicity. This assumption states that the production activity of a firm in one time period is totally irreconcilable or independent of production in preceding and following time periods.
ii. All inputs and outputs in the production process of a firm are of the same nature. This phenomenon is called homogeneity.
iii. The production function is differentiated twice.
iv. The production function and output-input prices are known. There exists no uncertainty regarding production function and input-output prices.
v. The accessibility and availability of input is not limited. This is a revealing that there is no budget constraint.
vi. The objective of the firm is to maximize profit or to minimize costs.

5.3.2 Concept of production frontier

Production frontier is defined as the relationship between input and output. The production frontier function represents the utmost possible output reachable from a given level of inputs. It reflects the highest output that can be attained at each input level given the current state of technology in the industry (Coelli *et al*., 1998). The production frontier is used as a standard against which the technical efficiency of production of a firm, farm or organisation is measured. Farrel (1957) as cited by Mushungi and Belete (2005) referred to the frontier as the best practice for efficiency studies.

An average production function used to assess efficiency and optimum usage of inputs has been criticised on various bases. Average production function represents the mean output for a given level of input and this is the important distinction between the production frontier and the average production function.

Upton (1979) points out that the average production function is not an adequate representation of a complex and dynamic farming system. Simultaneous equation bias and the problem of multi-collinearity are raised by Yotopoulous and Nugents (1976). Ghatak and Ingersent (1984) are of the view that average production approach cannot distinguish between technical and allocative efficiency. It is possible that allocation of resources could be below the maximum technically efficient level, mainly due to the factors, such as lack of ability, knowledge and attitude.

Thus, to avoid such problems inherited in the average production function, production frontier has been used for the present study to estimate technical efficiency of maize and selected study vegetables (tomato, spinach and onion) growers.

5.3.3 Differences between productivity and efficiency

Productivity is a gauge of the output in physical terms with the use of certain quantity of inputs or simply, it is output produced per unit of inputs. Productivity is of two types which are total factor productivity and partial productivity. The former means that all factors of production are drawn in to measure productivity while the latter involves sub-set of factors of production e.g. labour productivity and land productivity (Hassan, 2004).

Efficiency is used to assess economic performance of a firm, farm or organisation and usually refers to the economic or productive efficiency of a firm, farm or organisation, which means, it is thriving in producing as much output as feasible from a known set of inputs (Farrell, 1957).

According to Koopmans (1951), a producer is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in at least one input requires an increase in at least one other input or a reduction in at least one output.

Efficiency has two components as identified by Farrell (1957) i.e. technical and allocative efficiency. Technical efficiency is the capability of a firm to produce as much output as achievable with given sets of inputs or the capacity of a firm to use as modest inputs as possible for a given level of output. The former is called input oriented efficiency measure and the latter is known as output oriented measure of technical efficiency. Technical inefficiency occurs when less than the maximum output is obtained with on-hand factors of production and it arises when timing and method of application of production inputs are mismanaged.

Allocative or price inefficiency arises when the ratio of marginal products of inputs is not the same as the ratio of market prices. According to Lovell (1993), a firm working allocatively efficient combines inputs and output in optimal combinations in the light of established prices. Economic efficiency is the combination of technical and allocative efficiency.

Based on Bhagavath (2013) seminal work, the input-oriented efficiency measure is used to illustrate the concepts of technical, allocative and economic efficiency. In figure 5 .1, two inputs factors; X_1 on the horizontal axis and X_2 on the vertical axis are used to generate a single output. SS' is the unit isoquant showing different combinations of two inputs to produce a single level of output, say Y. all combinations of inputs on this unit isoquant show technically efficient production.

Point Q on the efficient unit isoquant, SS', reflects that the firm is producing technically efficient at this point. Assume a firm is producing at a point P as shown in figure 5.1. At point P, the firm produces the same level of output Y as produced on unit isoquant, SS'. Now, the line from origin O to the point P, explain the technical efficiency of the observed firm. This OP line passes through the point Q showing that the same level of output, Y is produced with X_1 and X_2 inputs at the point Q (Coelli *et al*., 1998) as cited by Bhagavath (2013).

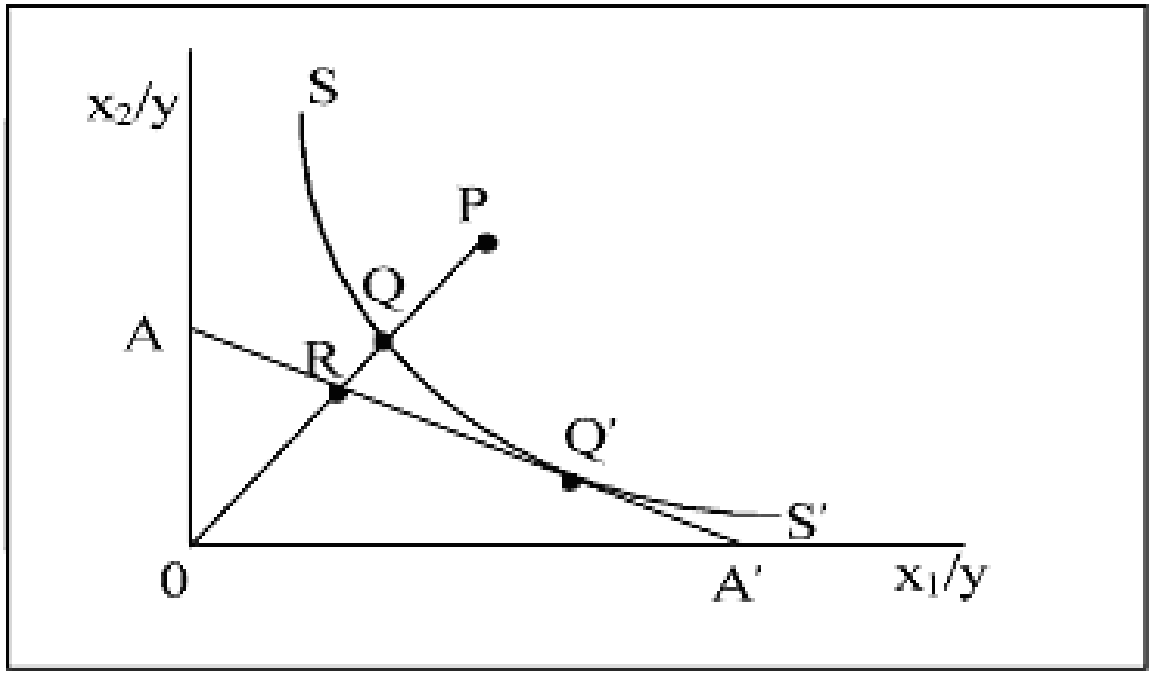


Figure 5.1 Technical and allocative efficiencies

Source: Coelli *et al*., (1998) as cited by Bhagavath (2013).

This reflects that the observed firm is producing technically inefficient, single the equal level of output, Y is produced using additional inputs at the point P compared to point Q. Thus, the technical efficiency of the observed firm can be delineated as the ratio of the distance from the point Q to the origin over the distance of the point P from the origin.

$$TE = \frac{OQ}{OP},$$

where TE represents the technical efficiency, OQ represent the distance from the point Q to the origin and OP represents the distance from the origin to point P.

When the prices of inputs are given, allocative efficiency could be calculated. An isocost line, AA', is drawn tangent to the unit isoquant at the point Q'. The slope of the isocost line represents the input price ratio. The allocative efficiency is defined as

$$AE = \frac{OR}{OQ},$$

Where AE represents the allocative efficiency, OR represents the distance from the origin to point R and OQ represents the distance from the origin to point Q.

The distance RQ shows the diminution in production costs that would occur if production were to happen at the point Q'. The production at the point Q' is both technically and allocatively efficient compared to the point Q where the production is technically efficient but allocatively inefficient (Coelli *et al*., 1998). Economic efficiency (EE) is defined as the product of technical and allocative efficiency.

$$EE = TE \times AE$$
$$EE = \frac{OQ}{OP} \times \frac{OR}{OQ}$$
$$EE = \frac{OR}{OP}$$

5.3.4 Measurement of technical efficiency

A number of frontier approaches are used to measure technical inefficiency. Schematic representation of methods of analysing technical efficiency is given in figure 5.2. On the whole two approaches are used to estimate technical efficiency. These comprise frontier approach and non-frontier approach. Frontier approach is adopted to estimate technical efficiency on the basis of reasons discussed above in 5.2. Frontier approach for cross sectional data is further divided into two types, namely non-statistical methods and statistical methods.

Non-statistical methods include non-parametric and parametric approaches. The former is called deterministic approach having no fixed functional form for frontier including all observations in the model. It is also called data envelopment analysis (DEA) method. The latter is called probabilistic approach based on Cobb Douglas or other form concerning dropping of outliers. Statistical methods consist of non-stochastic and stochastic methods. Non-stochastic frontier approach measures technical efficiency signifying that all variation from frontier is the consequence of inefficiency. Stochastic frontier function (SF) implies that deviation from frontier is owing to random effect and inefficiency. Statistical methods are estimated by maximum likelihood (ML) and corrected ordinary least squares (COLS) methods (Ali and Byerlee, 1991).

In literature, two approaches parametric and non-parametric have been adopted to find out technical efficiency of various enterprises. Parametric approach involves econometric modelling and mathematical modelling is involved in non-parametric (DEA) approach. These two approaches have certain advantages and disadvantages over each other and these advantages and disadvantages are discussed by Battese (1992); Bravo-Ureta and Pinheiro (1993); Forsund *et al*. (1980); Fried *et al*. (1993); Coelli (1996); Coelli and Perelman (1999).

Some of the disadvantages of non-parametric approach (DEA) are as follows;

i. Schmidt (1986) argued that the results obtained by non-parametric approach might be less precise because non-parametric approach makes less use of information than the parametric approach.
ii. A sub-set of observations is used to measure the frontier. Therefore, Farrell's model is sensitive to extreme observations and measurement error (Forsund *et al*., 1980).
iii. One limitation of this approach is that it is difficult conceptually to separate the effects of uncontrollable environmental variables and measurement error from the effects of differences in farm management (Jaforrullah and Whiteman, 1999).

iv. The other disadvantage of DEA is that, tests of hypothesis in relation to differences in technical efficiency cannot be performed statistically (Schmidt, 1986; Jaforrullah and Whiteman, 1999).

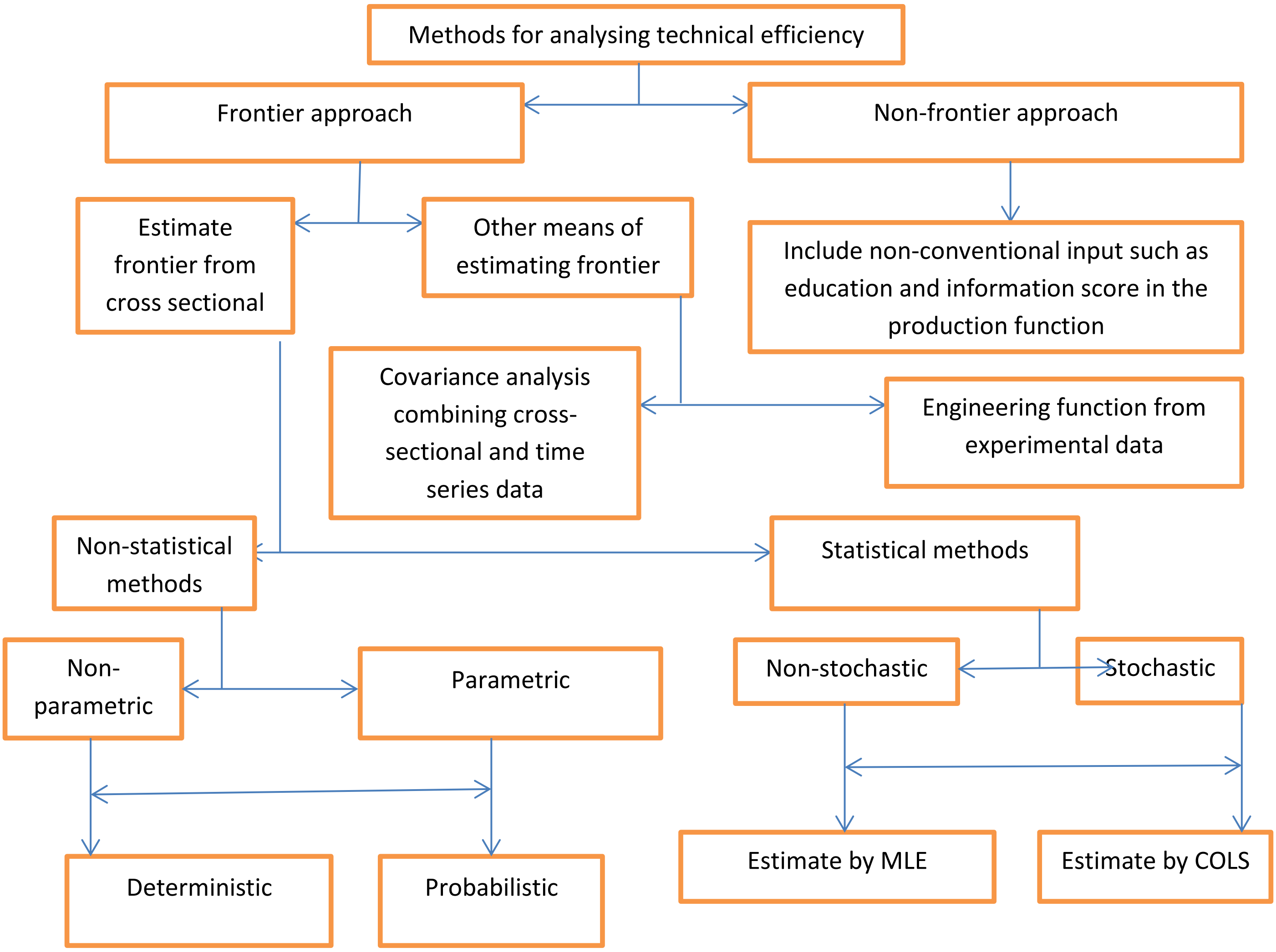


Figure 5.2 Schematic representations of methods of analysing technical efficiency

Source: Ali and Byerlee (1991)

Keeping in view the disadvantages of non-parametric approach as discussed above, the parametric approach is used for the present study. Parametric approach is further divided into deterministic and stochastic frontier production functions. Battese (1992) and Coelli *et* *al*. (1998) have reviewed development in econometric frontier production function. The methodology developed by Coelli *et al*. (1998) has been followed in the present study.

Subsequent to the seminal work of Farrell (1957), it is assumed that the production function of fully efficient firms is known. But the production function is not known in reality. The solution to this problem is provided by Farrell (1957), who proposed that the sample data could be used to estimate the production function by implying a non-parametric piece-wise linear technology or a parametric function, such as the Cobb-Douglas production function. Aigner and Chu (1968) used the parametric functional approach for a sample of, say N firms.

$$Y_i = f(X_i, \beta)e^{-\mu_i} \qquad \text{I} = 1,2, \ldots, N$$

The above production function can be written in log form as

$$\ln(Y_i) = X_i\beta - \mu,$$

where Y_i is the output for the i-th firm, X_i is a vector of k-input used by the i -th firm, β is a vector of unknown parameters to be estimated, μ is associated with technical inefficiency in a production and it represents the natural logarithm. The above model is called deterministic frontier production function because the observed output Y_i is circumscribed above by the deterministic quantity $\exp(X_i, \beta)$. Technical efficiency (TE_i) of the i-th firm is defined as

$$TE_i = \frac{Y_i}{\exp(X_i, \beta)} = \frac{\exp(X_i, \beta - \mu)}{\exp(X_i, \beta)} = \exp(-\mu_i)$$

Thus, technical efficiency is the ratio of actual output to potential (frontier) output with on-hand technology and accessible resources. The value of technical efficiency lies between zero and one. The firm is thought to be fully efficient if technical efficiency (TE_i) becomes equal to one. At this level of technical efficiency, the firm or farm achieves the highest possible level of output Y_i, but when the value of technical efficiency is below one, it indicates technical inefficiency of the i-th firm (Coelli *et al*., 1998).

Afriat (1972) recommended a model similar to the one above. However, the μ_i's were believed to have a gamma distribution in that model. The maximum likelihood method was used to estimate the parameters of the model developed by Afriat (1972). The parameters of the model developed by Afriat (1972) could also be estimated by corrected ordinary least square (COLS). However, Schmidt (1986) criticized COLS because the statistical characteristics of the corrected intercept are not known.

The most important distinction between non-parametric and parametric deterministic frontier model is a specific functional form constructed for the latter. Schmidt (1986) concluded that the maximum likelihood estimates of the parameters for the statistical model can be obtained by linear and quadratic programming if the μ_i's have exponential or half-normal distribution, respectively.

On the other hand, the deterministic frontier production model is also criticized, since it assumes that all deviations from the frontier are the outcome of technical inefficiency (Russell and Young, 1983). However, the performance of a firm can be affected by two types of factors, namely exclusively outside the control of the firm and under the control of the firm. Factors fully outside the control of the firm take account of weather, climate and failure of market and measurement errors. Factors under the firm's control also affect the performance of the firm or farmers and these factors include socio-economic characteristics and management practices. Therefore, a parametric frontier production function was developed to include these effects while determining technical efficiency of the firms (Aigner *et al*., 1977; Meeusen and Van den Broek, 1977). The stochastic frontier production includes firm's specific random shocks and technical efficiency separately into the analysis.

5.3.5 The Stochastic frontier production function

As discussed above, the deterministic production function model is used in this study and the model assumes that all irrigation schemes in the sample have the frontier, and it also assumes that all the deviations from frontier are ascribed to technical inefficiency. This assumption of deterministic frontier production function has been criticised. In the real world, irrigation schemes or any type of farming is affected by random factors such as bad weather, fortune and measurement errors along with factors under the control of the irrigation scheme or farm, and technical inefficiency arises due to variations in the management of factors under the control of the irrigation scheme or farm.

Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977) showed that deviations from the production frontier were due to two types of factors such as factors entirely outside the control of the irrigation scheme or farm and factors under the control of the irrigation scheme or farm, signifying that deviations are not completely under the control of rrigation scheme or farm as assumed earlier, but some factors such as bad weather and measurement errors are wholly outside the control of the irrigation scheme or farm. Hence, Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) proposed independently the stochastic frontier production function, incorporating both kinds of factors into the model.

In this model, error term was decomposed into two components, one concerning factors outside the control of the irrigation scheme or farm, and the other relating to factors under the control of the irrigation scheme or farm. So, this model is also called composed error model. One advantage of this model is that it separates technical efficiency effects from the random noise. This model points out that the firm's output is affected by technical .inefficiency along with measurement errors and other factors such as effects of weather and luck combined effects of unspecified variables in the model (Coelli *et al*., 1998).

The stochastic frontier production function model for the cross-sectional data is as follows

$$Y_i = f(X_i \beta) e^{\varepsilon_i}$$

And $\varepsilon_i = v_i - \mu_i$ where i = 1, 2, 3,….,N

Here v_i is a random error and it captures measurement errors and other random factors outside the control of irrigation scheme or farmer. Aigner *et al*. (1977) assumed that v_i's independent and identically distributed normal variables with mean zero and constant variance, σ_v^2 independent of the μ_i's. The μ_i's show the technical inefficiency effects and they are connected with technical inefficiency of the irrigation scheme or farmer. The μ_i's are assumed to be identically and independently distributed exponential or half normal random variables (Coelli *et al*., 1998).

According to Coelli *et al*. (1998), the observed output Y_i is called stochastic, since it is circumscribed above by the stochastic quantity, $f(X_i, \beta)\exp(v_i)$. This stochastic frontier does not take into consideration noise in production and estimation of standard errors and tests of hypotheses are also possible. These estimations are not feasible with the earlier deterministic models because of the defiance of the ML regularly conditions. The random error v_i can be positive or negative and so, the stochastic frontier output, Y_i diverge about the deterministic part of the frontier model $\exp(X_i, \beta)$.

5.3.6 Estimation of stochastic frontier production function

According to Richmond (1974), the parameters of the stochastic frontier production function can be estimated by means of the maximum likelihood (ML) method or corrected ordinary least square (COLS) method. The maximum likelihood estimator is asymptotically more efficient than the COLS estimator, as argued by Coelli (1995). Technical efficiency can be estimated using computer software such as LIMDEP econometrics packages (Greene, 1992) and the FRONTIER 4.1 program (Coelli, 1996). These computer programme are used to find the maximum likelihood estimates for the parameters of the stochastic frontier production function.

Aigner *et al*. (1977) proposed the log likelihood function for the model assuming half-normal distribution for the technical inefficiency effects. Aigner *et al*. (1977) expressed the likelihood function in terms of the two variance parameters as $\sigma_S^2 = \sigma^2 + \sigma_V^2$ and $\lambda = \frac{\sigma}{\sigma_v}$.

However, Battese and Corra (1977) proposed that the parameter, $\lambda = \frac{\sigma^2}{\sigma^2{}_x}$, be used because it has a value between one and zero.

5.4 The empirical model

This study used the stochastic frontier production function of Cobb-Douglas to analyse data collected from different irrigated farming sectors. A number of econometrics models have been suggested and applied in the analysis of cross-sectional and panel data on producers. Stochastic frontier model is likely to be more appropriate than the data envelopment analysis (DEA) in agricultural applications, especially in developing countries, where data are heavily influenced by measurement error and the effects of weather, disease and other factors (Coelli *et al.*, 1998). For this study a stochastic frontier production function model was thus selected as the most suitable technique to analyse the collected data from the three management system of the irrigation schemes.

5.4.1 The production function form

Separate stochastic frontier production function, of the Cobb-Douglas type, using the Frontier 4.1 program of the type proposed by Battese and Coelli (1995) was estimated for the three management organisation system of the different irrigation schemes of Limpopo Provinces.

In this study, the analysis focused on important crops grown by the farmers at different management organization of the irrigation schemes. These are maize and some selected common vegetables (Tomato, onion, and spinach). Maize as outlined before is the main staple food and cash crop among the small-scale farmers whereas vegetables are the main cash crop and also serve as a food crop for small-scale farmers in Limpopo Province. A production function relating output to input was adopted by this study to generate the regression parameters. Other conditioners such as socio-economic factors on households were considered.

The most general expression of the Cobb-Douglas function is

$$Y = AL^{\alpha} K^{\beta} .u \text{ ,}$$

where Y stands for output, L measures labour input and K measures capital input. Intercept A, is the constant which represents the technology of the society that generated the observations upon which the parameters of the function were estimated. Parameter (A) might also be thought of as the combined impact of inputs that are considered to be fixed on the production function. Two important properties of the Cobb-Douglas production function (Coudere and Marijse, 1991) are:

a) α and β are elasticities of production with respect to labour and capital.

$$\alpha = \frac{\delta Y / Y}{\delta L / L}$$

$$\beta = \frac{\delta Y / Y}{\delta K / K}$$

b) The function is homogenous of degree, α +β. If $\alpha + \beta > 1$; there are increasing returns to scale, $\alpha + \beta = 1$ indicates constant returns; and $\alpha + \beta < 1$, indicates diminishing returns to scale.

The Cobb-Douglas production function has some limitations. One of the limitations is that the function cannot represent simultaneously the three stages of the Neo-classical production function but it can do so for one stage at a time. Also that, the elasticities of production for the Cobb-Douglas type of production functions is constant irrespective of the amount of each input used.

Despite its well-known limitations, the Cobb-Douglas production function was chosen because the methodology employed requires that the function be self-dual (Bravo-Ureta and Evenson, 1994). Also Xu and Jeffrey (1997) noted that although there are other more flexible forms, the functional forms have a limited effect on empirical efficiency measurement. The other reason as to why the specified Cobb-Douglas production function was chosen was because of its ease of interpretation of returns to scale. The model, which was employed for the analysis of maize and selected common vegetables yields, involves stochastic frontier production functions, in which the parameters of the production functions are specified to be a function of the variables associated with the production of the maize and three types of vegetables (tomato, onion and spinach). The model was presented in terms of a Cobb-Douglas production function.

For purposes of exposition, the Cobb-Douglas model is given in terms of maize and selected common vegetable crops involving six input variables and five explanatory variables for the inefficiency effects in the stochastic frontier. This study was based on the assumption that, all six input variables are sufficiently homogeneous and unambiguously defined.

The general model for this study relating production, Y, to a given set of resources X, and other conditioning factors was given as follows:

$$Y = b_0 X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} + u,$$

where : Y= Annual total farm output of maize or vegetables (kg)

: X_1= Land devoted to either maize or vegetables (hectares)

: X_2= Family and hired worker days used in maize or vegetables Production (Man days)

: X_3= Capital (cost of tractor service)

: X_4= Fertilizer used (in kg)

: X_5= Seeds used (in kg)

: X_6= Expenses on pesticides, irrigation water, and chemicals (in rand)

: u = Disturbance term

: b_1, b_2, b_3, b_4, b_5 and b_6 = the elasticity's to be estimated.

5.4.2 Model specification

In order to be able to use the Cobb Douglass procedure for estimations, the function was linearized and transformed to be as follows;

$$\ln Y = b_{0i} + b_{1i} \ln X_{1i} + b_{2i} \ln X_{2i} + b_{3i} \ln X_{3i} + b_{4i} \ln X_{4i} + b_{5i} \ln X_{5i} + b_{6i} \ln X_{6i} + v_i - u_i \ ,$$

where the subscript, i indicates the i-th farmer in the sample (i= 1, 2, 3, n), In representing the natural logarithm (i.e., logarithm to base e)

Output (Y) is the total quantity of either maize or selected common vegetables harvested in that year and measured in kg per hectare.

Land (X_1) is the area of the farm(s) devoted to the production of maize or selected common vegetables. It is measured in hectares.

Labour (X_2) is the total of maize or selected common vegetables activity. It is expressed in adult equivalent days per hectare and is the sum of family labour and hired labour. Male and female labour is counted equally.

Capital (X_3) Coudere and Marijse (1991)'s argument will be used. There is not much variation in the types of equipment farmers possesses. All are assumed to use tractors. To represent capital, a cost of tractor service charged per hectare used for irrigation schemes.

Fertilizer (X_4) includes both basal and top dressing fertilizers. Although some farmers use animal manure, this has been also included as long as he/she knows how many kilograms have been used (It is measured in kilograms).

Seed (X_5) for both certified and home produced (recycled seeds) is considered and is measured in kilograms.

Cost (X_6) pesticides, irrigation water, chemicals costs are included and measured in Rand.

The v_i represents random errors associated with measurement errors in the yields of maize/ selected common vegetables reported or the combined effects of input variables not included in the production function, where v_{is} are assumed to be independent and was obtained by truncation (at zero) of the normal distribution with mean, μ_i and variance, σ^2 such that

$$\mu_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i},$$

where δ - coefficients are unknown parameters to be estimated, together with variance parameters, which are expressed in terms of land size (Z_{1i}), family size

(Z_{2i}), education (Z_{3i}), age (Z_{4i}), gender (Z_{5i}) and income level (Z_{6i}) as defined below.

Land size	= the total number of hectares held by the farmer.
Family size	= total number of household members.
Education	= the number of years of schooling completed by the household head.
Age	= the age of the household head in years.
Gender	= the gender of the household head.
Income level	= the level of household income (Rands)

The computer program Frontier 4.1 that was designed by Battese and Coelli (1995) was used to analyse the data. The maximum likelihood estimates of the parameters of the frontier model were estimated, such that the variance parameters were expressed in terms of the parameterisation:

$\sigma_s^2 = \sigma_v^2 + \sigma$ and y = $\dfrac{\sigma^2}{\sigma_s^2}$

CHARPTER SIX

DESCRIPTIVE AND EFFICIENCY RESULTS

6.0 Introduction

This first section of the chapter presents the descriptive statistics of the sampled population and the last section presents the empirical results from the analysis. The chapter is devoted to technical efficiency analysis. Results of the stochastic frontier production function of the Cobb-Douglas type and the technical inefficiency effects model for the maize, tomato, onion and spinach growers in different management organisation or institutional arrangements of the irrigation schemes have been discussed in this chapter. The stochastic frontier production function model was chosen because it is able to measure the effect of inputs on output as inputs are used to produce output and the model is also able to determine the inefficiency factors.

The study used the three types of management practice of the irrigation schemes. The results of this study were based on those three management practices of the irrigation schemes. The description of these three management practices of the irrigation schemes was also be outlined in this chapter.

6.1 Descriptive results

The human resources component of a farming enterprise forms an indispensable ingredient in agricultural production. It is through man's ingenuity that production inputs are sequentially integrated and made compatible with one another in order to produce desired results. Man is able to manipulate the production requisites to meet his own ends. A human being may therefore rightly be considered the origin as well as the destination in the production process (Bembridge, 1997 as cited by Mushunje and Belete, 2005).

Land, capital, labour and management are always given as the main factors of production in agriculture. The management input includes both the physical properties and personal qualities possessed by the farmers. According to Bembridge (1997), this subdivides the human resource input into two distinctly different and mutually exclusive inputs i.e. labour and decision making and management.

Bembridge (1997) also observes that the human element is a key factor in agricultural and rural development because of its importance in decision making which is fundamental to good management and successful farming. Sebotja (1985) as cited by Mushunje and Belete (2005) also pointed out that the biological characteristics as well as social, economic and psychological traits of a farming community influence the efficiency of farming and dictate the communication strategy and the technology that must be developed for the area.

The study therefore considers some socio-economic characteristics of the sampled farmers at different irrigation schemes in Limpopo Province. These were assessed to find out whether they have a positive or negative impact on efficiency. These characteristics include household size, gender of the household and the members of the household, total number of years of schooling for the head of the household, age of the head of household, income from farming, average non-farm income and the number of wives of head of the household. It is necessary to have the information of this nature since farmers are integral part of the household.

A household is a group of related or unrelated persons who usually reside in the same dwelling and share common housekeeping arrangements for food and other essentials for living (Simon *et al*., 2011). Household information is among the most important data in surveys, not only because most people live in households and the household is the basic social and economic unit of society. Most day-to-day activities are organized around the household. The head of household is the person assumed to be responsible for the day-to-day running of the household. He/she is that person living in the same household who is acknowledged by other members to be its head (Ellis and Lipton, 1996). Such a person holds some primary authority and responsibility for the household's affairs, mainly economic and cultural.

Table 6.1: Descriptive results for the sampled population

Variable	Options	Frequency Percentage
Types of management practices of the irrigation schemes	○ Integrated water	46%
	○ Specialised water	27%
	○ Multipurpose water	27%
	Total	**100%**
Age of the farmer	○ Between 21 and 40 years	1%
	○ Between 41 and 60 years	42%
	○ At least 61 years	57%
	Total	**100%**
Gender of the farmer	○ Male	22%
	○ Female	78%
	Total	**100%**
Educational qualification of farmer	○ No formal qualification	12%
	○ Primary qualification	37%
	○ Secondary qualification	49%
	○ Tertiary qualification	2%
	Total	**100%**
Marital status of the farmer	○ Single	3%
	○ Married	90%
	○ Divorced	5%
	○ Widow or Widower	2%
	Total	**100%**
Occupation of the farmer	○ Employed	1%
	○ Self employed	16%
	○ Unemployed	35%
	○ Retired	21%
	○ Permanently farming	27%
	Total	**100%**
Ethnic group of the farmer	○ Ba-pedi	42%
	○ Vha-tsonga	22%
	○ Vha-venda	14%
	○ Ndebele	18%
	○ Afrikaans	4%
	Total	**100%**

Source: Field survey

6.1.1 Types of management practices of the irrigation schemes

Figure 6.1 below presents the spatial distribution of the farmers at different irrigation schemes who served as the respondents in this study. This spatial distribution is based on the types of management practices of the irrigation schemes in Limpopo Province.

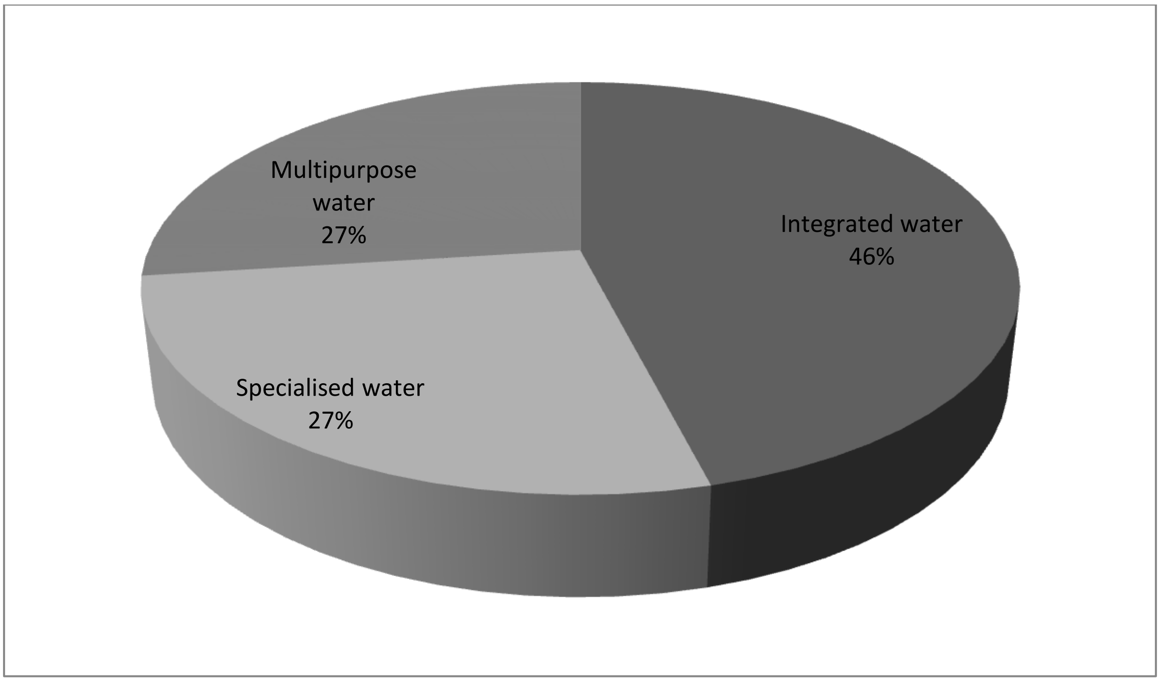


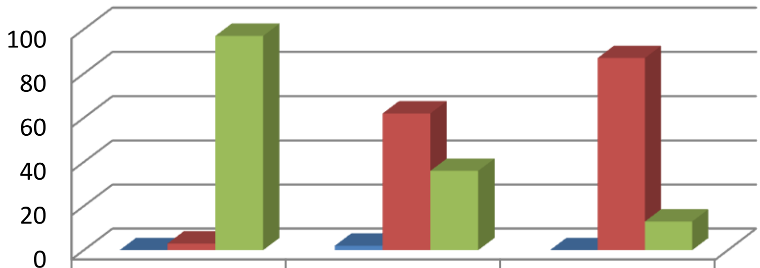
Figure 6.1: Types of management practices of the irrigation schemes

Source: Field survey

Figure 6.1 above, farmers operating in the integrated water management practices amounted to 46% while specialised water management practices were levelled with multipurpose water management at 27%. Most of the irrigation schemes in Limpopo Province operate as an integrated management practices, thus the sampled farmers constituted to 46% as compared to the 27% of the other two management practices.

6.1.2 Age of the farmers

The age factor is regarded as one of the most significant variable in agricultural sector which is correlated by numbers of studies with the experience of farming.



	Integrated water	Specialised water	Multipurpose water
Between 21 and 40 years	0	2	0
Between 41 and 60 years	3	62	87
At least 61 years	97	36	13

Figure 6.2: Age of the farmers at different management practices of the irrigation schemes

Source: Field survey

The three age categories (21 and 40; 41 and 60 and at least 61 years) that farmers fall under are on the basis of the three types of management practices of the irrigation schemes. Figure 6.2 above shows that farmers under integrated water management were 0%, 3% and 97% respectively for all three age categories. Specialised water management accumulated 2%, 62% and 36% for all those age categories. Multipurpose water management showed 0%, 87% and 13%, respectively for the three age categories. On average farmers between the age of 41 and 60 years were more represented than those between 21 and 40 and at least 61 years. The advantage of middle aged farmers is that they are more skilled and have good experience in crop production.

6.1.3 Gender of the farmer

The gender of the farmers in the integrated, specialised and multipurpose water management is shown in figure 6.3 below.

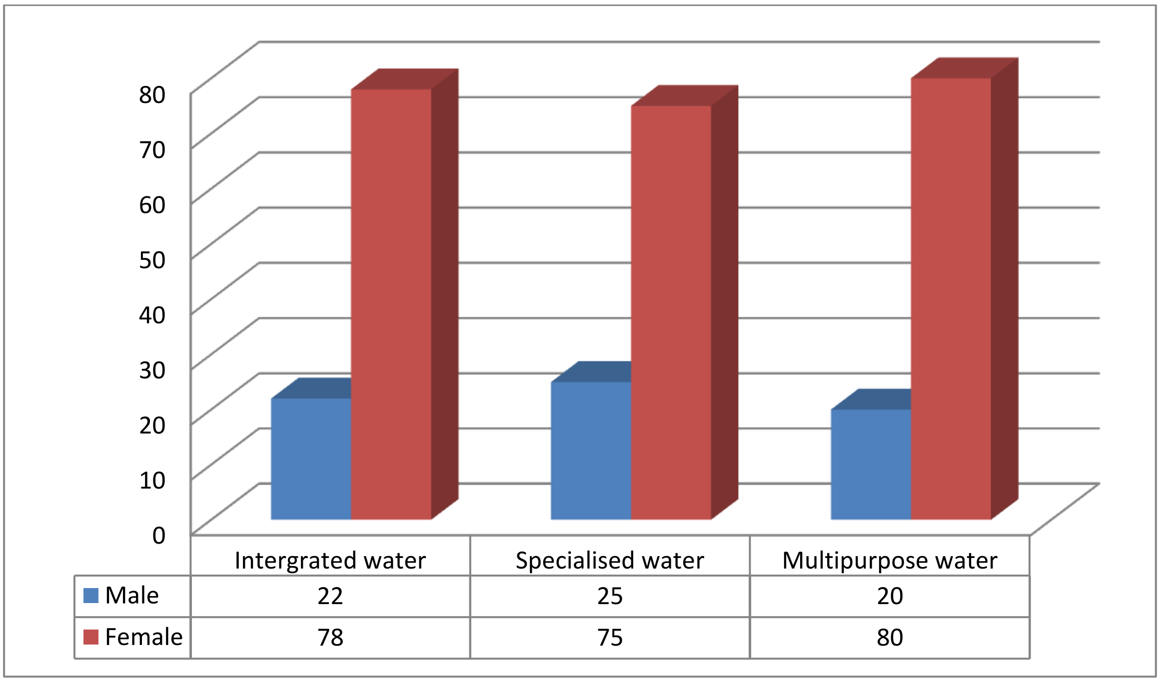


Figure 6.3: Gender of the farmers at different management practices of the irrigation schemes

Source: Field survey

Gender reflects a set of behavioural norms ascribed to men and women in a given social group or system. It reflects attitudes and beliefs that a particular cultural group considered appropriate for males and females on the basis of their gender (Peter, 2004).

I. Male

According to (Syed *et al*., 2003) men are mainly involved in productive and community tasks while women play multiple roles. In most male-headed households there is involvement of husband and wife in making crucial decisions in the production processes as well as in the disposal of the products within the household. The crucial decisions considered were those made on investments to be made in production, the inputs to be used on crops, the disposal of products and the use of income from crops produced. In figure 6.3 above, in all three categories men were lowly represented with 22%, 25% and 20% respectively.

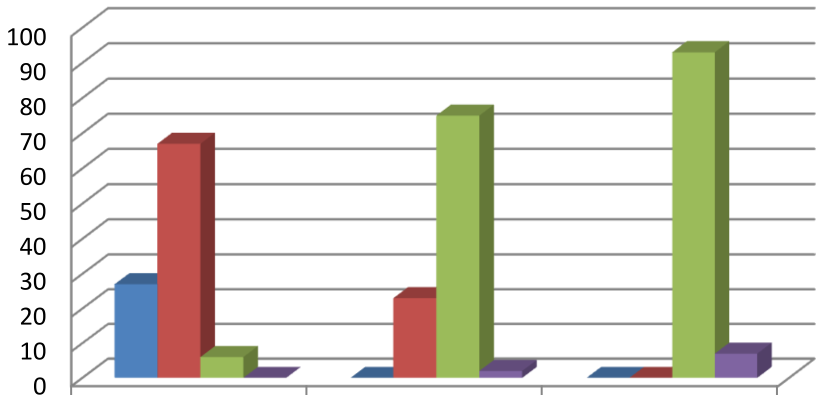
II. **Female**

Most research finds slight evidence that women are more environmentally concerned or possesses stronger environmental attitudes than men; however, gender does not appear to be as significant a predictor of environmental concerns or attitudes as other socio-demographic variables (Brody *et al*. 2004). This is because women's goals, values, and beliefs are intimately bound with the notion of sustainable agriculture. They want to increase the livelihood of their families, contribute towards community building, be stewards of their land, live in balance with nature, and preserve family farms.

In addition, they are striving for personal autonomy and control over the way they farm. The women experience the creation of sustainable farming systems as a long-term endeavour which may involve several generations (Chiappe, 1994). Drawn from this notion, it is not a surprise to see those higher percentages in figure 6.3 representing females than their male counterparts. They represented a three third with 78%, 75% and 80%, respectively.

6.1.4 Education qualification of farmers

The level of education of farmers has been proven by the number of studies that it positively correlated with the productivity of the farmer. This implies that, the higher the qualification of a farmer, the higher the probabilities of the farmer being productive.



	Integrated water	Specialised water	Multipurpose water
No formal qualification	27	0	0
Primary qualification	67	23	0
Secondary qualification	6	75	93
Tertiary qualification	0	2	7

Figure 6.4: Educational level of the farmer at different management practices of the irrigation schemes

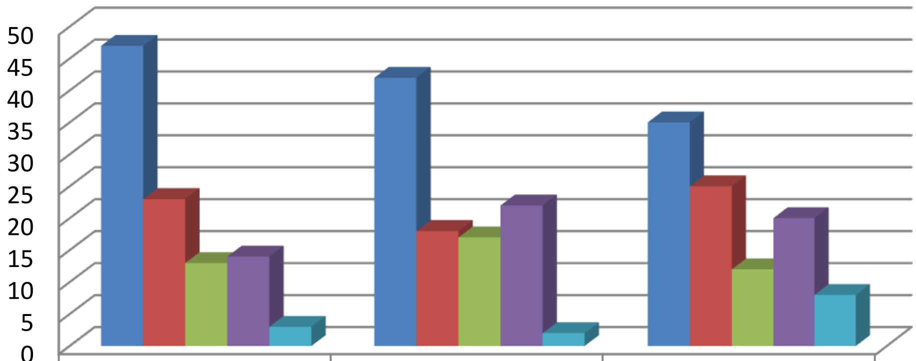
Source: Field survey

The education status indicates the advanced and positive, determined minds of the farmers towards the modern agricultural practices and technological interventions. There were 27% illiterate farmers only under integrated water management indicating a low need for motivation and create awareness on improved technologies through training and exposure visits. Of the educated, 67%, 23% and 0% had primary education for integrated and specialised water management and multipurpose. A chunk of the analyses 6%, 75% and 93% had secondary qualification for all three categories. This higher level of education indicates that print media can be easily utilized for the training of farmers. Only 2% and 7%, respectively of the last two categories represented tertiary qualification.

Ajrawat and Kumar (2009) concluded that the education was positively and significantly related to farmer’s knowledge level. Hassan (2004) also found a significant relationship of age and education of respondents with the adoption of improved production technology.

6.1.5 Ethnic group of the farmer

Ethnic group of farmers is also regarded as an important factor in agricultural sector since it develops values and team loyalty. The familiarity of team member’s ethnic group creates smoother, more effective communication and yields better results in terms of performance.



	Integrated water	Specialised water	Multipurpose water
Ba-pedi	47	42	35
Vha-tsonga	23	18	25
Vha-venda	13	17	12
Ndebele	14	22	20
Afrikaaners	3	2	8

Figure 6.5: Ethnical group of the farmer at different management practices of the irrigation schemes

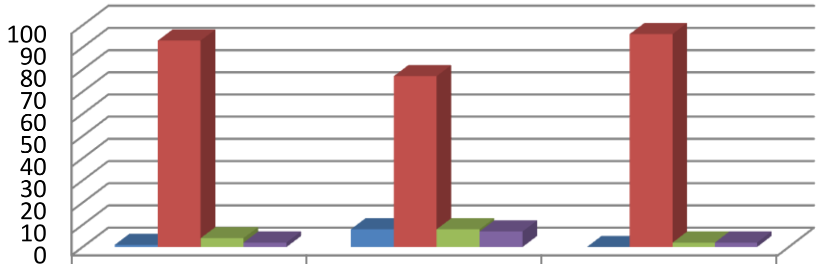
Source: Field survey

Existing local, state, and federal regulations increasingly require that citizens be involved in decisions likely to affect them. This appears to be particularly important when decisions directly affect the place where people live. For example, research and experience suggests that citizens are likely to actively engage in decision processes when their neighbourhood is threatened, a syndrome known as NIMBY which refers to “Not in My Backyard” (McAvoy and Kok, 1999).

In figure 6.5 above, it is evident that all five groups were represented. In all three water management practices the Ba-pedi people represented the majority percentage, 47%, 42% and 35%. This is due to the regional boundary of the study which is predominantly a pedi place adopted from the homelands designated during the apartheid regime. Vha-tsonga accumulated a second bigger portion with 23%, 18% and 25%. Although the activities of neighbourhood groups vary, their involvement in local planning has been on-going since the 1950s (Altman and Wandersman, 1987; Berry *et al*., 1993). This can be witnessed by the existence of the Vha-Venda, Ndebele and Afrikaners within our sample. Vha-Venda accumulated 13%, 17% and 12% while Ndebele people had 14%, 22% and 20%. Surprisingly, Afrikaners the richest group when it comes to farming knowledge in South Africa had a very little percentage, 3%, 2% and 8%. This might be attributed to their love for livestock and game farming which need less or no irrigation at all.

6.1.6 Marital status of the farmer

Marital status of the farmers has been suggested by a number of studies to be one of the important factors in agricultural sector, more especially in acquiring land in the rural area. Married people are likely to be given land for farming by the tribal authorities than those who are not.



	Integrated water management	Specialised water management	Multipurpose water management
Single	1	8	0
Married	93	77	96
Divorced	4	8	2
Widow or Widower	2	7	2

Figure 6.6: Marital status of the farmers at different management practices of the irrigation schemes

Source: Field survey

There were three types of management practices of the irrigation schemes and four marital status categories that farmers fall under. Figure 6.6 above shows that farmers under integrated water management were 1%, 93%, 4% and 2% respectively for all four categories. Specialised water management accumulated 8%, 77%, 8% and 7% for all those categories. Multipurpose water management showed 0%, 96%, 2% and 2%, respectively. On average farmers who are married were more represented than other farmers. The advantage of married farmers can be drawn from extra income that families might share or add to farming.

6.2 Results of the empirical analysis

Before the results are presented, it is important to state that an assumption was made about the variables used. It was assumed that all the inputs are sufficiently homogeneous and unambiguously defined. For example, labour was considered to consist of family and hired labour. The two types of labour were added together, thus implicitly assuming that they have the same effects on output. The same assumptions were made for other inputs like capital, fertilizer, seed and pesticides.

It is important to note that the above assumptions might however have affected the elasticities of variable inputs due to possible heterogeneity of the inputs e.g. variety of irrigation methods, seeds, fertilizers and pesticides used. Two assumptions were made for the land input. The first was to assume homogeneity of land and the second one treated each natural region separately to test for the average technical efficiencies of each farming region. The effect of inter-cropping is also overlooked because of the problems of measurement and aggregation as farmers inter-plant maize with different kinds of crops; e.g. cowpea, water melons, cucumbers, pumpkins etc.

The maximum likelihood estimates of the parameters of the stochastic frontier production function of Cobb-Douglas type for the farmers at different types of the management organization of the irrigation schemes in Limpopo Province were obtained using the computer program Frontier version 4.1. The results are presented based on the following enterprises: Maize, Tomato, Onion and Spinach respectively.

6.2.1 Empirical results on maize enterprise

Maize in the Limpopo province serves as the major field crop, the main stable food and cash crop among the small-scale farmers, occupying more than 50% of all land cropped and providing more than 65% of gross farm income (Dalton *et al*., 1996). Maize can also be included in the poultry diet up to 70% and is more susceptible for infestation with mycotoxins producing fungi than other grains such as wheat, sorghum and millets (Iji *et al*., 2004). According to NDA (2011), maize is truly an astonishing crop: plant one seed and you get over 500 kernels in return. It utilises sunlight very effectively, outstripping the yield per hectare of other grain crops. Current varieties need 450 to 600 mm of water per season, which is mainly acquired from soil moisture reserves. At maturity, each maize plant will have consumed 250 litres of water. Improving the water use efficiency for maize will therefore go a long way in producing more maize from less water (NDA, 2011). The regression for maize is presented in table 6.2.

Table 6.2 Maximum likelihood estimates for the parameters in the Cobb-Douglas stochastic frontier production function for the different management organization of irrigation schemes for the production of maize

Variable	Parameter	Estimated coefficients		
Types of management organisation of the irrigation schemes		Integrated	Specialised	Multipurpose
Stochastic frontier constant	β_0	**0.95***** (0.13) [7.26]	**0.45*** (0.17) [2.72]	**0.31** (0.27) [1.11]
Land	β_1	**0.87***** (0.14) [6.11]	**0.65**** (0.14) [4.72]	**- 0.47*** (0.20) [2.32]
Seed	β_2	**0.53**** (0.16) [3.22]	**0.42*** (0.20) [2.11]	**0.77***** (0.14) [5.34]
Fertiliser	β_3	**0.31** (0.18) [1.73]	**- 0.43*** (0.20) [2.12]	**0.63**** (0.13) [4.71]
Labour	β_4	**- 0.47*** (0.21) [2.24]	**0.66**** (0.16) (4.21]	**0.32** (0.18) [1.74]
Capital	β_5	**0.58**** (0.15) [3.92]	**0.55**** (0.16) [3.36]	**0.49*** (0.16) [2.98]
Pesticides	β_6	**- 0.02** (2.00) [0.01]	**0.41*** (0.18) [2.34]	**0.53**** (0.17) [3.11]
Sum of coefficients	$\sum \beta_s$	1.80	0.96	1.29
Adjusted R^2		0.89	0.76	0.66
Inefficiency model constant	δ_0	**0.53**** (0.17) [3.21]	**(0.97)***** (0.14) [7.12]	**(0.11)** (0.78) [0.14]
Land size	δ_1	**-0.42*** (0.21) [2.01]	**-0.03*** (0.01) [2.17]	**0.12** (12.00) [0.01]
Family size	δ_2	**0.87***** (0.16) [5.46]	**0.95**** (0.32) [3.30]	**0.22*** (0.10) [2.13]
Education	δ_3	**-0.22**** (0.05) [4.34]	**-0.27**** (0.06) [4.75]	**-0.02**** (0.01) [3.78]
Age	δ_4	**-0.12*** (0.06) [2.00]	**-0.08*** (0.04) [2.01]	**-0.21*** (0.07) [2.88]

Income level	δ_5	**-0.28** (0.26) [1.09]	**-0.32** (0.16) [1.92]	**-0.01** (0.50) [0.02]
Gender	δ_6	**0.47** (1.42) [0.33]	**0.22**** (0.05) [4.62]	**0.28**** **(0.08)** [3.67]
Variance parameter	σ^2	**0.01**** [3.45]	**0.04**** [2.18]	**0.06**** [2.78]
	γ	**0.99***** [6.13]	**0.96**** [2.22]	**0.95**** [4.00]
Log (likelihood) function		**-28.28**	**-34.14**	**-38.02**
Average technical Efficiency		**0.83**	**0.67**	**0.71**

*Significant at 10% **Significant at 05% ***Significant at 1%

Figures in brackets ( ) are the standard error of estimates whereas figures in parentheses [ ] represent t-ratios of coefficients.

The MLE of the parameters of the stochastic frontier model of maize showed that estimates of the parameters for the frontier production function, inefficiency model and the variance parameters of the model in the three management practice of the irrigation schemes (table 6.2). The parameter sigma squared, (σ^2) were found to be 0.01, 0.04 and 0.06 in the integrated, specialised and multipurpose water management practice of the irrigation schemes, respectively. The parameter sigma's squared were found to be significant at 95% in the three management practices of the irrigation schemes. This indicated a good fit and correctness of the distributional form assumed for the composite error term. Gamma (γ) indicated that systematic influence, which was un-explained by the production function, was the dominant source of random error. The gamma estimates (0.99), (0.96) and (0.95) in the integrated, specialised and multipurpose water management practice of the irrigation schemes, respectively show the amount of variation resulting from the TEs of the maize farmers. This implied that more than 95% of the variations in maize production were due to differences in technical efficiencies.

6.2.2 Empirical results on tomato enterprise

According to NDA (2011), tomatoes contribute about 24% of the total vegetable production in South Africa. Growing of tomatoes in tunnels is becoming a popular and important crop production method in South Africa. The tomato is a perennial but is grown as an annual plant. South Africa is the second world exporter of the tomato. The regression for tomato is presented in table 6.3.

Table 6.3 Maximum likelihood estimates for the parameters in the Cobb-Douglas stochastic frontier production function for the different management organization of irrigation schemes for the production of Tomato

Variable	Parameter	Estimated coefficients		
Types of management organisation of the irrigation schemes		Integrated	Specialised	Multipurpose
Stochastic frontier constant	β_0	**0.99***** (0.14) [6.99]	**0.71***** (0.14) [5.00]	**0.66**** (0.13) [4.99]
Land	β_1	**- 0.32*** (0.13) [2.37]	**- 0.39*** (0.18) [2.12]	**-0.22*** (0.11) [2.01]
Seed	β_2	**0.83***** (0.14) [6.12]	**0.97***** (0.13) [7.21]	**0.98***** (0.13) [7.43]
Fertiliser	β_3	**0.57**** (0.15) [3.77]	**0.66**** (0.16) [4.20]	**0.81***** (0.16) [5.02]
Labour	β_4	**-0.03** (0.03) [1.05]	**-0.22** (0.15) [1.42]	**- 0.33** (0.20) [1.65]
Capital	β_5	**-0.01** (0.01) [0.89]	**-0.04** (0.04) [1.02]	**-0.22** (0.21) [1.06]
Pesticides	β_6	**-0.02** (0.03) [0.77]	**-0.22*** (0.10) [2.16]	**-0.27*** (0.10) [2.69]
Sum of coefficients	$\sum \beta_s$	1.02	0.76	0.75
Adjusted R^2		0.86	0.74	0.71
Inefficiency model constant	δ_0	**0.52**** (0.16) [3.21]	**0.47*** (0.16) [2.87]	**0.43*** (0.21) [2.01]
Land size	δ_1	**-0.22**** (0.07) [3.33]	**-0.12*** (0.04) [2.89]	**0.22*** (0.08) [2.67]
Family size	δ_2	**0.79***** (0.15) [5.13]	**0.76***** (0.13) [5.63]	**0.70***** (0.14) [5.01]
Education	δ_3	**-0.13*** (0.06) [2.13]	**-0.15*** (0.07) [2.01]	**-0.20*** (0.06) [3.12]
Age	δ_4	**-0.01**** (0.01) [3.32]	**-0.03**** (0.01) [3.10]	**-0.31**** (0.10) [3.13]

Income level	δ_5	**-0.04** (0.04) [1.07]	**-0.01** (0.01) [1.00]	**-0.02** (0.02) [1.32]
Gender	δ_6	**0.22** (0.18) [1.20]	**0.12** (0.12) [1.03]	**0.09** (0.09) [1.00]
Variance parameter	σ^2	**0.01**** (4.22)	**0.03**** (3.55)	**0.18*** (2.24)
	γ	**0.99***** (6.88)	**0.95***** (4.97)	**0.94**** (3.78)
Log (likelihood) function		**-43.82**	**56.34**	**53.33**
Average technical Efficiency		**0.78**	**0.68**	**0.67**

*Significant at 10% **Significant at 05% ***Significant at 1%

Figures in brackets ( ) are the standard error of estimates whereas figures in parentheses [ ] represent t-ratios of coefficients.

The MLE of the parameters of the stochastic frontier model of maize showed that estimates of the parameters for the frontier production function, inefficiency model and the variance parameters of the model in the three management practice of the irrigation schemes (table 6.3). The parameter sigma squared, (σ^2) were found to be 0.01, 0.03 and 0.18 in the integrated, specialised and multipurpose water management practice of the irrigation schemes, respectively. The parameter sigma's squared were found to be significant at 95% in the integrated and specialised water management practices of the irrigation schemes while it was found to be significant at 90% level in the multipurpose water management practice. This indicated a good fit and correctness of the distributional form assumed for the composite error term. Gamma (γ) indicated that systematic influence, which was un-explained by the production function, was the dominant source of random error. The gamma estimates (0.99), (0.95) and (0.94) in the integrated, specialised and multipurpose water management practice of the irrigation schemes, respectively show the amount of variation resulting from the TEs of the tomato farmers.

This implied that more than 90% of the variations in maize production were due to differences in technical efficiencies.

6.2.3 Empirical results on onion enterprise

Onions are the third most popular vegetable in South Africa, after potatoes being first and tomatoes being second. Onion is widely used in cooking; they add flavour to dishes such as stew, soup and salads (DAFF, 2012). Onions are produced in almost all the provinces of the RSA, mainly in the Western Cape, Northern Cape, North West and Limpopo Province. In 2009, onion contribution to the gross value of agricultural production increased sharply by 60% due to high production volume which occurred while the prices were still favourable to the producers. Onion industry gross value has decreased by 10.5% and 0.4% in 2010 and 2011 respectively. In South Africa, the average consumption of onion is approximately 390 659 tons per annum. According to DAFF (2012), South Africa is self-sufficient in terms of onion production and surplus is also exported. The regression for onion is presented in table 6.4

Table 6.4 Maximum likelihood estimates for the parameters in the Cobb-Douglas stochastic frontier production function for the different management organization of irrigation schemes for the production of onion.

Variable	Parameter	Estimated coefficients		
Types of management organisation of the irrigation schemes		Integrated	Specialised	Multipurpose
Stochastic frontier constant	β_0	**0.45*** (0.21) [2.17]	**0.67**** (0.16) [4.12]	**0.56**** (0.17) [3.33]
Land	β_1	**0.88***** (0.14) [6.12]	**0.82***** (0.14) [6.02]	**0.78***** (0.13) [5.88]
Seed	β_2	**0.78***** (0.14) [5.66]	**0.78***** (0.13) [5.88]	**0.78***** (0.13) [5.88]
Fertiliser	β_3	**0.38*** (0.18) (2.12)	**0.40*** (0.17) (2.32)	**0.44*** (0.17) (2.56)
Labour	β_4	**-0.22** (0.23) [0.99]	**-0.25** (0.25) [1.02]	**-0.27** (0.19) [1.45]
Capital	β_5	**0.03** (0.08) [0.38]	**0.15** (0.17) [0.88]	**0.20** (0.12) [1.63]
Pesticides	β_6	**-0.13** (0.15) [0.89]	**-0.22** (0.21) [1.03]	**-0.24** (0.15) [1.65]
Sum of coefficients	$\sum \beta_s$	1.72	1.68	1.69
Adjusted R^2		0.93	0.89	0.91
Inefficiency model constant	δ_0	**0.82***** (0.16) [5.13]	**0.63**** (0.15) [4.22]	**0.68**** (0.16) [4.22]
Land size	δ_1	**-0.44*** (0.17) [2.64]	**-0.42*** (0.16) [2.63]	**0.44*** (0.19) [2.34]
Family size	δ_2	**0.92***** (0.15) [6.20]	**0.89***** (0.15) [6.01]	**0.72***** (0.14) [5.22]
Education	δ_3	**-0.28**** (0.09) [3.12]	**-0.32*** (0.11) [2.91]	**-0.31*** (0.11) [2.88]
Age	δ_4	**-0.42**** (0.10) [4.32]	**-0.38**** (0.11) [3.42]	**-0.41**** (0.12) [3.43]

Income level	δ_5	**-0.02** (0.01) [1.61]	**-0.12** (0.06) [1.91]	**-0.16** (0.09) [1.87]
Gender	δ_6	**0.27** (0.26) [1.03]	**0.41** (0.34) [1.20]	**0.19** (0.10) [0.98]
Variance parameter	σ^2	**0.05**** (2.71)	**0.06**** (2.73)	**0.04**** (4.11)
	γ	**0.99***** (5.22)	**0.98***** (5.19)	**0.99***** (5.21)
Log (likelihood) function		**53.71**	**49.64**	**52.93**
Average technical Efficiency		**0.86**	**0.80**	**0.83**

*Significant at 10% **Significant at 05% ***Significant at 1%

Figures in brackets ( ) are the standard error of estimates whereas figures in parentheses [ ] represent t-ratios of coefficients.

The MLE of the parameters of the stochastic frontier model of onion showed that estimates of the parameters for the frontier production function, inefficiency model and the variance parameters of the model in the three management practice of the irrigation schemes (table 6.4). The parameter sigma squared, (σ^2) were found to be 0.05, 0.06 and 0.04 in the integrated, specialised and multipurpose water management practice of the irrigation schemes, respectively. The parameter sigma's squared were found to be significant at 95% in the three management practices of the irrigation schemes. This indicated a good fit and correctness of the distributional form assumed for the composite error term. Gamma (γ) indicated that systematic influence, which was un-explained by the production function, was the dominant source of random error. The gamma estimates (0.99), (0.98) and (0.99) in the integrated, specialised and multipurpose water management practice of the irrigation schemes, respectively show the amount of variation resulting from the TEs of the onion farmers. This implied that more than 95% of the variations in maize production were due to differences in technical efficiencies.

6.2.4 Empirical results on spinach enterprise

Spinach has a high nutritional value and is extremely rich in antioxidants, especially when steamed or quickly boiled (DAFF, 2012). It is widely produced in South Africa, mostly in Limpopo Province by small-scale farmers. Spinach, along with other leafy vegetables is considered to be rich in iron and vitamins by many consumers. Spinach is sold loose. Bunched, packaged fresh in bags, canned or frozen. According to DAFF (2012), spinach contributes about 16% of the total vegetable production in South Africa. The regression for onion is presented in table 6.5.

Table 6.5 Maximum likelihood estimates for the parameters in the Cobb-Douglas stochastic frontier production function for the different management organization of irrigation schemes for the production of spinach

Variable	Parameter	Estimated coefficients		
Types of management organisation of the irrigation schemes		Integrated	Specialised	Multipurpose
Stochastic frontier constant	β_0	**0.75**** (0.16) [4.71]	**0.88***** (0.17) [5.17]	**0.78***** (0.16) [5.00]
Land	β_1	**0.92***** (0.14) [6.72]	**0.91***** (0.14) [6.66]	**- 0.43*** (0.16) [2.75]
Seed	β_2	**0.56**** (0.15) [3.75]	**0.52**** (0.17) [3.02]	**0.94**** (0.28) [3.32]
Fertiliser	β_3	**0.44*** (0.19) [2.33]	**0.42*** (0.18) [2.31]	**0.52**** (0.17) [3.01]
Labour	β_4	**-0.38** (0.21) [1.82]	**-0.35** (0.20) [1.71]	**-0.37** (0.21) [1.80]
Capital	β_5	**0.33*** (0.16) [2.12]	**0.32** (0.97) [0.33]	**0.54**** (0.15) [3.50]
Pesticides	β_6	**-0.07** (0.09) [0.81]	**-0.22** (0.24) [0.93]	**0.41*** (0.19) [2.11]
Sum of coefficients	$\sum\beta_s$	1.80	1.60	1.61
Adjusted R^2		0.84	0.79	0.77
Inefficiency model constant	δ_0	**0.42*** (0.20) [2.11]	**0.67**** (0.16) [4.12]	**0.62**** (0.16) [4.00]
Land size	δ_1	**-0.33*** (0.14) [2.34]	**-0.27*** (0.13) [2.10]	**0.22** (22.0) [0.01]
Family size	δ_2	**0.91***** (0.15) [6.12]	**0.78***** (0.15) [5.30]	**0.72***** (0.14) [5.00]
Education	δ_3	**-0.07**** (0.02) [4.55]	**-0.04**** (0.01) [3.76]	**-0.13**** (0.04) [3.13]
Age	δ_4	**-0.22**** (0.07) [3.36]	**-0.23**** (0.08) [3.03]	**-0.27**** (0.07) [3.87]

Income level	δ_5	**-0.03** (0.03) [1.05]	**-0.02** (0.02) [1.01]	**-0.04** (0.03) [1.07]
Gender	δ_6	**0.51** (0.27) [1.91]	**0.46** (0,.26) [1.71]	**0.21** (0.20) [1.07]
Variance parameter	σ^2	**0.02***** (5.61)	**0.01***** (4.35)	**0.04***** (5.01)
	γ	**0.99***** (6.89)	**0.99***** (6.35)	**0.99***** (6.25)
Log (likelihood) function		**71.22**	**61.27**	**59.01**
Average technical Efficiency		**0.94**	**0.90**	**0.92**

*Significant at 10% **Significant at 05% ***Significant at 1%

Figures in brackets ( ) are the standard error of estimates whereas figures in parentheses [ ] represent t-ratios of coefficients.

The MLE of the parameters of the stochastic frontier model of spinach showed that estimates of the parameters for the frontier production function, inefficiency model and the variance parameters of the model in the three management practice of the irrigation schemes (table 6.5). The parameter sigma squared, (σ^2) were found to be 0.02, 0.01 and 0.04 in the integrated, specialised and multipurpose water management practice of the irrigation schemes, respectively. The parameter sigma's squared were found to be significant at 99% in the three management practices of the irrigation schemes. This indicated a good fit and correctness of the distributional form assumed for the composite error term. Gamma (γ) indicated that systematic influence, which was un-explained by the production function, was the dominant source of random error. The gamma estimates (0.99), in the integrated, specialised and multipurpose water management practice of the irrigation schemes, show the amount of variation resulting from the TEs of the spinach farmers. This implied that more than 95% of the variations in maize production were due to differences in technical efficiencies.

6.3 Elasticities of Production

The elasticity of production parameters for an individual input expresses the percentage increase or decrease in output that will emerge if the particular input is increased or decreased by one percent (%), holding all other inputs constant (Truran and Roger, 1979 as cited by Mushunge and Belete, 2005). The elasticities of dependent variable (mean output) with respect to six independent variables (inputs) are estimated at the values of the means of the inputs and the six inefficiency determinants.

In case the production function contains one input, then the output elasticity is also an indicator of the degree of returns to scale. As stated in chapter four (4), if the coefficient of output elasticity is greater than one (1), then production is experiencing increasing returns to scale. If the coefficient is less than one (1), then the production is experiencing decreasing returns to scale. If the coefficient is equal to one (1), then the production is experiencing constant returns to scale. The returns to scale may change as the level of production changes.

6.3.1 Land

According to Cornia (1985), land elasticity is regularly higher in land scarce than in land rich countries. Results from this study indicate that the production elasticities of land for all agricultural produce selected for this study i.e. maize, tomato, onion and spinach are higher in integrated water management practice as compared to multipurpose water management practice. The farmers in integrated, specialised and multipurpose water management are operating between 0.1 – 1.5 ha, 1.5 – 5 ha and at least 5.1 ha respectively.

The return to scale of land for maize production in the integrated, specialised and multipurpose water management was revealed to be 0.87, 0.65 and -0.47, respectively. The land was positively significant towards the productivity of maize in integrated and specialised water management practice at 1% and 5% level respectively. This implies that a one percent increase in land utilization will result in 0.87% and 0.65% increase in the productivity of maize. While the land was found to be negatively significant towards the productivity of maize in multipurpose water management practice at 10% level, which implied that a one percent increase in land use would results in 0.47% decrease in the productivity of maize.

The land elasticity of tomato production in the integrated, specialised and multipurpose water management was revealed to be -0.32, -0.39 and -0.22 respectively. The land was negatively significant towards the productivity of tomato in all three management practices at 10% level. This implies that a one percent increase in land utilization would result in 0.32%, 0.39% and 0.22% decrease in the productivity of tomato respectively. These results might have been influenced by the fact that most vegetable production does not require a big land size.

The production elasticity of land for onion production in the integrated, specialised and multipurpose water management was revealed to be 0.88, 0.82 and 0.78 respectively. The land was positively significant towards the productivity of onion in all three management practices at 1% level. This implies that a one percent increase in land utilization will result in 0.88%, 0.82% and 0.78% increase in the productivity of onion respectively.

The land elasticity of spinach production in the integrated, specialised and multipurpose water management was revealed to be 0.92, 0.91 and -0.43 respectively. The land was positively significant towards the productivity of spinach in the integrated and specialised water management practice at 1% level. This implies that a one percent increase in land utilization will result in 0.92% and 0.91% increase in the productivity of spinach respectively. While the land was found to be negatively significant towards the productivity of spinach in multipurpose water management practice at 10%, which implied that a one percent increase in land use would result in 0.43% decrease in the productivity of spinach.

The smallest production elasticity of land (0.22) was found in the multipurpose water management practice of the irrigation scheme for the production of tomato, while the highest production elasticity of land (0.92) was found in integrated water management practice of the irrigation scheme for the production of spinach.

6.3.2 Seed

Seed is the most vital and crucial input for crop production, one of the ways to increase the productivity without adding appreciably to the land now under cultivation by planting quality seed. The production elasticities of seed for maize production in all the three management practices of the irrigation schemes have the expected positive signs. The seed elasticity of maize production in the integrated, specialised and multipurpose water management was revealed to be 0.53, 0.42 and 0.77 respectively. The seed was positively significant towards the productivity of maize in integrated and specialised water management practice at 5%, 10% and 1% level respectively. This implies that a one percent increase in seed by farmers would result in 0.53%, 0.42% and 0.77% increase in the yield of maize respectively. This is due to the fact that yield directly depends on the plants per hectare and the population of plants is directly dependent on the quantity of seed used.

The seed elasticity of tomato production in the integrated, specialised and multipurpose water management was revealed to be 0.83, 0.97 and 0.98 respectively. The seed was found to be positively significant towards the productivity of tomato in integrated and specialised water management practice at 1%. This implies that a one percent increase in seed by farmers would result in 0.83%, 0.97% and 0.98% increase in the yield of tomato respectively. This result concur with those of Ahmad *et al*. (2002); Battese and Broca (1997).

The seed elasticity of onion production in the integrated, specialised and multipurpose water management was revealed to be 0.78, 0.78 and 0.78 respectively. The seed was found to be positively significant towards the productivity of onion in integrated and specialised water management practice at 1%. This implies that a one percent increase in seed by farmers will results in 0.78% increase in the yield of onion in all the three management practices of the irrigation scheme. This results concur with those of Ahmad *et al*. (2002); Battese and Broca (1997).

The seed elasticity of spinach production in the integrated, specialised and multipurpose water management was revealed to be 0.56, 0.52 and 0.94 respectively. The seed was found to be positively significant towards the productivity of spinach in integrated and specialised water management practice at 5%. This implies that a one percent increase in seed by farmers will results in 0.56%, 0.52% and 0.94% increase in the yield of spinach respectively. This results also concur with those of Ahmad *et al*. (2002); Battese and Broca (1997).

The smallest production elasticity of seed (0.42) was found in the specialised water management practice of the irrigation scheme for the production of maize, while the highest production elasticity of seed (0.98) was found in multipurpose water management practice of the irrigation scheme for the production of tomato.

6.3.3 Fertilizer

The demand for fertilizer in crop production depends on the price of the crop, the price of the fertilizer, price of the other inputs that serve as the substitute or complement to fertilizer and the parameters of the fertilizer production function (Lele, 1989).

The fertilizer elasticity of maize production in the integrated, specialised and multipurpose water management was revealed to be 0.31, - 0.43 and 0.63 respectively. The fertilizer was found to be positively insignificant towards the productivity of maize in integrated, negatively significant towards the productivity of maize in specialised water management practice at 10% and positively significant towards the productivity of maize in the multipurpose at 5%. This implies that a one percent increase in use of fertilizer by farmers in the integrated water management practice would result in 0.31% increase in the yield of maize, a one percent increase in use of fertilizer by farmers in the specialised water management practice would result in 0.43% decrease in the yield of maize and a one percent increase in use of fertilizer by farmers in the multipurpose water management practice would result in 0.63% increase in the yield of maize.

The fertilizer elasticity of tomato production in the integrated, specialised and multipurpose water management was revealed to be 0.57, 0.66 and 0.81 respectively. The fertilizer was found to be positively significant towards the productivity of tomato in integrated, specialised and multipurpose water management practice at 5%, 5% and 1% respectively. This implies that a one percent increase in fertilizer by farmers would results in 0.57%, 0.66% and 0.81% increase in the yield of tomatoes respectively. These results also concur with those of Lele (1989); Gerner and Harris (1993); FAO (2002).

The fertilizer elasticity of onion production in the integrated, specialised and multipurpose water management was revealed to be 0.38, 0.40 and 0.44 respectively. The fertilizer was found to be positively significant towards the productivity of onion in integrated, specialised and multipurpose water management practice at 10%. This implies that a one percent increase in fertilizer by farmers will results in 0.38%, 0.40% and 0.44% increase in the yield of onion respectively. This result also concur with those of Lele (1989); Gerner and Harris (1993); FAO (2002).

The fertilizer elasticity of spinach production in the integrated, specialised and multipurpose water management was revealed to be 0.44, 0.42 and 0.52 respectively. The fertilizer was found to be positively significant towards the productivity of spinach in integrated, specialised and multipurpose water management practice at 10%. This implies that a one percent increase in fertilizer by farmers would result in 0.44%, 0.42% and 0.52% increase in the yield of spinach respectively. This result also concur with those of Lele (1989); Gerner and Harris (1993); FAO (2002).

The smallest production elasticity of fertilizer (0.31) was found in the integrated water management practice of the irrigation scheme for the production of maize, while the highest production elasticity of fertilizer (0.81) was found in multipurpose water management practice of the irrigation scheme for the production of tomato.

6.3.4 Labour

The production elasticity of labour for maize production in the integrated, specialised and multipurpose water management was revealed to be -0.47, 0.66 and 0.32, respectively. The labour was found to be negatively significant towards the productivity of maize in integrated at 10%, positively significant towards the productivity of maize in specialised water management practice at 5% and positively insignificant towards the productivity of maize in the multipurpose. This implies that a one percent increase in labour in the integrated water management practice would result in 0.47% decrease in the yield of maize, a one percent increase in use of labour by farmers in the specialised water management practice would result in 0.66% increase in the yield of maize and a one percent increase in use of labour by farmers in the multipurpose water management practice would result in 0.32% increase in the yield of maize.

The return to scale of labour for tomato production in the integrated, specialised and multipurpose water management was revealed to be - 0.03, - 0.22 and - 0.33 respectively. The labour was found to be negatively insignificant towards the productivity of tomato in integrated, specialised and multipurpose water management practice. This implies that a one percent increase in the number of labour by farmers would result in 0.03%, 0.22% and 0.33% decrease in the yield of tomato respectively.

The labour elasticity of onion production in the integrated, specialised and multipurpose water management was revealed to be - 0.22, - 0.25 and - 0.27 respectively. The labour was found to be negatively insignificant towards the productivity of onion in integrated, specialised and multipurpose water management practice. This implies that a one percent increase in the number of labour by farmers would result in 0.22%, 0.25% and 0.27% decrease in the yield of onion respectively.

The labour elasticity of spinach production in the integrated, specialised and multipurpose water management was revealed to be - 0.38, - 0.35 and - 0.37 respectively. The labour was found to be negatively insignificant towards the productivity of spinach in integrated, specialised and multipurpose water management practice. This implies that a one percent increase in the number of labour by farmers would result in 0.38%, 0.35% and 0.37% decrease in the yield of spinach respectively.

The smallest production elasticity of labour (0.03) was found in the integrated water management practice of the irrigation scheme for the production of tomato, while the highest production elasticity of labour (0.66) was found in specialised water management practice of the irrigation scheme for the production of maize.

6.3.5 Capital

The return to scale of capital for maize production in the integrated, specialised and multipurpose water management was revealed to be 0.58, 0.55 and 0.49 respectively. The capital was found to be positively significant towards the productivity of maize in integrated, specialised and multipurpose water management practice at 5%, 5% and 10% respectively. This implies that a one percent increase in tractor by farmers would result in 0.58%, 0.55% and 0.49% increase in the yield of maize respectively.

The capital elasticity of tomato production in the integrated, specialised and multipurpose water management was revealed to be - 0.01, - 0.04 and - 0.22 respectively. The capital was found to be negatively insignificant towards the productivity of tomato in integrated, specialised and multipurpose water management practice. This implies that a one percent increase in the use of tractor by farmers would result in 0.01%, 0.04% and 0.22% decrease in the yield of tomato respectively.

The production elasticity of capital for onion production in the integrated, specialised and multipurpose water management was revealed to be 0.03, 0.15 and 0.20 respectively. The capital was found to be positively insignificant towards the productivity of onion in integrated, specialised and multipurpose water management practice. This implies that a one percent increase in the use of tractor by farmers would result in 0.03%, 0.15% and 0.20% increase in the yield of onion respectively.

The capital elasticity of spinach production in the integrated, specialised and multipurpose water management was revealed to be 0.33, 0.32 and 0.54 respectively. The capital was found to be positively significant towards the productivity of spinach in integrated and multipurpose water management practice at 10% and 5% respectively, whereas it was found to be positively insignificant towards the productivity of spinach in specialised water management practice. This implies that a one percent increase in the use of tractor by farmers would result in 0.33%, 0.32% and 0.54% increase in the yield of spinach respectively.

The smallest production elasticity of capital which is (0.01) was found in the integrated water management practice of the irrigation scheme for the production of tomato, while the highest production elasticity of capital which is (0.58) was found in integrated water management practice of the irrigation scheme for the production of maize.

6.3.6 Pesticides

Agricultural produce such as maize, tomato, onion and spinach are considered more sensitive to disease and insect attacks. This requires an appropriate quantity and timely application of plant protection measures (Ahmad *et al*., 1999). The return to scale for maize production in the integrated, specialised and multipurpose water management was revealed to be - 0.02, 0.41 and 0.53 respectively. The pesticides was found to be positively significant towards the productivity of maize in specialised and multipurpose water management practice at 10% and 5% respectively, whereas it was found to be negatively insignificant towards the productivity of maize in integrated water management practice.

The pesticide elasticity of tomato production in the integrated, specialised and multipurpose water management was revealed to be - 0.02, - 0.22 and - 0.27, respectively. The pesticide was found to be negatively insignificant towards the productivity of tomato in integrated water management practices while, it was found to be negatively significant in the specialised and multipurpose water management practice at 90%. This implies that a one percent increase in the quantity of pesticide by farmers would result in 0.02%, 0.22% and 0.27% decrease in the yield of tomato respectively.

The return to scale for onion production in the integrated, specialised and multipurpose water management was revealed to be - 0.13, - 0.22 and - 0.24 respectively. The pesticide was found to be negatively insignificant towards the productivity of onion in integrated water management practices while it was found to be negatively significant in the specialised and multipurpose water management practice at 10%. This implies that a one percent increase in the quantity of pesticide by farmers would result in 0.13%, 0.22% and 0.24% decrease in the yield of onion respectively. The plausibility of these results lies in the fact that pesticides are expensive and not easy to access.

The return to scale for spinach production in the integrated, specialised and multipurpose water management was revealed to be - 0.07, - 0.22 and 0.41 respectively. The pesticides was found to be negatively insignificant towards the productivity of spinach in integrated and specialised water management practice, whereas it was found to be positively significant towards the productivity of spinach in multipurpose water management practice at 10%.

The smallest production elasticity of pesticides which is (0.02) was found in the integrated water management practice of the irrigation scheme for the production of tomato and maize, while the highest production elasticity of pesticides which is (0.53) was found in multipurpose water management practice of the irrigation scheme for the production of maize.

6.4 General returns to scale

As stated in chapter four, the function is homogenous of degree, α +β. If $\alpha+\beta>1$; there are increasing returns to scale, $\alpha+\beta=1$ indicates constant returns; and $\alpha+\beta<1$, indicates diminishing returns to scale. The farmers operating as an integrated water management practice of the irrigation scheme are experiencing increasing returns to scale of 1.80, 1.72 and 1.80 in the production of maize, onions and spinach respectively while experiencing constant returns to scale (1.02) in the production of tomatoes. These results suggest that farmers in this case have an opportunity of increasing the level of inputs use in the production of maize, onion and spinach since the returns are higher that the costs whereas in the production of tomatoes farmers are advised not to change the resources allocations since the returns are exactly the same as the costs of inputs use.

The farmers operating as the specialised water management practice of the irrigation scheme are experiencing increasing returns to scale of 1.68 and 1.60 in the production of onions and spinach respectively while experiencing constant returns to scale (0.96) in the production of maize and decreasing return to scale (0.76) in the production of tomatoes. These results suggest that farmers in this case have an opportunity of increasing the level of inputs use in the production of onion and spinach since the returns are higher than the costs whereas in the production of maize farmers are advised not to change the resources allocations since the returns are exactly the same as the costs of inputs use. In case of tomatoes the farmer seemed to over-utilise the resources so they need to reduce the level of inputs use.

The farmers operating as the multipurpose water management practice of the irrigation scheme are experiencing increasing returns to scale of 1.98 and 1.61 in the production of onions and spinach respectively while experiencing constant returns to scale (1.29) in the production of maize and decreasing return to scale (0.75) in the production of tomatoes. These results suggest that farmers in this case have an opportunity of increasing the level of inputs use in the production of onion and spinach since the returns are higher than the costs whereas in the production of maize farmers are advised not to change the resources allocations since the returns are exactly the same as the costs of inputs use. In case of tomatoes the farmer seemed to over-utilise the resources so they are advised to reduce the level of inputs use.

6.5 Technical Inefficiency Determinants

Socio-economic, demographic, environmental, institutional and non-physical factors are expected to affect the efficiency (Kumbhakar and Bhattacharya, 1992; Ali and Chaudhry, 1990). Using the equations in chapter three, the study makes an attempt to investigate determinants of technical inefficiency. The coefficients of the explanatory variables in the technical inefficiency model are of particular interest in terms of making policy recommendations.

With regard to the sources of efficiency differentials among sample farmers for maize, tomato, onion and spinach, the estimates of technical inefficiency effects model provide some important insights. Explanatory variables with a large impact should be the main focus of efforts to improve efficiency in crop production, since these can be influenced relatively easily (Ali and Chaudhry, 1990).

6.5.1 Age

Age of the household head of the maize, tomato, onion and spinach producers in the integrated, specialised and multipurpose water management is included to assess the effects of age on the level of technical inefficiency. It is commonly believed that age can serve as a proxy for farming experience. It is estimated that the age has a negative significant effect upon the technical inefficiency effects in the production of maize, tomato, onion and spinach in all three management practices of the irrigation scheme. This implies that as the age of the farmers at different irrigation schemes increases, the technical inefficiency decline.

This suggests that the older farmers are technically more inefficient and these results are in line with those of Parikh *et al*. (1995). This mixture of signs is not unexpected, given the various effects that farmer age may have upon efficiency. According to Coelli (1996), the age of the farmers could be expected to have positive or negative effects upon the size of the inefficiency effects. He concluded that the older farmers are likely to have had more farming experience and hence have less inefficiency. It is also possible that the older farmers could be the more traditional and conservative and therefore, show less willingness to adopt new practices.

6.5.2 Educational level

The coefficient for years of schooling was revealed to be negative in the integrated, specialised and multipurpose water management practices of the irrigation schemes for the entire selected crop producers for the study (i.e. maize, tomato, onion and spinach) are significant. These results indicates that the more educated crop producers are, the more will they likely to become efficient as compared to their less educated counterparts, perhaps as a result of their better access to information and good farm planning

(Dhungana *et al*., 2004). Similar results were also reported by Ali and Flinn (1989); Kalirajan (1990); Kumbhakar *et al*. (1991); Kumbhakar and Bhattacharya (1992); Parikh *et al*. (1995); Llewelyn and Williams (1996); Sharif and Dar (1996); Wang *et al.* (1996); Battese *et al*. (1996); Ahmad and Bravo-Ureta (1996) as all cited by Bakhsh *et al*. (2007).

6.5.3 Family size

The estimated coefficient for the family size was revealed to be positively significant in the integrated, specialised and multipurpose water management practices of the irrigation schemes for the all selected agricultural produce (i.e. maize, tomato, onion and spinach) at 99%. While in the specialised and multipurpose water management for the production of maize, the family size was significant at 95% and 90% respectively.

The positive sign indicates that the larger the family size, the greater is the technical inefficiency. This major reason for the positive sign is allocation of financial resources to family members for their education and health if the composition of the family is such that more of the family members have the age below 10 years (Bakhsh *et al*., 2007). Farmers with large family size face difficulty to meet the financial requirement of growing crops as well as bringing up their children.

6.5.4 Land size

The estimated coefficient of land size was found to have negative significant towards farmers' technical inefficiency in the integrated and specialised water management practices for the production of maize, tomato, onion and spinach. While it was revealed to be positive significant in multipurpose water management practices for the production of tomato and onion, whereas positive insignificant in the production of maize and spinach.

According to Bakhsh *et al*. (2007), one of the key reasons for such results is the small farm size, indicating thereby that crop producers depend wholly on the returns from crop cultivation. Studies show that tenants operated farms are less efficient because of lack of security preventing long term investment on farms (Giannakas *et al*., 2001; Reddy, 2002).

6.5.5 Household Income level

The estimated coefficient of household income level was found to be negatively insignificant towards farmers' technical inefficiency the integrated, specialised and multipurpose water management practices for the production of maize, tomato, onion and spinach. The positive signs imply that the more the household income, the lesser the technical inefficiency even though it was found that the household income has no significant effects on the technical inefficiency in the integrated, specialised and multipurpose water management practices of the irrigation schemes for the production of maize, tomato, onion and spinach. This result is in line with the result of Simon *et al.* (2011) which states that the richest household in the area receives not less than 50 percent of the total income of the area because the group owns and controls larger proportion of the productive and financial resources in the area. Furthermore, improvement in both farm income and non-farm income resulted in relatively more decrease in the cost of technical efficiency, which in turn increased the overall economic efficiency, relatively more and hence increase in per capita income.

6.5.6 Gender

The estimated coefficient of the gender of the farmer was found to be positively insignificant towards farmers technical inefficiency the integrated, specialised and multipurpose water management practices for the production of maize, tomato, onion and spinach, perhaps this is as a results of the gender imbalances at various irrigation schemes. The contrary results are found in the specialised and multipurpose water management practices of the irrigation schemes for the production of maize whereby it was found to be positively significant towards farmers' technical inefficiency. According to the European Union Commission (2010), gender inequality generates wasted opportunities and cognitive errors in knowledge, technology and innovation. Research has shown that gender bias has important implications for the content of science itself. The integration of sex and gender analysis in the research content increases the quality of research and improves the acceptance of innovation in the market (European Union Commission, 2010).

6.6 Technical efficiency indices

This section presents an overview of the technical efficiency of farmer in the three management practices of the irrigation schemes. The technical efficiency per farmers in the three management practices of the irrigation schemes and other indexes are shown below in table 6.6, 6.7, 6.8 and 6.9.

Table 6.6: Technical efficiency of farmers at different irrigation schemes operating in integrated water management practices (i.e. aggregated efficiency for maize, tomato, onion and spinach per farmer)

Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency
1	0.653	27	0.622	53	0.944
2	0.622	28	0.431	54	0.763
3	0.894	29	0.523	55	0.673
4	0.592	30	0.613	56	0.711
5	0.919	31	0.821	57	0.627
6	0.732	32	0.649	58	0.648
7	0.993	33	0.718	59	0.621
8	0.992	34	0.422	60	0.886
9	0.489	35	0.612	61	0.868
10	0.876	36	0.552	62	0.793
11	0.671	37	0.614	63	0.618
12	0.527	38	0.637	64	0.596
13	0.852	39	0.527	65	0.793
14	0.391	40	0.926	66	0 .904
15	0.358	41	0.489	67	0.924
16	0.718	42	0.998	68	0.717
17	0.662	43	0.788	69	0.976
18	0.642	44	0.948	70	0.787
19	0.478	45	0.991	71	0.993
20	0.513	46	0.758	72	0.824
21	0.553	47	0.802	73	0.764
22	0.692	48	0.984	74	0.992
23	0.712	49	0.703	75	0.748
24	0.513	50	0.582	76	0.788
25	0.971	51	0.887	77	0.955
26	0.914	52	0.945	78	0.931
				79	0.736
				80	0.805

Mean technical efficiency = 0.74

Table 6.7: Technical efficiency of farmers at different irrigation schemes operating in as specialised water management practices (i.e. aggregated efficiency for maize, tomato, onion and spinach per farmer)

Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency
1	0.713	27	0.995	53	0.391
2	0.866	28	0.996	54	0.435
3	0.958	29	0.576	55	0.745
4	0.537	30	0.390	56	0.745
5	0.546	31	0.891	57	0.214
6	0.991	32	0.893	58	0.332
7	0.412	33	0.373	59	0.788
8	0.893	34	0.357	60	0.798
9	0.673	35	0.591		
10	0.893	36	0.339		
11	0.674	37	0.767		
12	0.895	38	0.991		
13	0.457	39	0.412		
14	0.785	40	0.673		
15	0.798	41	0.732		
16	0.825	42	0.825		
17	0.951	43	0.991		
18	0.508	44	0.798		
19	0.641	45	0.562		
20	0.965	46	0.689		
21	0.851	47	0.734		
22	0.998	48	0.689		
23	0.718	49	0.851		
24	0.225	50	0.991		
25	0.999	51	0.996		
26	0.889	52	0.866		

Mean technical efficiency = 0.72

Table 6.8: Technical efficiency of farmers at different irrigation schemes operating in as multipurpose water management practices (i.e. aggregated efficiency for maize, tomato, onion and spinach per farmer)

Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency	Farmers Number	Technical Efficiency
1	0.614	27	0.976	53	0.977
2	0.622	28	0.447	54	0.923
3	0.478	29	0.423	55	0.688
4	0.984	30	0.571	56	0.701
5	0.902	31	0.557	57	0.792
6	0.838	32	0.487	58	0.838
7	0.777	33	0.944	59	0.864
8	0.482	34	0.788	60	0.879
9	0.561	35	0.773		
10	0.764	36	0.982		
11	0.807	37	0.981		
12	0.966	38	0.944		
13	0.918	39	0.764		
14	0.681	40	0.607		
15	0.773	41	0.558		
16	0.734	42	0.897		
17	0.764	43	0.877		
18	0.764	44	0.893		
19	0.872	45	0.777		
20	0.911	46	0.991		
21	0.691	47	0.503		
22	0.728	48	0.327		
23	0.787	49	0.410		
24	0.807	50	0.532		
25	0.855	51	0.764		
26	0.864	52	0.935		
Mean technical efficiency = 0.76					

The above results from table 6.6, 6.7 and 6.8 showed that farmers operating on the multipurpose water management practices of the irrigation schemes are better in terms efficiency, followed by farmers operating under integrated water management type of irrigation schemes and lastly comes the farmers operating as specialised water management practice of irrigation schemes with mean technical efficiency of 0.76, 0.74 and 0.72 respectively. These results suggest that there is no correlation between the institutional arrangements of the irrigation schemes and the productivity, since the farmers operating under the specialised water management were expected to be more efficient than farmers operating under integrated water management practice of the irrigation schemes due to the resources availability. Specialised water management practice of the irrigation schemes is well equipped with the resources than the integrated management practices of the irrigation schemes.

Table 6.9: Mean, maximum, minimum efficiency scores and percentage of efficiency farmers at different management practice of irrigation schemes by districts for aggregated agricultural produce (i.e. maize, tomatoes, onions and spinach)

Technical Efficiency				
Management practices of the irrigation scheme	**Mean**	**Max**	**Min**	**Eff%**
Integrated management practices	0.74	0.998	0.358	**96**
Specialised management practices	0.72	0.999	0.214	**80**
Multipurpose management practices	0.76	0.984	0.327	**88**

Source: Author’s Analysis

Table 6.9 indicated that 96% of farmers operating in the integrated management practice of the irrigation scheme were found to be technically efficient with a maximum technical efficiency of 0.998 and minimum technical efficiency of 0.358, 88% of the farmers operating on the multipurpose management practices were found to be technical efficient with a maximum technical efficiency of 0.984 and the minimum efficiency of 0.327. Lastly, it has been revealed that 80% of the farmers operating on the specialised management practices of the irrigation were technically efficient with the maximum technical efficiency of 0.999 and the minimum efficiency of 0.214. This implies that the nature of the institutional arrangements or management practices of the irrigation schemes does not have significant effects on the technical efficiency of farmers.

Table 6.10 Likelihood test ratio of hypothesis of the thesis

Null hypothesis	Log-likelihood function	Test statistics λ	Critical values	Decision
INTEGRATED WATER MANAGEMENT PRACTICE				
$H_0 : \gamma = 0$	73.28	96.531	9.913	**Reject** H_0
$H_0 : \beta_{ij} = 0$	68.43	90.192	9.913	**Reject** H_0
$H_0 : \eta = 0$	- 53.71	8.478	9.913	**Accept** H_0
$H_0 : \nu = 0$	71.22	94.633	9.913	**Reject** H_0
SPECIALISED WATER MANAGEMENT PRACTICE				
$H_0 : \gamma = 0$	63.34	81.523	8.512	**Reject** H_0
$H_0 : \beta_{ij} = 0$	56.34	70.346	8.512	**Reject** H_0
$H_0 : \eta = 0$	- 49.64	7.024	8.512	**Accept** H_0
$H_0 : \nu = 0$	61.27	79.222	8.512	**Reject** H_0
MULTIPURPOSE WATER MANAGEMENT PRACTICE				
$H_0 : \gamma = 0$	63.34	87.523	5.580	**Reject** H_0
$H_0 : \beta_{ij} = 0$	56.34	77.235	5.580	**Reject** H_0
$H_0 : \eta = 0$	- 49.64	4.711	5.580	**Accept** H_0
$H_0 : \nu = 0$	61.27	85.245	5.580	**Reject** H_0

Source: Regression results

The critical values are at 5% level of significance and the critical values were obtained from table of Kodde and Palm (1986). The null hypotheses which include the restrictions that γ are zero not have a chi-square distribution because the restriction defines a point on the boundry of parameter space (Baten and Palm, 2012).

The results of the hypotheses tests for the yield model from the integrated, specialised and multipurpose water management practices of the irrigation schemes are presented in table 6.10 above. Under the null hypotheses, the test statistics was assumed to be asymptotically distributed as mixture of chi-square distribution with degree of freedom equal to the number of restrictions involved. The restrictions imposed by the null hypothesis are rejected when λ exceeds the critical value (Taymaz and Saatci, 1997 as cited by Baten and Blum, 2011).

Table 6.10 shows that the first null hypothesis in the three management practices of the irrigation schemes which specify that, $H_0 : \gamma = 0$, there is a low level of technical efficiency of the farmers in the three management practices of the irrigation schemes was rejected. Therefore, the study can conclude that the level of technical efficiency is high in all management practices of the irrigation schemes with the mean technical efficiency ranging from 0.72 to 0.76 percent.

Table 6.10 shows that the second null hypothesis in the three management practices of the irrigation schemes which specify that, $H_0 : \beta_{ij} = 0$, there are no significant socioeconomic determinants of the technical inefficiency of farmers in the three management practices of the irrigation schemes was rejected. Therefore, the study can conclude that there are socioeconomic determinants of the technical inefficiency of farmers in the three management practices of the irrigation schemes e.g. education level of farmers, age of farmers and land size were found to be significant determinants of technical inefficiency.

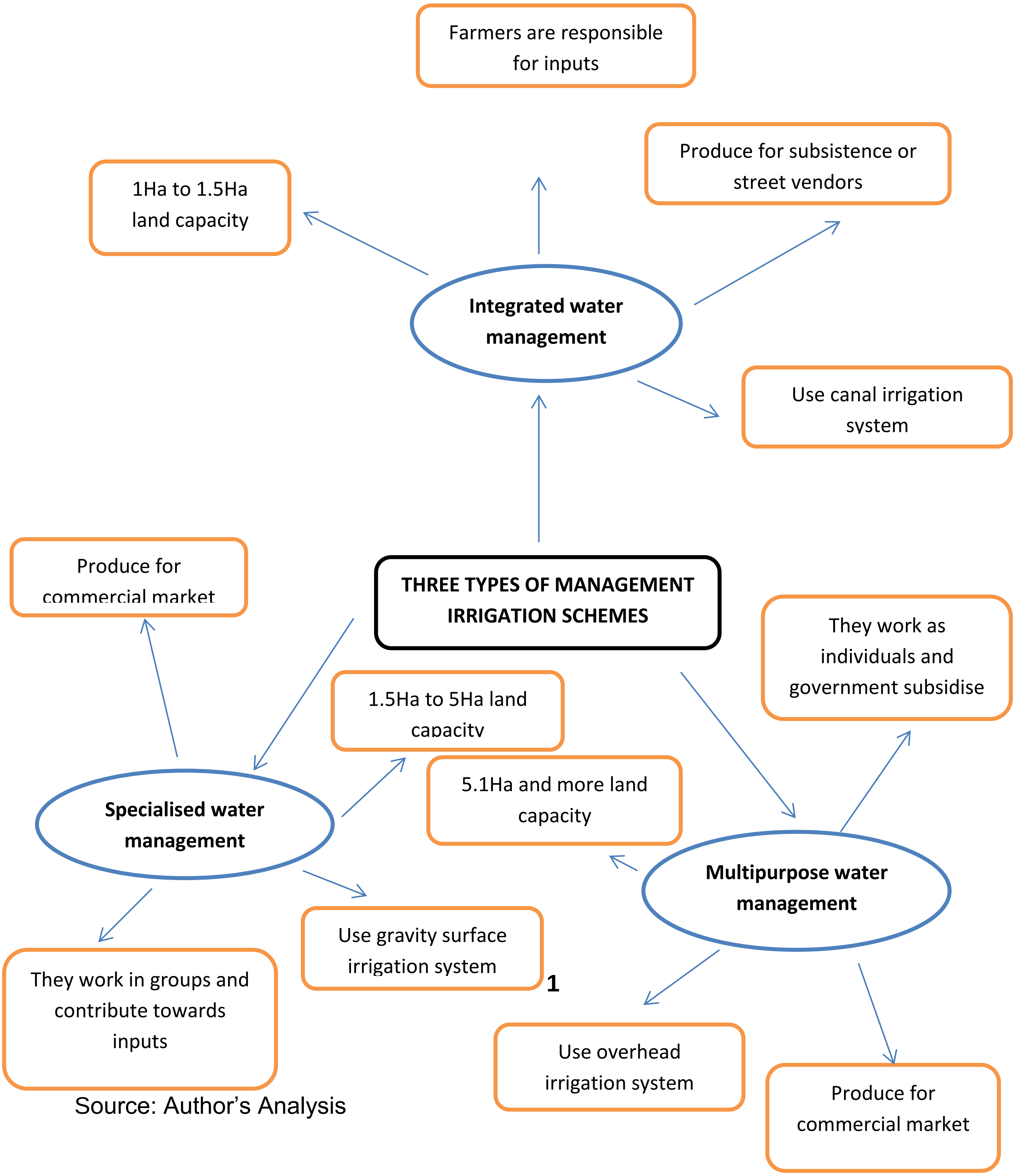
Table 6.10 shows that the third null hypothesis in the three management practices of the irrigation schemes which specify that, $H_0 : \eta = 0$, management practices or institutional arrangements of the irrigation schemes have no significant effects on the technical efficiency of farmers was accepted. Therefore, the study can conclude that institutional arrangements of the irrigation schemes have no significant effects on the technical efficiency of farmers. This was evidenced by the fact that the mean technical efficiency were found to have a margin of 0.2 percent and farmers in the integrated management practice had a mean efficiency of 0.74 which is higher than the one of specialised management practice of the irrigation scheme with the mean technical efficiency of 0.72.

Table 6.10 shows that the fourth null hypothesis in the three management practices of the irrigation schemes which specify that, $H_0 : \nu = 0$, there are no production efficiency gaps in farmers operating as the integrated, specialised and multipurpose management practices of the irrigation schemes was rejected. Therefore, the study can conclude that there are production efficiency gaps in farmers operating as the integrated, specialised and multipurpose management practices of the irrigation schemes. This was evidenced by the fact that the returns to scale were not the same in all the management practices of the irrigation schemes.

6.7 Institutional arrangement analysis

Irrigation is essential input to the soil for any vegetation to grow. It is used to lend a hand in the growing of agricultural products, maintenance of landscapes and potentials of vegetation by restoring humidity in depleted soils of dry areas and during periods of insufficient rainfall. Additionally, irrigation also has few other uses in crop production, which include shielding plants against frost, suppressing weed and wild vegetation in grain fields and helping in preventing soil conservation. Various irrigation schemes differ in terms of the nature, size and operation, source of water and irrigations and ownerships. The study has identified the three types of management organisation of the irrigation schemes based on some of the socio-economic features and the institutional arrangement of the irrigation schemes as highlighted in chapter two, namely integrated, specialised and multipurpose water management practice of the irrigation schemes. See the figure 6.7.

Figure 6.7 Institutional arrangements of the irrigation schemes



Source: Author's Analysis

The institutional arrangement analysis was the basis for the development context analysis, which is the study of environmental, economic, political, institutional, demographic and social patterns and their interaction (Benda-Beckmann *et al*., 1996). This analysis helps in identifying the constraints and opportunities for the irrigation schemes. A number of general patterns in the context of irrigation schemes at multipurpose, specialised and integrated practices are outlined below.

At the multipurpose water management level, the study revealed that there was a decline in production of staple food such as maize, typically high capital costs per hectare have resulted in new irrigation development becoming increasingly difficult to justify economically. In Limpopo Province, improved irrigation sites are already developed and new projects could be expected to cost even more per hectare than those developed in the past.

At the moment, nearly 30 percent of the provincial food comes from the multipurpose water management irrigation schemes which constitute 14 percent of the cultivated land. It can be expected that the Limpopo’s food supply will depend to larger extent on irrigation schemes in the future, and that on the national scale, water will become a scarce resource over the next century. This transition from an era of plenty to a situation of scarcity requires a review of existing policies for water development and allocation among users.

Since this types of management organisation or practices have the governmental support in terms of the inputs subsidies, the irrigation schemes have a potential to increase the production of vegetables and other crops. Additionally, they can influence the decision on water policies.

Furthermore, in Limpopo Province the number of female-headed irrigation schemes is increasing significantly in rural areas, as men migrate due to lack of employment and other income-generating activities which lead to feminisation of agriculture.

At the specialised water management practices which is well-known as community irrigation projects. Community irrigation projects are aimed at increasing the agricultural income of the rural poor and socially disadvantaged groups. The objectives of structural adjustment policies, economic efficiency and fiscal sustainability have initiated in many provinces a privatisation process of communal irrigation projects. This privatisation policy has had a significant impact on the irrigation sectors in South Africa. These policies often resulted in the following;

i. transfer of the operation to water users' associations of various kinds including maintenance responsibilities and the entire or partial costs of the irrigation systems,
ii. pricing of water based on quantity and quality used and
iii. creation of water markets for the buying and selling of water both among individual users and the agricultural, urban and industrial sectors (Sarker *et al*., 1997). Consequently, the role of the government and the involved ministries changes from operation and maintenance of schemes to overall planning, monitoring and evaluation.

Projects are also increasingly planned to match local capacity for implementation, which implies specific attention to an analysis of institutional capacity.

At the integrated water management practice level, intensification of traditional, low-cost irrigation developed on the initiative of farmers, receives increased support of local communities due to its potential for increasing food production. Successful implementation requires participation in planning and implementation by all farmers in order to create a sense of ownership and consequent commitment to the project. Farmers also help to ensure that the design is appropriate, which will attract commitment because it was adequately addressing the varied needs of the community. As part of the privatisation policies, water users' associations (WUAs) are created and all or part of the operation and maintenance responsibilities are transferred to these management practices.

For an irrigation scheme to have a positive and sustainable impact, stakeholders must be committed to the irrigation scheme because their priorities converge with those of the proposed irrigation scheme. Participatory livelihood analysis has assisted in assessing the male and female perceptions and their likely response to the opportunities of the irrigation schemes, as well as to the demands that the project may make on them, such as operation and maintenance of the irrigation schemes. Many people were engaged in irrigation to secure their basic needs and to earn income, but their activities depend greatly on their access to land, labour, water, market, knowledge and capital, which are the main resources in the context of irrigated agriculture.

Within any given culture, access to resources varies according to gender, age, educational qualification, wealth, caste and ethnicity and therefore, so does livelihood. When planning to implement an irrigation project, the resources available to each farmer, need to be assessed and the constraints that they face. Farmers must be aware of resources and constraints at all three levels (integrated, specialised and multipurpose water management practices) in order to determine which changes are needed at each level.

At the multipurpose water management practices, international and national policies determine resource availability and distribution, such as water resource policies, international funding and loan agreements and legal arrangements. At the specialised water management practices, resources and constraints may include the number of farm workers, transport facilities and annual budgets.

At the integrated water management practices, an analysis of the farming system highlights the farm activities such as crop production, off-farm activities such as drinking water collection and non-farm activities such as marketing. It shows the flow of resources to and from the household and which household members are involved, disaggregated by sex. In addition, more information can be collected on the gender-based use and control of resources within the household along with variations among the different socio-economic groups.

Currently, increasing emphasis is placed on the participatory planning and implementation of irrigation schemes, and on management transfer. Irrigation institutions need to evolve from the execution, operation and maintenance of the irrigation schemes, to a co-ordinating and facilitating role. In order to estimate institutional capacity for the integration of socio-economic and gender issues and participatory irrigation planning, it is important to:

i. assess the capacity, at the multipurpose and specialised water management levels of the irrigation schemes and agricultural service institutional to work in a participatory manner with all different groups of stakeholders,
ii. evaluate their motivation to work with and support female and male farmers from resource poor household,
iii. identify constraints and propose solution such as the training of existing workers or recruitment of additional staff,

iv. Assess at the integrated water management level, the importance of access to local groups and institutions for different socio-economic groups and for both female and male.

v. Consider at the integrated water management level, the opportunities and constraints for establishing or strengthening WUAs for new or rehabilitated schemes and the opportunities for various social groups and female and male, to actively participate in decision making processes.

CHAPTER SEVEN

SUMMARY, CONCLUSION AND POLICY RECOMMENDATION

7.0 Introduction

This chapter provides summary, conclusion and policy recommendations including further research areas. This was done by exposing the key thesis doctrines, which are its objectives, hypotheses and the way in which they have been achieved, answered and tested respectively. The way forward was also indicated through policy recommendations and opportunities for further research.

7.1 Summary

The water deficit caused by low and erratic rainfall and high evaporation demand limits dry land crop production in most parts of South Africa. Therefore, irrigated agriculture presents an attractive alternative under these conditions. According to the principles delineated in literature, an attempt was made to categorise irrigation schemes in terms of their management practices. The main criterion chosen to classify the management practices was whether the institutional arrangement of the irrigation schemes covers all the activities such as water management, agricultural extension, applied research, supply of inputs, access to credit, marketing aspects, basic infrastructure and social services or few of these activities with the farm. Within each of these categories, a further distinction is made depending on the degree to which management is controlled by an individual farmer, group of farmers or government.

There are three ways of increasing the production of crops and vegetables in Limpopo Province namely, by increasing the area planted, by developing new technology and by using available resources efficiently. The last option is the most suitable because this option does not require more land and development of new technology. The present study was designed to compare the level of technical efficiency of farmers at different management practices of the irrigation schemes (i.e. integrated, specialised and multipurpose water management practices of the irrigation schemes) in Limpopo province.

This thesis embraced of four objectives which were (1) to determine the level of technical efficiency of the farmers in the three irrigation management practices (2) to identify significant socioeconomic determinants of the technical inefficiency of farmers in three irrigation management practices (3) to determine the extent to which each socioeconomic determinant affect the efficiency of farmers at the different management organisations/institutional arrangement of the irrigation schemes and (4) to establish the effect of management practices/ institutional arrangements of the irrigation schemes on the technical efficiency of farmers and examine the production efficiency gaps in farmers operating as integrated, specialised and multipurpose water management practices of irrigation schemes with regard to efficiency.

The study used the stochastic frontier production function of Cobb-Douglas type to analyse data collected from different irrigated farming sectors. The results indicate that farmers in the integrated, specialised and multipurpose water management practices are operating efficiently given the resources available in the different irrigation schemes in Limpopo Province. The levels of the technical efficiencies differ with the type of the management practices of the irrigation schemes. Multipurpose water management has a highest mean technical efficiency of 0.76, followed by integrated water management practice with the mean technical efficiency of 0.74 while the least mean efficiency was found in the specialised water management practices with 0.72 mean technical efficiency.

In the integrated water management practices of the irrigation scheme for the production of maize, land was found to be the most significant factor towards the efficiency at 1% whereas labour was found to be the least significant factor towards efficiency at 10%. The other factors which were found to be significant are seed and capital at 5%. Fertiliser and pesticides were found to be insignificant in the production of maize. In the specialised water management practices of the irrigation scheme for the production of maize, land, labour and capital were found to be the significant factors towards efficiency at 5%. Whereas seed, fertiliser and pesticides were all found to be significant factors at 10%. In the multipurpose water management practices of the irrigation scheme for the production of maize, seed was found to be the most significant factor towards the efficiency at 1% whereas land and capital were found to be the least significant factors towards efficiency at 10%. The other factors which were found to be significant are fertiliser and pesticides at 5%. Labour was found to be insignificant in the production of maize.

In the integrated water management practices of the irrigation scheme for the production of tomato, seed was found to be the most significant factor towards the efficiency at 1% whereas land was found to be the least significant factor towards efficiency at 10%. The other factor which was found to be significant is the fertiliser at 5%. Labour, capital and pesticides were all found to be insignificant in the production of tomato. In the specialised water management practices of the irrigation scheme for the production of tomato, seed was found to be the most significant factor towards the efficiency at 1% whereas land and pesticides were found to be the least significant factor towards efficiency at 10%. The other factor which was found to be significant is fertiliser at 5%. Labour and capital were found to be insignificant in the production of tomato. In the multipurpose water management practices of the irrigation scheme for the production of tomato, seed and fertiliser were both found to be the most significant factors towards the efficiency at 1%

whereas land and pesticides were found to be the least significant factors towards efficiency at 10%. Labour and capital were found to be insignificant in the production of tomato.

In the integrated, specialised and multipurpose water management practices of the irrigation scheme for the production of onion, land and seed were both found to be the most significant factors towards the efficiency at 1% whereas fertiliser was found to be the least significant factor towards efficiency at 10%. Labour, capital and pesticides were found to be insignificant in the production of onion.

In the integrated water management practices of the irrigation scheme for the production of spinach, land was found to be the most significant factor towards the efficiency at 1% whereas the fertiliser and capital were found to be the least significant factors towards efficiency at 10%. The other factor which was found to be significant is seed at 5%. Labour and pesticides were found to be insignificant in the production of spinach.

In the specialised water management practices of the irrigation scheme for the production of spinach, land was found to be the most significant factor towards the efficiency at 1% whereas the fertiliser was found to be the least significant factor towards efficiency at 10%. The other factor which was found to be significant was seed at 5%. Labour, capital and pesticides were found to be insignificant in the production of spinach.

In the multipurpose water management practices of the irrigation scheme for the production of maize, seed, fertiliser and capital were found to be the significant factors towards efficiency at 5%. Land and pesticides were found to be significant factors at 10%. Only labour was found to be an insignificant factor in the production of spinach.

The study further identified the following socio-economic factors as the inefficiency determinants: land size, family size, and educational level of the farmer, age of the farmer, income level of the farmer and gender of the farmers. The following results were revealed by the analysis which was based on the extent to which these factors influence the inefficiency of farmers at different irrigation schemes in Limpopo Province.

In the integrated and specialised water management practices of the irrigation scheme, land size was found to be negatively significant towards inefficiency at 10% on average for the production of all selected crops i.e. maize, tomato, onion and spinach. In the multipurpose water management practices of the irrigation scheme, land was found to be positively significant towards inefficiency at 10% on average in the production of tomato and onions, whereas positively insignificant for the production of maize and spinach. The negative relationship between land and inefficiency implies that the higher the land size available for cultivation, the lesser the inefficiency occurs, while the positive sign implies that the higher the land size available for cultivation, the more the inefficiency occurs.

In the integrated, specialised and multipurpose water management practices of the irrigation schemes, family size was found to be positively significant towards the inefficiency at 1% in the production of tomato, onion and spinach. This result implies that as the family size increases there is a high likelihood of producing inefficiently. As for the production of maize, family size was found to be positively significant towards inefficiency at 1% in the integrated water management practice, 5% in the specialised water management practice and 10% in the multipurpose water management practice. These have resulted from the fact that in the integrated water management as compared to the multipurpose, a farmer relay on the family members for labour whereas in multipurpose, a farmer relay on hire worker than family members for farming.

For the production of maize and spinach, educational level of the farmers was found to be negatively significant toward inefficiency at 5% in the integrated, specialised and multipurpose water management practices of the irrigation schemes. As for the production of tomato, the educational level of the farmers was found to be negatively significant toward inefficiency at 10% in the integrated, specialised and multipurpose water management practices of the irrigation schemes. As for the production of onion, educational level of the farmers was found to be negatively significant towards inefficiency at 5% in the integrated water management practice, 10% in the specialised and multipurpose water management practices.

The age of the farmers for the production of tomato, onion and spinach was found to be negatively significant towards inefficiency at 5% in all the three management practices of the irrigation schemes i.e. integrated, specialised and multipurpose water management practices, while for the production of maize was it found to be negatively significant towards inefficiency at 1% in all the three management practices of the irrigation schemes.

In the integrated, specialised and multipurpose water management practices of the irrigation schemes, income level of the farmer was found to be negatively insignificant towards inefficiency for the maize, tomato, onion and spinach. Gender of the farmers for the production of tomato, onion and spinach was found to be positively insignificant towards inefficiency in all the three management practices of the irrigation schemes i.e. integrated, specialised and multipurpose water management practices. Whereas for the production of maize it was found to be positively significant towards inefficiency at 5% in the specialised and multipurpose water management practices, except in the integrated water management where it was found to be positively insignificant towards inefficiency.

The farmers operating in the three management practices of the irrigation schemes experienced an increasing return to scale in the production of onion and spinach. The highest increasing returns to scale was found in the multipurpose water management practice of the irrigation schemes in the production of onion. Farmers in both specialised and multipurpose irrigation management practices were found to experience a constant return to scale in the production of maize while farmers operating in the integrated irrigation management practice experience increasing returns to scale in the same crop. Farmers operating in the specialised and multipurpose irrigation management practices experience a decreasing return to scale in the production of tomatoes whereas farmers in integrated management practice experience a constant return to scale in the production of tomatoes.

The outcomes from the institutional arrangements analysis of the irrigation schemes in Limpopo Province revealed that the institutional capacity of the irrigation schemes played a significant role in the production efficiency of farmers. The three management practices of the irrigation schemes have an impact on the operation of the schemes. Various irrigation schemes differ in terms of the nature, size, operations, and human resource, source of water and irrigations and ownerships.

7.2 Conclusion

Overall, the mean technical efficiency of (0.74), (0, 72) and (0.76) for the integrated, specialised and multipurpose water management practices of the irrigation schemes respectively showed that there is a greater scope to increase maize, tomatoes, onion and spinach production with the current technology and resources available at the irrigation schemes. The most important contributors in maize, tomatoes, onion and spinach production were seed, fertilizer, capital and land. Thus an appropriate amount of seed, fertilizer, capital and land could increase the production of maize, tomatoes, onion and spinach.

An analysis of the determinants of technical efficiency was carried out and it showed that technical inefficiency in maize, tomatoes, onion and spinach production could be reduced by educating the farmers at different irrigation schemes in improved production techniques and proper use of available farm resources. Therefore, there is a need for strengthening the extension service on the modern lines. The study showed that the technical inefficiency can be reduced by utilising land, seed, fertilizer and pesticides efficiently. But further studies are required to decide on the optimum level of the above variables to prevent environmental degradation.

The institutional arrangements or the management practices of the irrigation schemes showed rare differences in affecting the efficiency of farmers at different irrigation schemes. It was expected that farmers operating as multipurpose management practices of the irrigation schemes would have the highest score of technical efficiency and allocative efficiency since they have better resources than the other management practice of the irrigation schemes. Therefore, there is a need for further studies on the direct impact of institutional arrangements on the productivity of a specific crop.

Therefore, the three of the four hypotheses stated in chapter one were rejected since the current study found that the level of technical efficiency are high in some cases in the three management practices of the irrigation schemes, the study identified the significant socioeconomic determinants of the technical inefficiency of farmers in integrated, specialised and multipurpose water management of the irrigation schemes. The study further revealed that there were no significant differences in the levels of technical efficiency in different management practices or institutional arrangements of the irrigation schemes. Lastly the study also showed that there are production efficiency gaps in farmers operating as integrated, specialised and multipurpose water management practice of the irrigation schemes since some of the farmers are under-utilising and over-utilising the resources as shown by the returns to scale.

7.3 Policy Recommendation

In many countries, agricultural policies are based on quantitative analysis of agricultural production system. Different types of quantitative analyses are performed and these include measuring scale economies, producers' responsiveness to output and input price variation and the relative efficiency of resource use (Russell and Young, 1983; Hassan, 2004 as cited Bakhsh *et al*., 2007). Therefore, there is a need to conduct such kinds of studies focusing on issues relating to policy options. This study will provide the picture of agricultural systems in Limpopo Province with emphasis on the irrigation schemes. On the basis of this study, the following suggestions or recommendations are made;

i. It is evident from the results that maize, tomatoes, onion and spinach yield at different management practices of the irrigation schemes could be increased substantially with current technology and available inputs if technical and allocative inefficiencies are overcome somehow. Education level of the farmer was found to be significant in all three management practices of the irrigation schemes (i.e. integrated, specialised and multipurpose water management practices of the irrigation schemes) for the production of maize, tomatoes, onion and spinach. Policies designed to educate famers at different irrigation schemes through proper agricultural extension services could have a great impact in increasing the level of efficiency and hence maize, tomatoes, onion and spinach productivities. The government (Department of Agriculture) should allocate more funds to strengthening the extension directorate and expanding the net of extension services to farmers at different irrigation schemes.

ii. Results reveal that overdoses of inputs such as pesticides and fertilizers, etc. do not increase output as in the maize, tomatoes, onion and spinach production in the integrated, specialised and multipurpose with a few exceptions. It is common perception among farmers at different irrigation schemes that agricultural production increases with high inputs use. Therefore, appropriate training of farmers in all three management practices of the irrigation schemes on how and when to use costly inputs is required to give a boost to maize, tomatoes, onions and spinach production.

iii. With referral from the results, land size was found to be significant in most of the farmers at different irrigation schemes for the production of maize, tomatoes, onions and spinach. It is of vital importance for the policy-makers to focus on the benefits of economies of scale in agricultural farming system. Therefore, land size should be increased for the farmers in integrated water management practice of the irrigation schemes to an optimum level in order for them to operate on technical efficiency. This is informed by their high level of technical.

iv. During the survey (2010 - 2011), it has been observed that about 60% of the irrigation schemes in Limpopo Province were in a state of collapsing, for different reasons. Irrigation schemes were established in order to insure food security, alleviate poverty and job creation. Therefore, it is of paramount importance for the government in collaboration with the private sector to revitalise the irrigation schemes in Limpopo Province irrespective of the institutional arrangements.

7.4 Areas for further studies

Although this study was designed to compare the level of efficiency of farmers in different management organisation/institutional arrangements of the irrigation schemes, certainly there are areas that need to be considered as gaps for further studies.

i. This study established the aggregated impact of institutional arrangements of the irrigation schemes on the technical and allocative efficiency where the outcome showed that farmers at integrated water management practices of the irrigation schemes have higher mean technical and allocative efficiency than the other two management practices of the irrigation schemes. Therefore, there is a need to study which will quantify the actual contribution of institutional arrangement on specific irrigation schemes.

ii. The present study was designed to compare the level of efficiency of farmers in different management organisation/institutional arrangements of the irrigation schemes in Limpopo Province due to financial and time constraints. The conclusion arrived at and the recommendation made in this study may not be applicable to irrigation schemes in other parts of South Africa. It is recommended that future researchers should consider the whole country to conduct a study of this nature.

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APPENDIX: ONE

APPENDIX ONE

TABLE I

UPPER AND LOWER BOUNDS FOR THE CRITICAL VALUE FOR JOINTLY TESTING EQUALITY AND INEQUALITY RESTRICTIONS[a]

df	α .25	.10	.05	.025	.01	.005	.001
1	0.455	1.642	2.706	3.841	5.412	6.635	9.500
2	2.090	3.808	5.138	6.483	8.273	9.634	12.810
3	3.475	5.528	7.045	8.542	10.501	11.971	15.357
4	4.776	7.094	8.761	10.384	12.483	14.045	17.612
5	6.031	8.574	10.371	12.103	14.325	15.968	19.696
6	7.257	9.998	11.911	13.742	16.074	17.791	21.666
7	8.461	11.383	13.401	15.321	17.755	19.540	23.551
8	9.648	12.737	14.853	16.856	19.384	21.232	25.370
9	10.823	14.067	16.274	18.354	20.972	22.879	27.133
10	11.987	15.377	17.670	19.824	22.525	24.488	28.856
11	13.142	16.670	19.045	21.268	24.049	26.065	30.542
12	14.289	17.949	20.410	22.691	25.549	27.616	32.196
13	15.430	19.216	21.742	24.096	27.026	29.143	33.823
14	16.566	20.472	23.069	25.484	28.485	30.649	35.425
15	17.696	21.718	24.384	26.856	29.927	32.136	37.005
16	18.824	22.956	25.689	28.219	31.353	33.607	38.566
17	19.943	24.186	26.983	29.569	32.766	35.063	40.109
18	21.060	25.409	28.268	30.908	34.167	36.505	41.636
19	22.174	26.625	29.545	32.237	35.556	37.935	43.148
20	23.285	27.835	30.814	33.557	36.935	39.353	44.646
21	24.394	29.040	32.077	34.869	38.304	40.761	46.133
22	25.499	30.240	33.333	36.173	39.664	42.158	47.607
23	26.602	31.436	34.583	37.470	41.016	43.547	49.071
24	27.703	32.627	35.827	38.761	42.360	44.927	50.524
25	28.801	33.813	37.066	40.045	43.696	46.299	51.986
26	29.898	34.996	38.301	41.324	45.026	47.663	53.403
27	30.992	36.176	39.531	42.597	46.349	49.020	54.830
28	32.085	37.352	40.756	43.865	47.667	50.371	56.248
29	33.176	38.524	41.977	45.128	48.978	51.715	57.660
30	34.266	39.694	43.194	46.387	50.284	53.054	59.064
31	35.354	40.861	44.408	47.641	51.585	54.386	60.461
32	36.440	42.025	45.618	48.891	52.881	55.713	61.852
33	37.525	43.186	46.825	50.137	54.172	57.035	63.237
34	38.609	44.345	48.029	51.379	55.459	58.352	64.616
35	39.691	45.501	49.229	52.618	56.742	59.665	65.989
36	40.773	46.655	50.427	53.853	58.020	60.973	67.357
37	41.853	47.808	51.622	55.085	59.295	62.276	68.720
38	42.932	48.957	52.814	56.313	60.566	63.576	70.078
39	44.010	50.105	54.003	57.539	61.833	64.871	71.432
40	45.087	51.251	55.190	58.762	63.097	66.163	72.780

[a] The values in the table are obtained by solving the equation $\alpha = \frac{1}{2}\Pr[\chi^2(df-1) \geq c] + \frac{1}{2}\Pr[\chi^2(df) \geq c]$ for c, given α and df.

often arise in empirical econometric work. The large sample distribution of the test statistic under the null hypothesis is a mixture of χ^2 distributions.

As in the case of testing equality constraints, the Wald test should be very useful when unrestricted asymptotically normal, consistent but not necessarily efficient estimates of the parameters θ can be easily obtained compared with estimation subject to nonlinear equality and inequality restrictions.

To avoid the computational problems involved in obtaining the asymptotic distribution of the Wald test, we derived upper and lower bound critical values, which should be useful in many applications.

APPENDIX: TWO

COMPARATIVE ANALYSIS OF EFFICIENCY ON DIFFERENT MANAGEMENT SYSTEMS OF IRRIGATION SCHEMES IN LIMPOPO PROVINCE, SOUTH AFRICA: A STOCHASTIC FRONTIER PRODUCTION APPROACH

This questionnaire is part of a PhD thesis on efficiency of farmers in different management organizations of irrigation schemes in Limpopo Province, Republic of South Africa. Information provided in this questionnaire is strictly confidential. The objectives of the study are to determine the level of technical and allocative efficiency of the farmers, to identify socio-economic determinants of the farmers' efficiency, to analyze the impact of management organization/ institutional arrangements on the technical and allocative efficiency of farmers and to examine the loopholes/gaps of farmers operating in an Integrated, Specialised and Multipurpose Water Management Organizations of irrigation schemes with regard to efficiency in Limpopo Province, South Africa

PARTICULARS OF THE INTERVIEW				
Name of Enumerator				
Date of interview				
Interview duration	Start		End	

DEMOGRAPHIC DETAILS				
Name of the irrigation scheme				
Name of the District				
Management practices of the irrigation scheme.	1. Integrated water management organization	2. Specialized water management organization	3. Multipurpose water management organization	4. Other: (Specify)

SECTION 1

Name of Respondent					
Ethic group	1. Ba-Pedi	2. Tsonga	3. Venda	4. Ndebele	5. Other: (Specify)
Race	1. Black	2. Coloured	3. White	4. Asian	
1.1 Respondent's Roster					
Marital status	1. Single	2. Married	3. Widowed	4. Other	
Gender	1. Male	2. Female			
Number of dependent.					
Age (years)	1. < 20 years	2 = 21 – 40 years	3. 41 - 60 years	4. > 61 years	
Educational Qualification	1= No education	2= Primary	3 = Secondary	4= Tertiary	
Occupation	1= Wage/Salary work (Employed)	2= Self employed	3= Unemployed	4= Retired 5= Schooling 6= Other :(Specify)	
1.2 Source of income for the respondent?					

1= Pensions	2= Farming	3= Child Grant	4= Salaries	5= Other: (Specify)
1.3. How much does the respondent spend per month (household expenditure)? Estimate				
1= income < R1000	2. Income between R 1001- R 3000	3. income between R 3001 – R6000	4.Income between R6001 – R10000	5. Income between R10001 Plus
1.4 How will you rate your Health condition				
1= Excellent	2= Good	3= Average/ Fair	4= Poor	5= Very Poor
1.5 Indicate proficiency in the following Languages (State) 1=Good,2= Fair,3= Poor				
Language	**Speak**	**Read**	**Write**	
English				
Afrikaans				
Sotho				
Zulu				
Xhosa				

SECTION 2

LAND AND FARMING

2.1 Do you have access to one or more arable fields for irrigation scheme?

1. Yes	
2. No	

2.2 If Yes, How many fields for irrigation scheme do you have access to? (Indicate number)

1	2	3	4	More (Specify)

2.3 What is the size of each of the fields for irrigation scheme?

	Area size
Field one	
Field two	
Field three	
Field four	

2.4 How did you obtain access to each of the fields?

	Field 1	Field 2	Field 3	Field 4
1. Bought from a private person (Title deed)				
2. Rented from another household				
3. Inherited from parents				
4. Given by Government				
5. Given by headman				

2.5 What are the most common forms of land tenure system in your area for irrigation schemes?

1. Freehold	
2. Communal	
3. Owner – operator ship	
4. Land/ tenancy	
5. Other: (specify)	

2.6 What crops have you produced in the past twenty four (24) months?

TOTAL PRODUCTION				
Crops	Area size	Units	Quantity	Total outputs
1. Maize				
2. Spinach				
3. Tomatoes				
4. Onions				
5. Other :(Specify)				

2.7 What quantities of crops are consumed at home, given away to friends/relatives and sold?

OUTPUT PROCUREMENT				
Crops	Home Consumption	Donations	Sales in physical quantity	Total outputs in monetary value
1. Maize				
2. Spinach				
3. Tomatoes				
4. Onions				
5. Other :(Specify)				

SECTION 3

FARM OPERATION

3.1 What are the sources of water supply in your irrigation scheme?

1. Boreholes	
2. River	
3. Dam	
4. Tap	
5. Other: (Specify)	

3.2 What type of irrigation system do you use in your irrigation scheme?

1. Spate irrigation	
2. Flood irrigation	
3. Sprinkler irrigation	
4. Pipe irrigation	
5. Other : (Specify)	

3.3 Who does the ploughing of your field or fields?

1. Self	
2. Hired labour	
3. Family and self	
4. Community co-operative	
5. Other : (Specify)	

3.4 How was the ploughing done?

1. By oxen	
2. By tractor	
3. By hand/hoes etc	
4. Other: (Specify)	

3.5 How much did you pay for the following inputs last season? Ct = Costs of the inputs and Qt = quantity of the inputs

INPUTS	Maize and Beans		Spinach		Carrots		Beetroots		Tomatoes		Onions		butternuts	
	Ct	Qt	Ct	Qt	Ct	Qt	Ct	Qt	Ct	Qt	Ct	Qt	Ct	Qt
1. Seeds														
2. Fertilizer														
3.Insecticide														
4.Herbicides														
6. Water														
7. Tractor														
8. Other: (Specify)														

3.6 Where did you buy the following farm inputs for maize?

INPUTS	Local shop (1)	Nearest town (2)	NTK (3)	Other Specify (4)
1. Seeds				
2. Fertilizer				
3. Insecticide				
4. Herbicides				
5. Other : (Specify)				

3.7 Where did you buy the following farm inputs for Spinach?

INPUTS	Local shop (1)	Nearest town (2)	NTK (3)	Other Specify (4)
1. Seeds				
2. Fertilizer				
3. Insecticide				
4. Herbicides				
5. Other : (Specify)				

3.8 Where did you buy the following farm inputs for Tomatoes?

INPUTS	Local shop (1)	Nearest town (2)	NTK (3)	Other Specify (4)
1. Seeds				
2. Fertilizer				
3. Insecticide				
4. Herbicides				
5. Other : (Specify)				

3.9 Where did you buy the following farm inputs for Onions?

INPUTS	Local shop (1)	Nearest town (2)	NTK (3)	Other Specify (4)
1. Seeds				
2. Fertilizer				
3. Insecticide				
4. Herbicides				
5. Other : (Specify)				

SECTION 4

LABOUR COMPOSITION

4.1 Who does most of the work in the field?

1 Husband	
2 Wife/wives	
3 Children	
4 Relatives	
5 Hired labour	
6 Other: Specify	

Additional information

____

____

____

4.2 What specific activities in which enterprise takes up most of your time?

ACTIVITY	Maize	Spinach	Tomatoes	Onions
1. Ploughing				
2. Weeding				
3. Spraying				
4. Harvesting				
5. Other: (Specify)				

Additional information

4.3 Roughly, how many hours do you spend in your field working?

1. Hours spent	Maize	Spinach	Tomatoes	Onions
2. Per day				
3. Per week				

4.4 Do you have a problem with obtaining labours?

1. Yes	
2. No	

If Yes, state the reason

4.5 Where do you obtain labour?

1	Hired labour from outside	
2	Family labour from household	
3	Assistance from neighbours	
4	Advertise (Labour Market)	
5 Other: (Specify)		

Additional information

4.6 For which operation do you use hired labour from outside and indicate the number of days labour is hired.

OPERATION	MAN DAYS
1 Land preparation	
2 Planting	
3 Weeding	
4 Spraying	
5 Fertilizer application	
6. Harvesting	
7. Other: (Specify)	

Additional information

____

____

4.7 How much do you pay in cash or in kind for the hired labour per day?

____

SECTION 5

MARKETING

5.1 Where do you sell your produce?

Market	Maize	Spinach	Tomatoes	Onions
1. Locally to neighbours				
2. Local shop				
3.Supermarket				
4. Nearest town as a walker				
5. Other: (Specify)				

5.2 How far is it to the main market for your produce? State

____

____

5.3 How do you get your produce to the market?

____

____

____

____

5.4 Do you have any problems with getting your produce sold?

1. Yes	
2. No	

If yes, state the problem you have

____

____

____

SECTION 6

Extension Services

6.1 Are you aware of advisory services or extension or government support institutions in your district?

1. Yes	
2. No	

6.2 Where do you obtain advice for your crop production?

1 Neighbours	
2 Extension officers	
3 Sales representatives	
4 None received	
5. Other: (Specify)	

Additional information

____

____

6.3 In the case where you obtaining advice from extension officers, how often do extension officers visit your field?

1 On daily basis	
2 Once a week	
3 Once a month	
4 Tice a month	
5. Other: (Specify)	

Additional information

____

____

6.4 What is your opinion (rate) on the quality of service provided by extension officers who visit your field?

1 Excellent	
2 Very good	
3 Satisfactory/ average	

4 Fair	
5. Poor	

6.5 Do you belong to one or more farmer's organization (s)?

1. Yes	
2. No	

1. Yes	
2. No	

If yes, which ones? (State it or them)

____

____

____

6.6 What services do this/these organizations perform?

1. Farmer representation at Local, Municipal, District or Provincial level	
2. Facilitation of training	
3. Facilitation of finance	
4. Other: (Specify)	

Additional information

____

____

SECTION 7

Credit Facilities

7.1 Have you ever needed to borrow money for farming?

1. Yes	
2. No	

If yes, who lends you money?

____

____

7.2 How much interest rate did they charge you? ______________________________

7.3 Is the information about how to obtain a loan sufficient for you?

1. Yes	
2. No	

7.4 If you borrowed money, why did you borrow?

1. Farmer representation at	
2. Facilitation of training	
3. Other: (Specify)	

Additional information

____

____

7.5 When borrowing from the bank or agencies, what collateral (security) was requested from you?

1. Percentage of loan?	
2. Titled deed	
3. Insurance policy	
4. Other: (Specify)	

Additional information

____

____

SECTION 8

Income

8.1 What income did you derived from your produce?

Income/ Revenue	Maize	Spinach	Tomatoes	Onions
Amount				

8.2 How much additional income did you derive from other sources?

Source of additional income	Amount/month	Net income per annum
Salaries & wages		
Remittances		
Rentals		
Lobola		
Income in kind		
Livestock sales		
Maintenance monies		
Pensions		
Other: specify		

8.3 Do you make profit in your irrigation scheme?

1. Yes	
2. No	

8.4 If yes, how much profit made per each crop last season?

Profit (TR – TC =Profit	Maize	Spinach	Tomatoes	Onions
Amount				

8.5 How much did you spend on the following items? (State the aggregate expenditure of the farm)

1. Labour	
2. Collection/Harvesting	
3. Trasnport	
4. Energy and fuel (Diesel, electricity or petrol)	
5. Machinery or equipment	
6. Training and information	
7. Management	
8. Water	
9. Other: (Specify)	

SECTION 9

General Question

9.1 Do you produce enough to feed your households and to cater for market year?

1. Yes	
2. No	

9.2 If no, why are you unable to produce enough food?

1. Land is too small	
2. Soil is too poor	
3. Labour is too scarce	
4. Inputs are expensive	
5.Other: (Specify)	

Additional information

____

____

9.3 Do you need more land for farming?

1. Yes	
2. No	

Additional information

____

____

9.4 If yes, you need the land for:

1. Grazing	
2. Cultivation of maize	
3. Cultivation of other crops	
4.Garden	

Additional information

____

____

9.5 Where is this land that you need?

1. State land	
2. Commercial farms	
3. Mission land	
4.Other: (Specify)	

Additional information

____

____

____

9.6 What is the management composition of the irrigation scheme?

____

____

____

____

9.7 List the most important things you need to improve your farming business

____

____

____

____

____

____

Acknowledgement and farewell

Thank you very much for your time and participation in answering this questionnaire

APPENDIX: THREE

UNIVERSITY OF THE LIMPOPO
ETHICS COMMITTEE

APPLICATION FOR HUMAN EXPERIMENTATION

(Completed forms, preferably typed, should reach the Chairperson of the Ethics Committee at least one month before the experimentation is due to start. Projects where the researcher only receives human material for analysis without actually being involved with collection from the experimental group must still register in the normal way. Researchers who are involved with projects which have been approved by Ethical Committees of other Institutions should provide this Committee with the necessary information and provide it with a shortened protocol for approval)

PROJECT TITLE: Comparative analysis of efficiency on different management systems of irrigation schemes in Limpopo Province, South Africa: A stochastic frontier production approach

PROJECT LEADER: Prof. Abenet Belete

DECLARATION

I, the signatory, hereby apply for approval to execute the experiments described in the attached protocol and declare that:

1. I am fully aware of the contents of the Guidelines on Ethics for Social science studies, and that I will abide by the guidelines as set out in that document (available from the Chairperson of the Ethics Committee); and

2. I undertake to provide every person who participates in any of the stipulated experiments with the information in Part II. Every participant will be requested to sign Part III.

Name of Researcher: Hlongwane Johannes Jan

Signature:

Date:

For Official use by the Ethics Committee:

Approved/Not approved
Remarks:

Signature of Chairperson:
Date:

PROJECT TITLE: Comparative analysis of efficiency on different management systems of irrigation schemes in Limpopo Province, South Africa: A stochastic frontier production approach

PROJECT LEADER: Prof. Abenet Belete

APPLICATION FOR HUMAN EXPERIMENTATION: PART II

Protocol for the execution of experiments involving humans

1. Department: Agricultural Economics and Animal Production.

2. Title of project: Comparative analysis of efficiency on different management systems of irrigation schemes in Limpopo Province, South Africa: A stochastic frontier production approach

3. Full name, surname and qualifications of project leader: Prof. Abenet Belete (PhD Agricultural Economics)

4. List the name(s) of all persons (Researchers and Technical Staff) involved with the project and identify their role(s) in the conduct of the experiment:

Name:	Qualifications:	Responsible for:
Hlongwane J J	M.Sc Agric (Agricultural Economics)	Researcher

5. Name and address of supervising physician: N/A

6. Procedures to be followed: A structured questionnaire will be compiled by the researcher and administered to selected farmers in order to collect relevant information that will be analysed and used for the purpose of the study.

7. Nature of discomfort: None

8. Description of the advantages that may be expected from the results of the experiment:

The study will:

a. Be helpful to the farmers at different irrigation schemes by providing better understanding of the efficiency and socio-economics determinants of technical and allocative efficiency on different management practices of the irrigation schemes in Limpopo Province.
b. It will further highlight the loopholes/gaps in relation to technical and allocative efficiency of farmers in different management practices of irrigation schemes.
c. The information regarding the impact or effect caused by the institutional arrangement of the irrigation schemes of efficiency is significant, since it can be a

learning paradigm to farmers and other stakeholder such as government and donors, in terms of providing support in redressing the conditions.

d. The recommendations of this study through publication will enable the farmers at different scheme to know socio-economic factors hampering the achievement of the following objectives of the irrigation scheme: higher agricultural output, higher labour absorption, food security and poverty alleviation in the rural areas.

e. Also serve as a resource material that the government can assimilate and disseminate by diffusion and induction techniques to farmers at different irrigation schemes.

Signature of Project Leader: Prof. Abenet Belete

Date:

PROJECT TITLE: Comparative analysis of efficiency on different management systems of irrigation schemes in Limpopo Province, South Africa: A stochastic frontier production approach

PROJECT LEADER: Prof. Abenet Belete

APPLICATION FOR HUMAN EXPERIMENTATION: PART II

INFORMATION FOR PARTICIPANTS

1. You are invited to participate in the following research project/experiment:

Comparative analysis of efficiency on different management systems of irrigation schemes in Limpopo Province, South Africa: A stochastic frontier production approach.

2. Participation in the project is completely voluntary and you are free to withdraw from the project/experiment (without providing any reasons) at any time. You are, however, requested not to withdraw without careful consideration since such action might negatively affect the project/experiment.

3. It is possible that you might not personally experience any advantages during the experiment/project, although the knowledge that may be accumulated through the project/experiment might prove advantageous to others.

4. You are encouraged to ask any questions that you might have in connection with this project/experiment at any stage. The project leader and her/his staff will gladly answer your question. They will also discuss the project/experiment in detail with you.

5. Your involvement in the project. The researcher will collect information from small-scale maize farmers through face to face interviews using a structured questionnaire. The interview will be carried out in such a way that privacy of the participants will be considered and their values and beliefs will not be violated.

This section is to be drawn up by the researcher and must be submitted together with the application form.

(*it is compulsory for the researcher to complete this field before submission to the ethics committee*)

UNIVERSITY OF LIMPOPO

ETHICS COMMITTEE

PROJECT TITLE: Comparative analysis of efficiency on different management systems of irrigation schemes in Limpopo Province, South Africa: A stochastic frontier production approach.

PROJECT LEADER: Prof. Abenet Belete

CONSENT FORM

I, ____ hereby voluntarily consent to participate in the following project: (*it is compulsory for the researcher to complete this field before submission to the ethics committee*)

I realise that:

1. The study deals with _____________________ (eg. effect of certain medication on the human body) (*it is compulsory for the researcher to complete this field before submission to the ethics committee*)

2. The procedure or treatment envisaged may hold some risk for me that cannot be foreseen at this stage;

3. The Ethics Committee has approved that individuals may be approached to participate in the study.

4. The experimental protocol, ie. the extent, aims and methods of the research, has been explained to me;

5. The protocol sets out the risks that can be reasonably expected as well as possible discomfort for persons participating in the research, an explanation of the anticipated advantages for myself or others that are reasonably expected from the research and alternative procedures that may be to my advantage;

6. I will be informed of any new information that may become available during the research that may influence my willingness to continue my participation;

7. Access to the records that pertain to my participation in the study will be restricted to persons directly involved in the research;

8. Any questions that I may have regarding the research, or related matters, will be answered by the researchers;

9. If I have any questions about, or problems regarding the study, or experience any undesirable effects, I may contact a member of the research team;

10. Participation in this research is voluntary and I can withdraw my participation at any stage;

11. If any medical problem is identified at any stage during the research, or when I am vetted for participation, such condition will be discussed with me in confidence by a qualified person and/or I will be referred to my doctor;

12. I indemnify the University of Limpopo and all persons involved with the above project from any liability that may arise from my participation in the above project or that may be related to it, for whatever reasons, including negligence on the part of the mentioned persons.

SIGNATURE OF RESEARCHED PERSON

SIGNATURE OF WITNESS

SIGNATURE OF PERSON THAT INFORMED THE RESEARCHED PERSON

SIGNATURE OF PARENT/GUARDIAN

Signed at ___________________________this ____day of _________________2010