Smallholder Irrigation and Agricultural Development in the Olifants River Basin of Limpopo Province: Management Transfer, Productivity, Profitability and Food Security Issues

by

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EXECUTIVE SUMMARY

South Africa has invested substantially in smallholder irrigation, particularly in the former homeland areas. In Limpopo Province alone, there are 171 irrigation schemes with assets valued at R4 billion. However, most of these irrigation schemes are not performing optimally. As a result, the original objective of generating employment and reducing rural poverty through the establishment of these schemes has not been achieved in many instances.

This study was undertaken with the objective of contributing to rural poverty alleviation by improving productivity, profitability, gender equity and environmental sustainability of smallholder irrigation. The specific objectives of the study were to (a) to assess productivity and profitability of smallholder irrigation and the potential for achievement of food security; (b) identify cropping and irrigation management practices; (c) determine the effects of irrigation practices on soil salinity; and (d) examine the institutional and organizational arrangements affecting smallholder irrigation.

The study was undertaken in six irrigation schemes in the Olifants River Basin of Limpopo Province. The schemes included Adriansdraai, Elandskraal, Sepitsi, Strydkraal, Veeplaats, and Wonderboom. A variety of crops are cultivated at the irrigation schemes, including maize, wheat, cotton, and vegetables. Plot sizes range from less than 0.1 hectare to five hectares.

Because of the nature smallholder irrigation issues, a multidisciplinary approach was adopted to achieve the objectives of the study. Consequently, participatory approaches and questionnaire surveys were used to collect data on socio-economic aspects while agronomic experiments and other tools of measurement were used to collect data of a technical nature.

The main findings of the study were as follows:

- Agricultural productivity in the irrigation schemes is generally low. This is particularly so in maize production.
- Although farmers practice crop rotation, leguminous crops are generally not included in the rotation.
- The most profitable enterprises included high value crops such vegetables and wheat. Most farmers producing maize were incurring losses. Farmers aspire to intensify the production of high value crops such as sunflower, sugarbean and groundnuts.
- There is a positive relationship between food security and land size. Farmers with smaller plots tend to experience food insecurity while those with larger ones do not experience food security problems.
- While farming plays a dominant role in poverty alleviation and food security, it does not generate sufficient household income regardless of farm (plot) size.
- Government withdrawal from support service provision in the irrigation schemes has created major problems for farmers. Some of the schemes have almost collapsed and access to support services has been severely reduced resulting in low productivity and food insecurity.

- The extension agent remains the main source of production and marketing information for the majority of farmers. However, extension officers themselves are not equipped to provide the required information due to inadequate training.
- Smallholder irrigation farmers aspire to remain in farming provided access to support services and irrigation water is improved.
- Farmers apply excessive amounts of water when it is their turn to irrigate their plots resulting in low water productivity.
- Salinity levels in all the irrigation schemes are within acceptable levels. Therefore, what is needed at this stage are measures to monitor salinity levels to ensure that the situation does not deteriorate.
- The current organizational arrangements in the irrigation schemes are characterized by major shortcomings in terms of meeting gender equity objectives and ensuring adequate participation of disadvantaged groups. Organizations such as irrigation committees and water user associations are dominated by men with little participation of women. Despite these shortcomings, the committees are highly rated and enjoy the support of farmers.
- The irrigation management transfer process in Limpopo Province is proceeding before the necessary success factors are in place and this may result in failures. The emphasis seems to be on rehabilitation of the irrigation schemes with little attention paid to other factors which are necessary for raising productivity and making farming profitable.
- The scope of water user associations is limited to irrigation related issues and does not go beyond provision of support services.

The following recommendations are made to address some of the problems identified:

- Practical training in water management and irrigation scheduling should be provided to both farmers and extension agents.
- Farmers should be encouraged or assisted to place more emphasis on the production of high value crops and vegetables.
- Farmers should be encouraged to include leguminous crops in their crop rotation systems.
- Measures should be taken to ensure that women are adequately represented on all organizations that are responsible for irrigation water management.
- The formation of water user associations should be closely monitored to ensure active participation of previously disadvantaged groups.
- Farmers should be provided with information about available farmer support services and where to obtain them. This should include training of extension agents and organizing workshops for smallholder farmers to be exposed to sources of support.
- Access to support services should be improved through partnerships among public and private sectors and community based organizations. Farmer organizations also need to be strengthened or established where they do not exist.
- The irrigation management transfer process should involve farmers to ensure that their restructuring needs are met.
- The capacity of water user associations should be strengthened so that they can play a meaningful role in the provision of support services.

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ACRONYMS

ARC	:	Agricultural Research Council
ARDC	:	Agricultural and Rural Development Corporation
CMA	:	Catchment Management Agency
DFID	:	Department for International Development
DWAF	:	Department of Water Affairs and Forestry
EC	:	Electrical Conductivity
ESKOM	:	Electricity Supply Commission
GDP	:	Gross Domestic Product
IMT	:	Irrigation Management Transfer
IWMI	:	International Water Management Institute
NGO	:	Nongovernmental Organization
NTK	:	Noordelike Transvaal Kooperasie
PTO	:	Permission to Occupy
SAR	:	Sodium Adsorption Ratio
UNIN	:	Universiy of the North
WRM	:	Water Resource Management
WUA	:	Water User Association

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The process leading to the awarding of a research grant to the then Faculty of Agriculture at the University of the North (UNIN) began with a visit from a representative of the International Water Management Institute (IWMI) in 1998. After a number of consultations, a research proposal entitled "Sustainable Local Management of Smallholder Irrigation" was developed and submitted to the Water Research Commission for consideration. The proposal was accepted and funding was made available to UNIN starting January 1999. The research process started soon thereafter.

Since one of the main objectives of the research was to build capacity at UNIN to undertake quality research on smallholder irrigation issues, an attempt was made to involve as many people and disciplines as possible in the research. The decision to establish a multidisciplinary research team was also motivated by the nature of smallholder irrigation issues that can only be adequately addressed through a multidisciplinary approach.

Because of the importance of smallholder irrigation in Limpopo Province and dearth of information on this subject, a research project of this kind was long overdue. UNIN has been working closely with the Provincial Department of Agriculture and Environment in Limpopo on many aspects of smallholder agriculture including smallholder irrigation. Through consultations, field observations, and government reports as well as advice from relevant stakeholders including IWMI, an inevitable conclusion was reached that smallholder irrigation in Limpopo Province was performing marginally and an intervention was deemed necessary. This research project was instituted with the aim of contributing to poverty alleviation through improving productivity, profitability, gender equity and environmental sustainability of smallholder irrigation.

The findings of the study are expected to have major implications for policy makers, researchers, extension practitioners, and smallholder irrigation farmers. At the policy level, it is expected that the research findings will assist the government in formulating relevant policies and develop support systems that will improve the productivity, profitability, and sustainability of smallholder irrigated agriculture in South Africa. The research is also expected to help researchers and extension practitioners to develop technical, social and economic interventions for building the capacity of smallholder irrigation farmers to better manage the irrigation schemes to achieve food security, reduce poverty and create job opportunities for themselves and their families. UNIN and other stakeholders will have a better understanding of smallholder irrigated agriculture and be able to contribute to the development of relevant technologies. Research and the curriculum in UNIN's School of Agriculture and Environmental Sciences will be enriched by incorporating aspects of smallholder irrigated agriculture.

1.2 PROBLEM STATEMENT

South Africa has invested substantially in smallholder irrigation to benefit smallholder farmers in the less developed areas. There are more than 200 small-scale irrigation schemes in South Africa irrigating about 50 000 hectares and providing income to over 37 000 farmers. However, this production is not as intensive as needed and often involves production of low-valued food crops which do not even meet subsistence food requirements. Only 37 percent of farmers can be considered commercially oriented (Backeberg, et al., 1996). With the economic value of water increasing, the need to meet environmental river basin requirements, and to alleviate poverty, smallholder irrigation must be more productive. Research has indicated that smallholder farmers can progress from subsistence oriented to market oriented production if suitable institutional reforms, particularly with respect to land tenure, are developed (Van Averbeke, et al., 1998).

Limpopo Province is one of the driest and poorest provinces in South Africa. The average household income of R1113 per annum (Statistics South Africa, 1998) in the province is the second lowest in the country, with 70 percent of the population below the poverty line. The province also has the lowest human development index of 0.43 compared to the national average of 0.69. The unemployment rate is estimated at 46 percent (Statistics South Africa, 1998). The previous government established 171 smallholder irrigation schemes in the province with the objective of improving the livelihood of smallholder farmers and their families. The value of assets in the irrigation schemes is estimated at R4 billion. These schemes were administered in a top-down manner with emphasis on food self-sufficiency. In the new dispensation, the Limpopo Department of Agriculture and Environment has instituted a revitalization programme for smallholder irrigation schemes. The revitalization programme is based on the principles of economic viability, sound business and appropriate technologies to empower smallholder irrigation farmers to become commercial farmers. This is to be achieved by analyzing farmers' needs and aspirations, providing training and capacity building, institutional arrangements, infrastructure rehabilitation, monitoring and after-care and possible partnership with agribusiness.

There are over 18 500 hectares of smallholder irrigation in Limpopo Province. Productivity is generally low, and farmers' incomes are often below subsistence levels. The provincial authorities are intending to hand over the management of smallholder irrigation schemes to scheme beneficiaries when revitalization has been completed. Such revitalization programmes need to be well informed by research outputs in the areas of irrigation scheme management, market reliability and accessibility, capacity building interventions, institutional arrangements, etc. However, to date little research has been done on these issues, including current productivity and constraints experienced, and future potential of smallholder irrigation schemes. A study by Stewart Scott Consulting Engineers (1998) of eleven irrigation schemes in Limpopo Province found a number of constraints on the development and viability of irrigation schemes. These include small plot sizes, allocation of plots to individuals not interested in farming, inadequate access to credit, inadequate infrastructure, and lack of interaction between farmers and extension officers. The same problems of low productivity, poor relations between farmers' groups and support institutions may exist in the irrigation schemes included in this study. On the other hand, the study found positive trends that groups of commercially oriented farmers were emerging at some of the irrigation schemes. These farmers have successfully developed farms of up to five hectares on certain irrigation schemes producing high valued crops and taking advantage of market opportunities.

The original revitalization programme in Limpopo Province was based on the outcome of irrigation workshops held in 1997 in all the six districts in the province. These workshops revealed that there were serious challenges facing smallholder irrigation schemes. These were in the areas of land size and tenure, water availability and assurance of supply, inappropriateness of irrigation and drainage designs, farmers' skills and knowledge of irrigation farming, market availability and accessibility, etc. Further studies commissioned by the Limpopo Department of Agriculture and Environment in terms of the revitalization strategy during the pilot phase coupled with the Water Care Programme confirmed the above findings.

1.3 OBJECTIVES OF THE STUDY

The overall goal of the research is to contribute to poverty alleviation through improving crop productivity, profitability, gender equity and environmental sustainability in smallholder irrigation schemes.

The specific objectives of the study are to

- assess productivity, profitability, and potential for achievement of food security;
- identify cropping and irrigation management practices for improved water productivity;
- determine the effects of irrigation practices on soil salinity and alkalinity levels;
- determine the extent to which poverty alleviation and empowerment of farmers can be achieved through self-management of irrigation systems;
- document the social organization of smallholder irrigation, with special reference to identification of stakeholders' access, rights and aspirations;
- identify economic, social, institutional and policy issues affecting smallholder irrigation water use;
- identify organizational designs that ensure a reasonable amount of equity among stakeholders;
- support action research to test the proposed strategies; and
- facilitate capacity building for carrying out practical and applied research.

1.4 STUDY AREA AND SELECTION CRITERIA

The study area includes smallholder irrigation schemes located along the Olifants River in Limpopo Province.

1.4.1 Description of the Olifants River Basin

The whole Olifants river basin covers an area of 54 600 square kilometres. Soils are mainly well drained clay to loamy. The most common crop is maize while 80 percent of the livestock kept is cattle. The basin has 2500 reservoirs of which 90 percent have capacities smaller than 20 000 cubic metres. There are 30 large reservoirs whose capacities are larger than two million cubic metres and a total storage of 1100 million cubic metres. The estimated usage of water in the basin in 1987 was 1060 million cubic metres per year including evaporation. The mean annual runoff is 1.235 million cubic metres per year. In the late 1980s, irrigated agriculture used about 500 million cubic metres of water per year. Although irrigation is still the major water user in the basin, this value has gradually declined (Stimie et al., 2001).

Ecological needs were estimated to be 200 million cubic meters per year in the 1990s. There are about 200 mines in the basin which use about 90 million cubic metres per year. A relatively small amount of water is sent downstream from Arabie dam to Polokwane for domestic use (Stimie et al., 2001).

The main issues identified in the Olifants river basin are:

- availability of water in relation to demand;
- quality of water;
- impact of land use on water resources;
- availability of management information; and
- coordination of basin management practices.

The basin can be divided into five homogenous regions (Stimie et al., 2001):

- the highveld region above the Loskop dam;
- the irrigated region between the Loskop dam and Arabie dam;
- the underdeveloped or rural poor region from the Arabie dam to the confluence of Steelpoort and the Olifants rivers;
- the Steelpoort catchment; and
- the lowveld region, which ends at the confluence of Steelpoort and Letaba rivers with the Olifants river.

The Olifants river basin supplies irrigation water to many smallholder irrigation schemes. The upper and lower parts of Arabie/Olifants scheme cover 1544 hectares in a narrow band over about 50 kilometres on the right bank of the Olifants river. There are 1195 smallholder farmers with plots of mostly 1.28 hectares. The farmers irrigate with traditional sprinklers and partly with furrows. Water is taken from canals and storage dams that are fed by pumped river water.

The following schemes are found in the upper Olifants river: Hindustan, Coetzeesdraai, Krokodilheuwel, Vogelstruiskonje, Gataan, De Paarl and Nooitgezien. Schemes found in the lower Olifants river basin include: Wonderboom, Vlakplaats, Haakdoringsdraai, Strydkraal, and Mooiplaats. In the middle part of the Olifants river are found Veeplaats and Goedverwacht. These cover 524 hectares on the right bank of the river. On the left bank are Bradfontein, Adriansdraai and Sepitsi which together cover 180 hectares. These middle-part schemes were newly constructed in the 1980s and consist of larger plots of 2.5 to 10 hectares.

1.4.2 Criteria for Selecting Irrigation Schemes

The following criteria were used to select the irrigation schemes included in this study:

- operational status (i.e. whether the scheme was operational);
- plot size (included schemes with plot sizes in the following categories: less than 0.1 hectare, 0.1-1 hectare, 1.28 hectares, 2.5 hectares, and 5 hectares);
- type of irrigation system (flood or sprinkler);
- involvement of a support institution (Department of Agriculture or Agricultural and Rural Development Corporation (ARDC)); and
- existence of salinity problems.

The selected irrigation schemes were Wonderboom (less than 0.1 hectare food plots with flood irrigation), Sepitsi (0.12 hectare plots and supported by ARDC), Veeplaats (2.5 hectare plots, with sprinkler irrigation, some salinity problems, and supported by ARDC), Adriansdraai (5 hectare plots, with sprinkler irrigation and supported by ARDC), and Strydkraal (5 hectare plots, presence of salinity problems and supported by the Department of Agriculture).

Due to problems experienced at Veeplaats, it was decided to replace it with Elandskraal. A major problem arose when the management of Veeplaats was transferred from the local community to an individual commercial farmer by the local traditional leader. Under this new arrangement, the farmers became employees of the commercial farmer and the research project objectives could no longer be met if Veeplaats was retained. Problems were also experienced at Adriansdraai, Sepitsi and Strydkraal resulting in the collection of incomplete data. At Adriansdraai, the irrigation pump was damaged by the 1999/00 floods and was never fixed. This led to the total collapse of the scheme's activities. According to the farmers, the Land Bank allocated some funds to re-establish the system, but the money was mysteriously embezzled by one consultant who promised to assist them in marketing their produce. The problem of embezzlement of funds also affected Sepitsi farmers and was never resolved as the farmers were not willing to have any dealings with the person who embezzled their funds even though he was prepared to resolve the problem. The irrigation system at Strydkraal had been non-functional since the inception of the research. This is predominantly due to a breakdown of the pump and the difficulty in acquisition of funds to repair it. Farmers at this scheme are still determined to continue with their farming operations and are optimistic that funding would be available in the near future to activate the scheme. The traditional leader (*Kgoshi*) at this location, however, continues to use his personal centre pivot and sprinkler systems for crop irrigation.

1.5 OUTLINE OF SUBSEQUENT CHAPTERS

The remaining chapters of the report are organized as follows:

Chapter two reviews literature on smallholder agriculture and its role in rural development. The contribution of agriculture to the South African economy is first described followed by a discussion on Limpopo Province's agricultural economy. The nature of smallholder agriculture and its role in rural development is briefly discussed. The second part of the chapter focuses on the productivity and profitability of smallholder agriculture including constraints limiting the achievement of the above. The chapter also touches on the role of projects as tools for promoting rural development. The chapter ends with a discussion on the Limpopo Province's agricultural development strategy covering four focus areas.

In chapter three, the role of smallholder irrigation in agricultural development is described followed by a brief analysis of management and production issues affecting smallholder irrigation. The chapter also presents a historical background and characteristics of smallholder irrigation in South Africa. Smallholder irrigation in Limpopo Province and its role in agricultural development are also described. Organizations affecting smallholder irrigation and the process of irrigation management transfer (IMT) in the province are outlined. A case study of a smallholder irrigation project exposed to irrigation management transfer is described. The chapter also reviews experience with IMT in other parts of the South Africa and elsewhere with lessons drawn from this experience.

Chapter four describes the research methods employed in the study. The description covers both technical and socio-economic aspects of data collection.

The results of the study are presented in chapter five covering both technical and socio-economic aspects.

The final chapter presents the conclusions and recommendations of the study for policy makers, researchers and practitioners.

CHAPTER 2: AGRICULTURE AND ITS ROLE IN RURAL DEVELOPMENT

2.1 PLACE AND CONTRIBUTION OF AGRICULTURE IN THE SOUTH AFRICAN ECONOMY

With 70 percent of poor people in South Africa residing in rural areas (Government of South Africa, 1995; Department of Agriculture, 2001), improving agricultural productivity, particularly smallholder agricultural productivity, becomes crucial though not a sufficient condition for the eradication of rural poverty. Agriculture's direct contribution to GDP, employment and exports has declined significantly in the postwar period. According to the Department of Agriculture (1995), agriculture's share of GDP has dropped from 17 percent in the 1950s to around four percent in the 1990s.

The number of farm workers employed in the commercial farm sector has also declined since the 1970s. The number of people employed in agriculture has declined from more than a million and half in the 1970s to less than a million in the 1990s (Mather, 2000). The decline in the number of people employed in agriculture is attributed to the rapid mechanization and industrialization of agriculture in the late 1960s. According to Mather (2000), the contribution of agriculture to exports and to the country's balance of payments has also declined as a percentage of total exports. While the value of agricultural exports was over ten percent in the 1970s, it has since declined to four percent in the 1990s.

The above figures may seem to suggest that agriculture's contribution is minimal. However, the real contribution of the sector to the economy is much larger if one considers the indirect role of agriculture through forward and backward linkages. Fertilizer, chemical and implement manufacturers are dependent on a growing agricultural economy. For example, in the 1993/4 season farmers spent over R500 million on packaging material, R1.6 billion on fuel, R1.18 billion on fertilizer and R1 billion on dips and sprays (Department of Agriculture, 1995). Many of these companies are dependent on the sale of chemicals and machinery to farmers. There are also important forward and backward linkages between agriculture and industry. In the early 1990s, only 34 percent of what farmers produced was consumed directly, the remaining 66 percent was processed in some form by the manufacturing sector.

Research by van Zyl and Vink (1992) has shown that increases in agricultural production have large positive impacts on growth, employment and the balance of payments. The output multiplier for agriculture is 1.6 meaning that for every R1 million of agricultural production, an additional R0.6 million is generated in other sectors of the economy. According to van Zyl and Vink (1988), agriculture also has a strong multiplier effect on employment and input-output analysis suggests that more jobs are created in agriculture with increased production than for any other sector of the economy.

2.2 LIMPOPO PROVINCE'S AGRICULTURAL ECONOMY

Limpopo Province is a small contributor to the country's GDP. The province's contribution to the GDP in 1991 was 3.7 percent and increased to 3.8 percent in 1996 (Statistics South Africa, 1998). The province is vulnerable to external shocks due to its high degree of dependence on primary sectors of mining and agriculture.

Agriculture contributes approximately 38 percent to the GDP of the province and provides 17 percent of the formal employment (Statistics South Africa, 1998). Other than the formal employment potential, most rural households rely on some agricultural activity to put food on the table. There are segments of the rural population who derive their livelihoods from micro and medium enterprises other than agriculture. The point of emphasis is that better opportunities for growth, employment and economic competitiveness are more accessible in the agricultural sector than other sources of livelihoods more so in areas which have favourable conditions for agricultural development.

The northern and lowveld regions of Limpopo Province are considered to have the potential capacity to be competitive in both domestic and foreign economies. The two regions are the country's largest producers of subtropical fruit, citrus and vegetables. However, exploiting the potential calls for commitments by all stakeholders to address past imbalances in critical areas such as land tenure.

Land holding patterns in the province typify the long-term effects of colonialism, segregation, the apartheid land policy and past socio-economic planning. It is estimated that 88 percent of the people in the province occupy only 30 percent of the available land (Development Bank of Southern Africa, 1995) and the great majority of this land is held under some form of communal tenure (Lahiff, 1997). Like the rest of the country, the province's agricultural sector is comprised of both commercial and smallholder farmers. The focus of this study is on the latter, particularly the smallholder irrigation farmers.

2.3 NATURE OF SMALLHOLDER AGRICULTURE

In order to describe the nature of smallholder agriculture one needs to have a good understanding of who the smallholder farmer is. Consequently, this section attempts to provide a definition of smallholder farmers and relies heavily on Machethe and Mollel (2000).

Despite widespread reference to the smallholder farmer in the literature on agricultural and rural development, few analysts attempt to define or describe the smallholder farmer. Possible reasons for this include (a) the difficulty in defining the smallholder farmer; (b) assumption that everybody knows who the smallholder farmer is; (c) argument that there is no need for a precise definition of a smallholder farmer; and (d) acknowledgment that "smallholder farmer" means different things depending on the country one is looking at and, therefore, no single definition would suffice.

Various terms are used in the literature to describe smallholder farmers. These include "small-scale farmers", "resource-poor farmers", "subsistence farmers", "peasant farmers", "food-deficit farmers", "household food security farmers", "land reform beneficiaries" and "emerging farmers". The main criteria often used to classify farmers as smallholder farmers by various analysts include (a) land size; (b) purpose of production, i.e. whether for home consumption or market; (c) income level, i.e. whether poor or rich; and, in South Africa, (d) racial group, i.e. whether one is white or black and, thus, historically advantaged or disadvantaged, respectively. The following definitions of farmers have been used in South Africa:

- Van Zyl et al. (1991) classify farmers into three main categories, namely, commercial, emerging and subsistence farmers. Commercial farmers are defined to include those who operate in the market economy. Emerging farmers are those who cannot function (participate) in the market economy because of restrictions in the (economic) environment. Subsistence farmers include those who produce mainly for home consumption and produce surpluses by coincidence.
- Botha and Treurnicht (1997) identify four categories of farmers: fully commercial

farmers, emerging commercial farmers, land reform beneficiaries and household food security farmers.

- The Farmer Support Services Working Group Workshop (1997) identify categories of clients for extension as emerging farmers, land reform beneficiaries, subsistence farmers and commercial farmers who are further subdivided into small, medium and large farmers. These categories of farmers are not defined.
- Catling and Saaiman (1996:160) define a small-scale farmer or grower as a "historically disadvantaged individual or group having access to land which normally supports a small or medium agricultural enterprise."

Eicher (1990) identifies four types of farmers in Africa:

- Resource-poor farmers --- these are farmers who sell some of their labour to large-scale farmers and engage in rural nonfarm activities to meet their food needs. They produce some of their food and buy the rest.
- Smallholders and herders -- these rely mainly on family labour to produce food, livestock, and export crops for both domestic and international markets.
- Middle "progressive" farmers -- they own and operate their farms and can bear the risk of farm innovation, provide seasonal jobs, and generate a marketable surplus.
- Large-scale farmers -- these are farmers who produce mainly for the market, possess political power and are skilled in extracting subsidies and services from the state.

Until the early 1990s, it was generally accepted in South Africa that "commercial farmers" referred to white commercial farmers and "smallholder farmers" to black farmers in the former homelands. However, the reality today is that a number of blacks, albeit small, have graduated into the commercial farmer category. Therefore, it is no longer appropriate to consider all commercial farmers to be white. Nevertheless, it should be recognized that the majority of the approximately 50 000 commercial farmers in South Africa are still white (Department of Agriculture, 2001). As regards the smallholder farmer category, there is no evidence that the racial composition has changed. Therefore, it is reasonable to conclude that smallholder farmers are black.

In the search for a definition of a smallholder farmer within the South African context, our point of departure is that smallholder farmers are black farmers most of whom reside in the former homelands. Furthermore, we note that not every black farmer is a smallholder farmer and smallholder farmers are not a homogeneous group. The heterogeneous nature of smallholder farmers is apparent from the definitions of farmers presented above by various analysts. Despite the recognition that smallholder farmers in South Africa are heterogeneous, there are no clear criteria for assigning farmers to the different categories of smallholder farmers. Thus, it is not clear why one category of farmers is different from the other. Furthermore, the number and needs of farmers in the different categories are not known.

Smallholder farmers are defined here to include black farmers ranging from those whose main source of livelihood is nonfarm activities (those where farming constitutes only a minor source of their livelihood) to those whose livelihood is derived mainly from farming. Some of these farmers are poor while others are not. Thus, we identify the following categories of smallholder farmers:

- Resource-poor farmers --- those whose sources of livelihood include farming and nonfarm activities and have total assets and annual income whose value does not exceed that of a household which would be considered as poor in terms of the country's criteria.

- Middle-income farmers --- these are farmers whose main source of livelihood is farming and have total assets and annual income worth more than that of a poor household but not enough to be classified as rich.

Resource-poor farmers would include subsistence farmers (i.e. those who produce mainly for home consumption) and those with small gardens for fruits and/or vegetable cultivation. Farming does not generate enough income for them to meet all their needs and, therefore, must engage in nonfarm activities to make ends meet. These farmers cannot afford to pay for support services and rarely sell their produce. Also included in this category are those who derive their livelihood mainly from nonfarm activities and engage in farming (e.g. gardening) to augment their nonfarm income. Resource-poor farmers are generally risk-averse, rely mainly on family labour, own a few animals, and have a small piece of farmland. In addition, they face high transaction costs. Delgado (1998) argues that reducing these transaction costs will determine whether resource-poor farmers' access to assets, information, services and markets will increase.

Middle-income farmers include those who are richer than resource-poor farmers and farming is their main source of income. These farmers may also engage in nonfarm activities to augment their farm income. They produce mainly for the market but do not have enough resources and technical expertise to increase their product market share. They cannot compete effectively with large-scale commercial farmers. Unlike resource-poor farmers, middle-income farmers are not risk-averse, often they are members of farmers' organizations, can raise some collateral for commercial bank loans and can contribute towards the cost of farmer support services.

2.4 ROLE OF SMALLHOLDER AGRICULTURE IN RURAL DEVELOPMENT

Agriculture is an important source of income and livelihood for many rural households in developing countries. Carter and May (1997) identify agricultural production as one of the most important sources of income for rural households in South Africa. Eicher (1999) notes that two-thirds of people in Africa derive their livelihood from agriculture.

Smallholder agriculture is important to employment, human welfare, and political stability in Sub-Saharan Africa (Delgado, 1998). In addition, smallholder agriculture can moderate the rural exodus, create growth linkages and can enlarge the market for industrial goods (Eicher and Rukuni, 1996). Smallholder agriculture is also considered to be both a major cause of and potential solution for poverty reduction and economic growth (Jazairy et al., 1992;DFID, 2002).

In South Africa, the number of smallholder farmers, as defined above, is estimated to be 3.24 million (Department of Agriculture, 2001). At an average household size of five persons, this means that smallholder agriculture supports approximately sixteen million persons -- more than thirty percent of the total population.

To maximize the contribution of smallholder agriculture to poverty reduction, agricultural productivity must be raised and sustained. This must occur in such a way that environmental sustainability is promoted. A misperception exists that there is always a trade-off between productivity and environmental sustainability and, therefore, the two cannot be pursued together. Productivity and environmental sustainability must be pursued together. Reardon (1998) notes that environmental sustainability emerged as a critical issue in African policy circles in the late 1980s because of famine, growing evidence of land degradation, deforestation, and desertification, and because of a rebirth of concern for the environment in developed countries.

2.5 PRODUCTIVITY AND PROFITABILITY OF SMALLHOLDER AGRICULTURE

A distinction is often made between "partial factor productivity" and "total factor productivity". Partial factor productivity refers to the productivity of a single factor of production and is calculated by dividing total output of one or more crops and livestock by the amount of the factor used. Total factor productivity is the sum of total output of crops and livestock divided by the amount of all factors used in production. "Productivity" in this study refers to partial productivity.

Ruttan (1998) argues that productivity differences in agriculture are increasingly a function of investments in scientific and industrial capacity and in the education of rural people rather than of natural resource endowments. Bonnen (1998) contends that increases in productivity arise not only from technological change but also from institutional innovation, improvements in human capital and in the availability of biological and physical capital. An inverse relationship has been observed between productivity and farm size, i.e. productivity tends to be higher on small farms than large farms (Berry and Cline, 1979; Binswanger and Elgin, 1998).

The productivity of smallholder farmers in most African countries is often considered to be low and has been declining during the past two decades. Low smallholder agricultural productivity implies low smallholder agricultural profitability. The value added per worker in agriculture in the 1990s was 12 percent lower than in 1980. Average incomes in the 1990s were 16 percent lower than in the 1980s. Agricultural output has also been falling or leveling off in many African countries. For example, yields of most important food grains, tubers and legumes are no higher currently than in 1980 (New African Partnership for Africa's Development, 2003).

Low productivity of smallholder farmers is one of the most important reasons for the failure of most African countries to achieve food security. Raising agricultural productivity is necessary if African countries are to overcome the problems of poverty and food insecurity. This will require a significant increase in investment in all factors that contribute to agricultural productivity and lifting the constraints thereon.

2.6 CONSTRAINTS ON SMALLHOLDER AGRICULTURE

Increasing smallholder agricultural productivity requires that smallholder farmers gain access to reliable and good quality farmer support services such as extension, finance and marketing. Increasing smallholder agricultural productivity is particularly important in view of the increasing scarcity of land for cultivation which makes extensification an ineffective response to the demand for increased agricultural production. Thus, smallholder farmers should be assisted to produce more from the existing land because prospects for increasing agricultural production through land expansion are not good.

Agricultural service organizations in South Africa were designed along racial lines with the result that smallholder farmers' needs have not been adequately addressed. The major service organizations were geared to white commercial agriculture. Thus, while the interests of white commercial farmers were catered for, many smallholder farmers either had limited or no access to support services. Where smallholder farmers had some access to farmer support services, the quality of the services has been inferior. Although formerly white organizations are reorienting their activities to address the needs of smallholder farmers (e.g. Agricultural Research Council and Land Bank) and former homeland agricultural service organizations (e.g. Agricultural development corporations and provincial departments of agriculture) are being restructured, many smallholder farmers still do not have access to support services.

Getting smallholder agriculture moving requires that support services be accessible to the majority of smallholder farmers. International experience indicates that with adequate access to farmer support services, smallholder farmers can increase productivity and production significantly. For example, smallholder farmers in Zimbabwe (average farm size of between 2 and 3 hectares) doubled maize and cotton production in the 1980s when extension, marketing and credit services were provided (Rukuni and Eicher, 1994). Significant achievements have also been made by smallholder farmers in Southeast Asia. Although quantification of the impact of support services such as extension is rarely undertaken (Purcell, 1994), there is some evidence that extension has increased productivity and income (Birkhaeuser et al., 1991; Bindlish and Evenson, 1993; Bindlish et al., 1993; Umali-Deininger, 1997).

Agricultural support services are important for successful land distribution. In addition to making land accessible to smallholder farmers through land reform, smallholder farmers must gain access to farmer support services and reliable markets to ensure that smallholder farming is profitable on a recurring basis (Eicher and Rukuni, 1996). Global experience indicates that it is fruitless to embark on land distribution without concurrently taking measures to improve access to farmer support services for smallholder farmers. Improving access to support services may require that agricultural service organizations be transformed so that they can provide good quality services to smallholder farmers. However, improving the performance of agricultural service organizations addresses only one of the prime movers of smallholder agricultural development and, therefore, not a sufficient condition for getting smallholder agriculture moving. Other prime movers are human capital, new technology, rural capital formation (infrastructure and improved livestock herds) and a favourable economic policy environment (Timmer, 1990; Eicher, 1990; Eicher and Rukuni, 1986).

According to New African Partnership for Africa's Development (2003), for African agriculture to be productive and profitable, the following challenges need to be addressed:

- Low effective demand for agricultural products due to poverty;
- Poor and un-remunerative external markets;
- Low level of investment due to risk arising from unfavourable climatic conditions;
- Limited access to technology and low rate of technology adoption;
- Low levels of investment in rural infrastructure resulting in high transaction costs; and
- Organizational weaknesses for service provision.

In addition to removing the above constraints, it will be necessary to improve the policy and regulatory framework for agriculture to encourage participation of local communities in rural areas and the private sector.

2.7 PROJECT APPROACH TO SMALLHOLDER AGRICULTURAL DEVELOPMENT

Projects have been regarded as the most appropriate tools for promoting rural development in developing countries. According to Gittinger (1982) "projects are the cutting edge of development". The project approach to development has been embraced in many developing countries including South Africa. In particular, smallholder irrigation projects were established in the former homelands to promote food self-sufficiency and to contribute to rural development. In addition to creating employment opportunities, it was hoped that smallholder farmers would improve their productivity and, thus, produce not only for home consumption but also for the market. Although there have been some successes, the overall record of smallholder irrigation projects in achieving their intended objectives in the former homelands has been disappointing. Crosby (2000) notes that, with the exception of sugar cane projects, there are virtually no smallholder irrigation projects that have been successful. Common factors contributing to the failure of smallholder irrigation projects include (a) total dependence on government; (b) dilapidated irrigation water supply infrastructure; (c) ineffective water management; (d) low production levels; (e) little knowledge of irrigation and/or crop production; (f) ineffective extension services; (g) lack of markets and credit; (h) difficulty in sourcing production inputs; (i) expensive and ineffective mechanization services; (j) broken fences; and (k) damaged soils.

Lele (1979) notes that some of the targets which integrated rural development projects were meant to achieve in the early 1970s were often ambitious and that successful projects were difficult to replicate. A review of the World Bank's experience with integrated rural development projects indicates that half of the audited projects in sub-Saharan Africa had failed (World Bank, 1988).

The above review indicates that while projects are important tools for agricultural and rural development, their record has generally not been impressive. However, this does not mean that the project approach should be abandoned. Rather, it implies that care should be taken in the implementation of projects to avoid past mistakes.

2.8 LIMPOPO PROVINCE'S AGRICULTURAL DEVELOPMENT STRATEGY[1]

The mission of the Provincial Department of Agriculture and Environment in Limpopo Province is to increase economic growth and reduce poverty by empowering people to manage natural resources in a sustained manner. Six strategic focus areas have been identified and include:

2.8.1 Restructuring and Transformation of Agro-projects

This strategic focus area includes commercial farms and farmer settlement projects previously managed and supported by the ARDC. In restructuring these farms, two models are proposed. The restructuring of commercial farms will involve a combination of strategic equity partner, black economic empowerment, community and workers' trusts. In restructuring farmer settlement projects, the private-public partnership model will be adopted.

To ensure success in this strategic focus area, three key challenges will need to be addressed. These are land claims, tenure security and financing.

2.8.2 Land Reform Programme

The focus here is on three types of programmes:

[1] Based on Department of Agriculture and Environment (2003)

- Support to Land Restitution Farms and the Settlement Land Acquisition Grant farms in order to make them profitable through provision of starter packs, training and after-care support as well as support for organizational linkages (credit, markets, etc.).
- Support to Land Redistribution for Agricultural Development programme. This will entail facilitating access to land for the previously disadvantaged communities, training and after-care.
- Rehabilitation and flood repair of 171 irrigation schemes involving 50000 hectares. Three components have been identified: (a) physical infrastructure; (b) organizational arrangements; and (c) farmer capacity building.

2.8.3 Poverty Eradication and Food Security

The following projects are being implemented as an attempt to achieve food security in the province:

- Group farming projects for vegetables, poultry and piggery;
- Homestead/backyard food gardens;
- Family milk production schemes to produce milk for consumption and sale;
- Family egg production; and
- Fish production.

2.8.4 Animal Disease Control

Three approaches have been adopted for animal disease control and they are

- Educational campaigns;
- Repair and provision of infrastructure; and
- Administering of disease control measures in accordance with the Disease Control Act.

In addition to disease control, three strategies will be used to improve livestock production. These are (a) livestock breeding/development for cattle, goats and poultry; (b) strengthen livestock farmer organizations; and (c) improve access to marketing infrastructure.

2.8.5 Human Resource Development

The focus will be on the following:

- Farmer training centers. Colleges of Agriculture will be upgraded to farmer training centers to provide practical training in poultry, maize, vegetables and priority commodities.
- Training of extension personnel. This will include induction, pre-service and in-service training.
- Provision of scholarships for scarce specialized fields (e.g. veterinary science, engineering, entomology, etc.).

To achieve the above, partnerships will be developed with universities. With regard to extension services, a number of problems that affect service delivery in South Africa have been identified (Duvel, 2003). They include the following:

Weak linkages between Research and Extension

While there are successful technology development and transfer models for smallholder farmers, linkages between research and extension as well as training have generally been weak. The Agricultural Research Council was established to serve the needs of the large-scale white commercial farmers. While the situation has been reversed by policy, a thorough understanding of the smallholder farming system is still lacking. Other alternatives being pursued to address the situation is the introduction of Farming System Research and Participatory Extension Approaches. These approaches allow researchers and extension agents to involve farmers in the adaptation of technologies under field conditions so as to maximize benefits to farmers.

Lack of Accountability

In most extension systems worldwide extension agents tend to be more responsive to their supervisors than to farmers. The supervisors evaluate the performance of the extension agents and promote them on the basis of the evaluation. There are greater incentives to respond to supervisors than responding to the needs and opinions of farmers.

True accountability exists when farmers decide about the kind of extension support they need and who should provide it. When farmers are given the responsibility of hiring extension staff through farmer associations or local councils, the problem of accountability will be addressed.

Poor Coordination

For more than 50 years lack of proper coordination has been a problem in South Africa and in spite of all endeavours no widely acceptable solution has been found or implemented. One of the reasons for lack of progress is that the solution is sought in better collaboration rather than coordination. Improving collaboration does not address the problems of coordination. The establishment of a coordinating structure that becomes a representative mouthpiece of the community should address the problem of coordination. The community mouthpiece interacts on a regular basis with the service providers.

Competence of Extension staff

The extension personnel are inadequately trained in the technical subject matter and educational process skills. This undermines their confidence, credibility and ultimately their performance. Proper training and competence can be regarded as basic requirements or preconditions for effective extension delivery. Eighty percent of all frontline extension workers and 48 percent of all supervisors and managers have only an agricultural diploma. One way to reduce the knowledge gap of extension workers is to introduce an extensive knowledge support system of subject matter specialists who will work systematically to upgrade the knowledge level of the extension workers.

Monitoring and Evaluation

As currently practiced monitoring and evaluation employ a minimum of evidence with limited criteria. The extension objectives should be formulated to include a full spectrum of criteria ranging from resource and opinions, behavior determinants, behavior change, outcome and impact in terms of job creation, increase in living standards etc. Extension evaluation has been limited to ‘summative’ which is done at the end of the programme. Evaluation is merely descriptive or qualitative in nature and not correlated directly to productivity. What is needed is an ongoing and continuous process of evaluation to be able to make adjustments in the programme if and when needed. The problem faced by the extension system is that the majority of the extension staff do not have sufficient time, experience or training to get involved in monitoring and evaluation.

Frequent Restructuring

A major problem in the Department of Agriculture is the frequent restructuring usually with change in leadership or senior management. This is often associated with high costs, delay and interruption of delivery programs and usually represent mere *ad hoc* reforms rather than the pursuit of measured, comprehensive and long term restructuring.

2.8.6 Communal Farmer Support

Farmers in communal areas face challenges in accessing farmer support services including inputs and mechanization. This may be attributed to a number of factors including the absence of strong farmer organizations. The above challenges will be addressed through

- Establishment of input supply centers;
- Provision of basic machinery; and
- Capacity building and establishment of farmer organizations.

The strategy outlined above promises to address many challenges in the agricultural sector of Limpopo Province. The success of the strategy will be determined to a large extend by the degree to which the Provincial Department of Agriculture incorporates lessons drawn from past experiences in agricultural and rural development both in South Africa and elsewhere. Lessons should be drawn from both failures and successes and appropriate adaptations should be made in the identified strategic areas.

While it is important to provide support to poor communities to eradicate poverty, projects should have an in-built element of sustainability to avoid the dependency syndrome that is associated with smallholder irrigation schemes. In the area of capacity development, the development of partnerships with universities is a welcome idea. The challenge will be to develop accredited training programmes for farmers in order to qualify for training grants from Sector Education and Training Authorities.

CHAPTER 3: SMALLHOLDER IRRIGATION AND AGRICULTURAL DEVELOPMENT

3.1 ROLE OF SMALLHOLDER IRRIGATION IN AGRICULTURAL DEVELOPMENT

Investing in smallholder irrigation is one the most effective ways to develop smallholder agriculture and, thus, contribute to poverty alleviation. The contribution of irrigation to poverty alleviation has been demonstrated in countries such as Bangladesh where growth in public sector funded canal irrigation and private sector funded tube-well irrigation have played a major role (Shah, 1993). Hussain and Hunjra (2004) note that although irrigation water is only a single factor in poverty alleviation, it plays a disproportionately powerful role. Sally et al. (2003) conclude that smallholder agriculture intensification by improving the management and productivity of land and water in a sustainable manner is a solution for both poverty reduction and agricultural growth in sub-Saharan Africa.

Irrigation development benefits the rural poor in various ways including (a) reduced food prices resulting from increased production; and (b) increased on-farm and off-farm employment leading to income generation for the poor. Thus, irrigation contributes to food security.

Smallholder irrigation schemes have not performed well in Africa. These schemes have performed poorly in terms of yields and economic returns (Barghouti and Le Moigne, 1990; Underhill, 1990). The poor performance of smallholder irrigation schemes means that farmers have not been able to produce enough yields to match the demand for food. In order to match the demand for food, it will be necessary to increase productivity because the scope for increasing food production by increasing the area under cultivation is limited. The growing scarcity of water will make it extremely difficult to expand food production by increasing the area under cultivation. Mehra and Esim (1998) note the growing concern in the decline in the area under irrigation. Some of the factors responsible for this include increased competition for the use of irrigation water for urban and industrial consumption, depletion of groundwater and other alternative water sources, and increased salinity. Salinity has reduced the productivity of irrigated areas. Postel (1996) estimates that more than ten percent of the world's irrigated area may have enough salt build up to lower yields.

Because water is scarce, it is important to use it efficiently and increase its productivity. The International Water Management Institute (2000) notes that there is scope for doubling the productivity of water in many cases. Significant increases in water productivity may come from improved water management and improved plant varieties and agronomic practices. The unreliability of water supplies has contributed significantly to the poor performance of smallholder irrigation schemes in terms of productivity and profitability. The productivity of smallholder irrigation schemes can be increased by improving the reliability of water supplies. The International Water Management Institute (2000) concludes that weak institutions are often to blame for poor reliability of water supplies. Therefore, improving water productivity by ensuring that water supplies are reliable will require the right mix of manageable technologies, the organizational skills necessary to use these technologies and appropriate incentives for farmers and water service providers.

3.2 MANAGEMENT AND PRODUCTION ISSUES IN SMALLHOLDER IRRIGATION

Unavailability of water for crop growth and development during a growing season is a major limiting factor in crop production in semi-arid regions of the world. The situation is further worsened by the increasing human population which has resulted in simultaneous increased demand for water for domestic and industrial use. South Africa is classified as a water scarce country implying that even with the highest feasible efficiency and productivity, the country will not have sufficient water resources to meet its agricultural, domestic, industrial and environmental needs in the year 2025 (Seckler and Amaransinghe, 2000). Despite the threat on water resources, irrigation water continues to be an important resource in crop production to date. Irrigated farmland is reported to provide 60 percent of the world's grain production. It is, therefore, critical to develop appropriate water saving techniques in crop production to ensure efficient use of water resources.

An important aspect of irrigation water management in crop production is to increase water productivity which is assessed through gain in crop yield per unit of irrigated water applied. A three-fold increase in irrigated rice yields per volume of water applied over the past two decades has been reported (Hong et al., 2000). The authors further reported a 16 percent increase in rice yields and a consequent 19 percent drop in land area planted to rice during the same period. The high increases in efficiency of production and hence significant savings in water resource are primarily attributed to, among other things, the simultaneous improvement in production practices such as use of suitable crop varieties and efficient fertilizer management. Thus, more efficient water use in agricultural systems is possible and will be achieved if management practices in crop production are improved as well (Fereres et al., 1992). The interactive effect of water and nutrient ions on crop growth and yield is an important consideration in any research aimed at improving biological and economic productivity in irrigation schemes. The greatest crop response to nitrogen has been observed to occur when water is not limiting.

Limpopo Province is considered semi-arid with a greater portion of the region receiving less than 600 mm of annual rainfall and experiencing high summer temperatures. Despite the harsh limitations imposed by the environment on agricultural productivity, several small-scale farming activities occur throughout the province. Crops grown include a wide array of field and vegetable crops as well as fruit crops. Several production constraints are encountered on the production fields of the resource-poor farmers in the region, yet most of these farmers have never benefited from any research intervention. Crop yields are marginal and continue to decline in most parts of the region.

A preliminary study in the province indicated the following as major factors contributing to the poor crop productivity: low soil water, nitrogen and phosphorus status; improper planting method (broadcast); poor stand establishment after seedling emergence, low use of organic and inorganic fertilizers; and pest problems in some instances. Low productivity is usually attributed to inadequate amounts of water, but even in several areas with adequate amounts and proper distribution of rainfall as well as access to irrigation water, good crop growth and yield cannot be maintained. This emphasises the importance of other resources besides water as major determinants of yields. An additional cause of low productivity among small-scale farmers is limited access to land which forces farmers to intensively cultivate the same piece of land year after year without much external input. Such intensive practice results in rapid decline in the capacity of soils to supply nutrients once agricultural activities commence. Therefore, for cropping systems to remain productive and sustainable, it is necessary to replenish the reserve nutrients removed or lost from the soil. In the case of nitrogen, inputs into agricultural systems may be in the form of nitrogen fertilizers or be derived from atmospheric nitrogen via biological nitrogen fixation. Clearly where agricultural activities are currently mining soil reserves, external nutrient inputs in the form of fertilizer or biological nitrogen fixation must be increased if farmers are to have any prospects of meeting their yield targets. The need to find ways of restoring soil fertility and also to develop appropriate cropping practices for resource poor farmers in the province is therefore paramount. Complex interactions exist between crop plants and the growth resources needed to maintain these crops in diverse agro-environments. A clear understanding of these interactions is essential for achieving effective growth and yield in crop plants.

3.3 SMALLHOLDER IRRIGATION AND AGRICULTURAL DEVELOPMENT IN LIMPOPO

3.3.1 Historical Background on Smallholder Irrigation in South Africa

Despite failures and problems, particularly in many African countries, smallholder irrigation is still considered to be a potential driving force for rural development and poverty alleviation in numerous parts of the developing world. Increasing competition for scarce water resources requires that land use patterns adapt to accommodate alternative water needs and assure adequate returns from agricultural activities in future. This calls for increased water productivity, agricultural productivity and profitability. While in the past primarily technical solutions were sought, now institutional aspects of water management are gaining more and more importance among researchers and policy makers (Merrey, 1999). As a result, new legal and institutional arrangements are discussed and implemented in many countries.

South Africa's smallholder irrigation sector comprises 50 000 to 100 000 hectares of arable land. This area covers five to eight percent of the total irrigated area (Backeberg and Odendaal, 1998). Despite this small proportion, smallholder irrigation is considered to be an important component of the government's rural development strategy (Ministry of Agriculture and Land Affairs, 1998).

Two categories of smallholder irrigation can be distinguished, namely, food garden projects and irrigation schemes. Food garden projects are established through local, governmental, or non-governmental initiatives with the aim of improving food security and generating income for households.

Smallholder irrigation schemes in South Africa were established by government in the 1940s to improve self-sufficiency in food production and to contribute to rural development in the former homelands. Before the restructuring of state assets began in the late 1990s, these irrigation schemes were managed by government agencies and received substantial subsidies on production and marketing arrangements, infrastructure and production loans. People involved in irrigated agriculture in South Africa comprise an estimated 24 000 to 100 000 subsistence farmers, 17 000 to 24 000 commercial farmers and 32 000 to 88 000 permanent labourers (Ministry of Agriculture and Land Affairs, 1998).

Estimates of the potential for irrigation expansion in South Africa vary. Backeberg (2000) estimates that the potential is 283 350 hectares but that water is only available for 178 000 hectares in total. The Agricultural Policy Document (Ministry of Agriculture and Land Affairs, 1998) estimates the potential as 200 000 hectares. Table 1 provides statistics on South Africa's irrigation potential.

Eastern Cape and KwaZulu-Natal have probably enough water to irrigate available land while Mpumalanga and Limpopo have probably reached the limit of formal irrigation. Any additional areas in these two provinces can only be irrigated if water savings are made through more efficient methods in existing schemes. It is clear from the above statistics that existing and future irrigation development at any scale will need to be water efficient.

Table 1. South Africa's irrigation potential

Province	Land currently irrigated (ha)	Extra land that could be irrigated (ha)	Land available for further development (ha)
Eastern Cape	154 930	48 629	52 000
KwaZulu-Natal	170 244	99 563	77 000
Mpumalanga	157 420	35 810	7 000
Limpopo	135 146	11 070	2 000

Source: Backeberg (2000)

The success of smallholder agriculture in South Africa has been limited compared with other countries in the sub-region. Smallholder irrigation schemes designed and constructed for many farmers were planned in the same way as commercial farms with expensive, sophisticated infrastructure and equipment expected to be shared between several farmers. Design solutions appear to have been scaled down versions of first world technology rather than finding a solution that would work well for smallholder farmers. Management of these schemes was done by the government or its agencies, resulting in unsustainable, poorly performing smallholder irrigation schemes with a high degree of dependency among the farmers and cultivators.

Smallholder irrigation projects across the country are presumably in transition from government ownership to farmer ownership; from subsistence farming to commercial farming; from food crops to cash crops and from individual to group management. This is in line with international efforts to develop the social infrastructure in irrigation through irrigation management transfer. Since 1994, the restructuring of state-owned assets was undertaken on an ad hoc basis and in many instances farmers, workers, parastatals themselves and government are negatively affected by mismanaged restructuring.

The fundamental social problems of contemporary agricultural development were not seriously considered during the restructuring process. In smallholder irrigation, the impact of such oversight is felt by the marginalized groups which derive their livelihood from these projects. Although technical and economic considerations receive a great deal of attention, the people related issues, the real needs of the farmers are frequently subordinated or ignored, with detrimental consequences for sustained development.

According to Cernea (1984) there is a growing consensus that farmer participation in irrigation development and operation is important for the effective transfer of irrigation management and systems. Groups of farmers who use irrigation water are needed to maintain and allocate water locally. The farmers' knowledge of local conditions is needed in the development of the physical systems.

Cernea (1984:80) suggested the following useful guideline for determining the appropriate degree of government authority in irrigation management transfer:

"In general, government should unambiguously avoid doing that which communities can do themselves in their own interest, but should intervene when exceptional problems are beyond a community's power to overcome".

The following characterize smallholder irrigation in Africa including South Africa:

History of Dependency

Irrigation management transfer in the African context gained momentum with the simultaneous withdrawal by government from a long standing system of support to and management of small farmers' economies. Structural adjustment programmes called for the down-sizing and restructuring of parastatals such as the ARDC in the South African situation, the National Irrigation Board in Kenya and the White Nile Agricultural Schemes Administration in Sudan which left smallholder irrigation schemes throughout Africa reeling under the withdrawal symptoms. These parastatals managed smallholder irrigation through an elaborate top down command and support system that has eventually proven unsustainable (Shah et al., 2000). The system allowed for full irrigation subsidies as well as mechanized cultivation planting and fertilizer application. All that farmers had to do was weed, harvest and move irrigation pipes around.

In some projects in South Africa, the government provided labour to weed, harvest, move pipes around, organized and transported produce to the market. In such projects, farmers only came to collect the cheques at the end of the whole production chain. The plot holders were neither farmers nor entrepreneurs. As noted by Bembridge (1999:11) "scheme managers have been attempting to manage farmers rather than encourage entrepreneurial development". The long-term effects of these support systems in many African countries have been a strange legacy of impoverishment and dependency.

High Cash Costs due to Mechanization

In many parts of Africa, the tradition of using draught animal power has disappeared in favour of heavy equipment for ploughing and land preparation, spraying and harvesting. This high level of mechanization of farm operations became a major contributor to high cash costs. While parastatals and the state were still providing for the services, farmers felt no constraint. However, of late, with the withdrawal of the state and parastatals from these projects, accessing equipment at affordable rates has emerged as a major problem (Shah et al., 2000).

Absence of Credit, Inputs and Output Markets

One of the most critical problems threatening the viability of South African smallholder irrigation is the absence of credit, compounded by poor linkages to input and output markets. In past regimes in Africa, such issues as credit access were provided for in contract farming arrangements with parastatals. Output markets and input supply were centralized. Traditional markets have recently been diluted by bulk and affordable produce from large-scale farmers. Access to credit requires collateral mostly in the form of land rights which some smallholder farmers do not possess.

Land Tenure

In addition to land tenure rights, an important consideration for successful management transfer is to assign clear water rights. Bembridge (2000) noted that insecure tenure limits farmer incentives in making long-term development investments on their land. Land tenure is a major institutional issue which will have a bearing on irrigation management institutions. In principle, farmlands are communally owned. Within customary arrangements farmers feel they have secure tenure on the plots assigned to them as emerged in the Arabie Olifants scheme from the study by Lahiff (1999) and Mphahlele et al. (2000). Rukuni (2002) suggests that communal ownership of land and present tenure arrangements would promote productivity only if the communal ownership were secure. In his view, problems of tenure insecurity emerged primarily because all communal land that tends to be viewed as state owned gives every bureaucrat the power to intervene at will.

In Dingleydale and New Forest schemes in Limpopo Province, Shah et al. (2000) observed that farmers are uncertain whether they are allowed to rent land or not and are reluctant to discuss the matter in detail.

Small Plot Sizes

In Limpopo, the average plot size is about one hectare (Shah et al., 2000). Working in such tiny plots, farmers cannot be held responsible for not committing resources and time to farming. The common tendency is for the farmer to embark on a variety of livelihood strategies to make ends meet. The small plots are simply kept as some form of 'security'. Those that are fully utilized are mostly owned by pensioners who are too old for other livelihood activities.

South Africa has great potential which has already been largely enhanced by means of several highly efficient technical systems; surface irrigation sprinklers and pivots. The country has four main types of irrigation organizations: government water scheme managed by the Department of Water Affairs and Forestry, where the state contributes to the infrastructure; the Irrigation Boards which support private groups; purely private developments and the development of the rural smallholder irrigation projects in the former homelands.

Field studies commissioned by IWMI on farmer managed irrigation in small and large farmer context along the Olifants River basin revealed that in the smallholder schemes farmers pay little or nothing for irrigation on a full cost of operation and maintenance basis and stand to pay even much more for water itself once the new full cost water pricing policy comes into force. "Yet farmer management in smallholder irrigation schemes was doomed to failure whereas Irrigation Boards are highly successful" (Shah et al., 2000:22). The distinguishing factor is that farmers in the Irrigation Boards have large farms, access to credit and well-established markets. Farming is their main source of livelihood and, therefore, a well functioning irrigation system is central to these farmers. Smallholder irrigation farmers do not have resources and management capacity to operate their tiny schemes profitably.

The smallholder schemes in the former homelands have a lot in common with those on the White Nile in Sudan (Shah et al., 2000). Both have a long history of dependency on parastatals; have extremely high level of mechanization of smallholder cultivation; face poor infrastructure and institutional arrangement for input supply and output marketing for smallholder farmers. Both countries have comparable conditions with respect to land tenure insecurity and ambiguity about land rights.

Characterized by high state investment with low production yields, South Africa's smallholder irrigation projects are regarded in most aspects as a liability to the state. The state has disengaged from irrigation management in favour of the end users taking charge of maintenance and service costs through the Water User Associations and Irrigation Committees.

There are successful farmer managed irrigation projects in the sugar industry of KwaZulu-Natal and Mpumalanga. The success is attributed to smallholders enjoying access to credit, input supply, access to markets and capacity (Makhura and Mamabolo, 2000). A similar approach of community empowerment was used in Tanzania, Madagascar and Asia. Smallholders in such success examples indicate that resource-poor farmers can manage their irrigation schemes provided these offer the promise of viability and livelihood improvement (Shah et al., 2000). South Africa ought to develop a policy on irrigation management transfer which recognizes that farmer management of smallholder irrigation schemes can become sustainable provided broader and holistic lift strategy attacks at once the constraints on smallholder irrigation. Emphasis should be on people-driven development approach suited to the needs of end users taking into account farmer groups and their diversified cultures.

3.3.2 Smallholder Irrigation in Limpopo Province

Historical Background

A unique feature of the homelands was their rural nature characterized by low productive soils (Lahiff, 1997), low rainfall, limited natural resources, overpopulation (14 million in 1983) and corrupt administrators. In the face of limited opportunities for income generation other than remittances from migrant mineworkers and social welfare services, the previous government embarked on a job creation programme in the area of agriculture by establishing smallholder irrigation projects. The smallholder projects were characterized by a unique combination of food plot holders occupying on average one-hectare units and commercial plot holders on five-hectare units. The small food plot holders were subsistence farmers producing mostly for home consumption. These farmers were selected from local communities and the majority were women and men in the government social welfare programme. The household food security needs of the participants were addressed through subsistence production.

The commercial plot holders were largely comprised of senior public servants, business people, traditional leaders and their councilors. Some few unemployed community members who for one reason or the other commanded the respect of the community also joined the elite group on the commercial plots. The objective of rural employment creation was presumably achieved through this category of plot holders.

Irrigated Agriculture in Limpopo

In Limpopo, 135 772 hectares are used for irrigation farming which accounts for 1.1 percent of the total land area of 12.3 million hectares. The figure covers the former white districts (Development Bank of Southern Africa, 1995). In South Africa, irrigation development was regarded as one way of commercializing the African smallholder farmers. This idea of establishing state funded projects was the brainchild of the Tomlinson Commission (Tomlinson Commission Report, 1955). Land was the major asset required to implement the recommendations of the commission. Communities gave up their land in favour of establishing the projects. These rural communities, driven by poverty and hunger, were reduced to cheap labour pools for state projects.

Besides all these efforts, Lahiff (1997) maintains that economically the homelands remained extremely poor and underdeveloped with continued dependence on remittances from migrant workers in industrial South Africa and direct transfers from government for community and social services. The only beneficiaries of the government plan for rural employment creation through agricultural projects were the few individuals in senior public service positions. These individuals ventured into farming as a comfortable retirement option with minimal understanding of agriculture as a commercial business. For their willingness to register and provide an identity to the smallholder plots, the public servants were branded commercial farmers. Systems were created to sustain them as members of the commercial farming community. Free labour, loans, production infrastructure and inputs were provided by the state to these so-called commercial farmers – a practice that resulted in a false appearance of success in these projects. Once these free services were withdrawn, most of these projects collapsed. On the other hand, the small plot holders struggled through their subsistence production with limited support services.

Three to four decades later, members of the community who rely on farming for survival began to realize the error of forfeiting their land (albeit with informal land rights) to the benefit of the elite cliché of commercial farmers. To the majority of real smallholder farmers with no other source of income other than farming, the expected benefits of improved productivity, better income generation leading to sustainable livelihoods remain way out of reach. For this category of farmers, that level of expectation is today replaced by a dire situation wherein they are overburdened with debts from government loans; underutilized plots with sophisticated irrigation infrastructure that only government technicians can operate. The situation led to the collapse of production projects including irrigation projects.

Withdrawal of Farmer Support by Government

Since their establishment, smallholder irrigation schemes were managed and operated by government departments, parastatals (such as ARDC) and/or NGOs. These agencies ensured access to financial markets for the provision of production, operation, maintenance and infrastructure loans to smallholder irrigation farmers. However, there was an increasing recognition that government is a poor businessperson, has neither the drive nor capacity to successfully manage production projects. Consequently, the concept of restructuring materialized influenced by many other factors. The main objectives of restructuring were among others to:

- Increase economic growth and employment by promoting effectiveness, sustainability and viability;
- Meet basic needs by focusing on the poor and disadvantaged communities;
- Reduce state debt by management transfer; and
- Develop human resources by promoting efficient use of training and retraining, redressing previous discriminatory practices and enhancing technical and managerial capacity.

With regard to the smallholder irrigation farmers, there was a recognition that change to smallholder commercial farming has to be a gradual process. The withdrawal of government from providing support services to smallholder irrigation farmers did not follow a gradual process resulting into detrimental consequences.

An appraisal study by IWMI in May/June 1999 shows that cultivation in the upper and lower part of Arabie/Olifants scheme had strongly declined after the withdrawal of ARDC services in 1997/98. The study noted that

"The sudden withdrawal of ARDC services in the maize season of 1997/1998 led to a massive abandonment of cultivation. In most farms, there has not been any cultivation since the wheat crop of 1997. The sudden lack of ploughing services (before, these were provided at subsidized rates) and the lack of provision of seeds, fertilizers and pest management chemicals (before, ARDC provided this in kind as a loan to be repaid after harvest) led to the collapse of a number of smallholder irrigation schemes. A major problem was the requirement to pay the full amount for electricity to ESKOM (Electricity Supply Commission) from 1 April 1998 onwards. Before, this was gratis for farmers and paid by the ARDC" (van Koppen and de Lange, 1999:4).

In the same study, farmers complained about lack of transparency by ARDC in terms of deduction of production costs that ARDC made and on the quantity and price of the harvest that ARDC usually marketed. Farmers' net profits were marginal and decreasing.

During the transition period, there was no mechanism put in place to assist farmers to cope with the withdrawal of the ARDC. The main problems that these farmers faced were the breakdown of the old pumps, the high repair costs and the continuing lack of clarity about the responsibility to repair if the government is still the owner of the infrastructure. Water stress due to these problems affected their harvests (van Koppen and de Lange, 1999).

Gender Issues

In the smallholder irrigation schemes, the participation of women in decision-making has been limited even though they are the majority in irrigated agriculture. Van Koppen and de Lange (1999) estimate that 90 percent of the farm decision makers and water users in Arabie/Olifants scheme are women. Our observation in the five irrigation schemes included in the study indicates that the majority of the members of irrigation committees (which act as users associations in the transitional period) are men.

In the process of the establishment of water user associations which run parallel to the establishment of Catchment Management Agencies (CMAs), public participation and fair representation of all stakeholders is emphasized. The initial process of establishment of WUAs and CMAs in Limpopo is already flawed. A very limited public of the disadvantaged group participated in the process and they were mostly men.

Two male farmers wanted to initiate the process of establishment of the entity to take over assets in their irrigation scheme (Veeplaats). When they invited other irrigation schemes, only a few members (mostly men) from three irrigation schemes showed interest (van Koppen and de Lange, 1999).

There are indications from current observations that new structures that are going to be established to manage and run the irrigation schemes will have at the leadership level more men than women. Women farmers may continue to be marginalized. In favour of women as members of the new legal entity, the following advantages are mentioned by chiefs, village headmen, extension officers and men as well as women farmers:

- Women are the majority in irrigated agriculture. Experience has shown that in the Olifants river basin, men are not interested in irrigated agriculture – they are mostly interested in livestock rearing. There are more off-farm employment opportunities for men than women (van Koppen and de Lange, 1999).
- Currently, PTO communal land is issued in the name of the head of the household who are mostly men. Women obtain lifelong tenure security rights through their in-laws. With the new legal entities being established, there is need to reverse the registration of plots so that those who work the land on a continuous basis have access to all benefits that are related to being right owners of the land. This process has already been started with one of the chiefs endorsing the decision to register plots in the names of women.

3.3.3 Institutional Arrangements Affecting Smallholder Irrigation In Limpopo Province

The institutional framework affecting smallholder irrigation in South Africa changed drastically after the political changes in 1994. A number of Acts were promulgated with major implications for smallholder agriculture. These include the Marketing Act of 1996, National Water Act of 1998, Land Bank Act of 2002 and Communal Land Rights Act of 2004. The new institutional framework called for major transformations in the organizations that provided services to smallholder farmers, especially the parastatals. For example organizations such as the Land Bank and Agricultural Research Council had to reorient their activities so as to address the needs of smallholder farmers. Some of the organizations that were established in the former homelands (e.g. ARDC, provincial departments of agriculture, etc.) to provide services to smallholder farmers were restructured resulting in the withdrawal from the provision of some of the services that were available to these farmers at no cost.

Smallholder irrigation farmers were probably most affected by the promulgation of the Water Act of 1998. The Act makes provision for the establishment of catchment agencies and water user associations to manage water resources at river-basin level. In terms of the Act, water rights are granted in the form of user rights rather than being based on the existence of land rights.

In 2002, the Land and Agricultural Development Bank Act (Act No. 15, 2002) was promulgated. This Act affects access to rural finance for smallholder farmers as it alters the mandate of the Land Bank to include providing services to smallholder farmers who were previously excluded. The transformation of the Land Bank has also meant the phasing out subsidized loans which commercial farmers have benefited over the years.

Land tenure security has always been a problem in the former homelands. The communal land tenure system did not provide for land to be owned by the people who were using it. This has made it impossible for smallholder farmers in the former homelands to use land as security for loans. The Communal Land Rights Act (Act No. 11 of 2004) was promulgated to address some of the shortcomings of the communal land tenure system. The Act makes provision for communities to own land in the former homelands and to use it as security for loans. The Act further provides the same legally secure tenure, rights and benefits to any person regardless of gender.

3.3.4 Organizational Arrangements Affecting Smallholder Irrigation in Limpopo Province

A number of organizations were involved in one way or the other in the provision of services to smallholder farmers in the irrigation schemes under study. These are described below:

The Provincial Department of Agriculture

The provincial Department of Agriculture is one of the key role players in smallholder irrigation in Limpopo Province and provided the following services:

- The creation and maintenance of irrigation infrastructure;
- Agricultural extension services;
- Mechanization services;
- Irrigation water; and
- Development of cooperatives and appointment of managers to run the cooperatives;

The sudden withdrawal of the services of the ARDC in 1998 led to a massive abandonment of cultivation due to lack of provision of seeds, fertilizers, and chemicals for pest and disease control. Farmers were provided with loans for the purchase of inputs. The produce was also marketed by ARDC and costs of production covered through the process. The provincial Department of Agriculture was expected to implement a policy to gradually phase out subsidies to farmers in the irrigation schemes to move towards full cost recovery for services rendered. This policy was implemented very quickly without a transition period to allow farmers to recover from the shock of subsidy withdrawal.

Local Authorities

Local authorities play a critical role in the project area through land administration and allocation. The chiefs themselves are also involved in farming and may, therefore, monopolize irrigation water use. For example, the chief at Strydkraal bought a center pivot system from the Department of Agriculture and can irrigate his plots while other farmers have no water. At Veeplaats, the chief owns more land than any other farmer. She used her authority to lease land at Veeplaats to a white farmer without consulting the Department of Agriculture. New projects or agricultural matters in the project area cannot be initiated without consultation with the local authority.

Irrigation Committees

Irrigation committees were established in all the schemes. Each committee consists of seven elected members. The committee is responsible for the allocation of water to individual plots, supervision of the moving of irrigation pipes and control of sprinkler scheduling. They also play a key role in the planning of agricultural activities in the schemes.

Department of Water Affairs and Forestry (DWAF), Water User Associations (WUAs) and Catchment Management Agencies

In 1995 a legislative review process was initiated for water resources management (WRM) in South Africa, culminating in the 1997 White Paper on a National Water Policy for South Africa and the National Water Act (NWA, Act 36 of 1998). These provide the imperatives for WRM by defining the purpose and objectives, as well as certain requirements for performing WRM.

DWAF is currently being restructured to conform to the requirements of the National Water Act. The responsibility of DWAF was to plan and implement bulk water supply infrastructure. In future, the responsibility of DWAF will include policy formulation, legislation, national strategy formulation, institutional development, coordination and support as well as monitoring and auditing water resource management. As CMAs become operational, DWAF's role in the authorization of water use will diminish.

WUAs are statutory bodies established by the Minister of Water Affairs and Forestry under section 92 of the National Water Act. They are cooperative associations of water users who wish to undertake water related activities for their mutual benefit. Irrigation boards and committees are required to transform into WUAs. The difference between WUAs and the former irrigation boards is that WUAs should incorporate all users of any water resources within the local area. The CMAs will be responsible for water charge collection, water authorization and licensing among other functions. CMAs draw representatives from local and Provincial Governments, current and potential water users, and environmental interest groups.

In compliance with the National Water Act, the Minister of Water Affairs and Forestry has started the process of establishing CMAs in the nineteen water management areas in South Africa. Each CMA is expected to develop a catchment management strategy relevant to the water management areas under its jurisdiction and ultimately carry out functions such as water resource planning in the catchment area, registration, water charge, collection, water authorization and licensing. CMAs are expected to become self-financing.

Several criticisms were leveled against the process of establishment of the CMAs (van Koppen et al., 2002). Even though participation of blacks was emphasized by DWAF, the participation of this group in the functioning of CMAs was minimal. In the initial stages, the role of the local government who is a key player was not specific. Although there was wide consultation in the formulation of proposals for CMAs, the language of communication was English. Translation was provided in summarized translations in the local language. While black participants had interest in establishing contacts with DWAF for the first time, they also criticized the consultants used by DWAF to assist in the formation of CMAs. The manner in which the issue was handled also came under heavy criticism by black participants. In the final meeting of the Stakeholders Reference Group in February 2002, the wishes of the poor stakeholders for a more integrated approach to water management by the CMAs – one that considered both the consumptive and productive uses of water in their communities—were disregarded.

3.4 IRRIGATION MANAGEMENT TRANSFER

3.4.1 The Irrigation Management Transfer Process in Limpopo Province

Historically, governments have been fully responsible for managing local irrigation schemes and systems for water supply to both irrigation and the municipal sectors. This was based on the fact that water is a common pool resource and, therefore, needs to be managed centrally. However, this model of water management has been associated with the following problems:

- Over dependence on technical solutions without supporting arrangements and stakeholder participation;
- Ineffective state management due to inadequate local cooperation or participation and incentives for successful systems;
- Failure of markets due to the complex and variable nature of water supply, large investment requirements for infrastructure and significant enforced costs; and
- High transaction costs for coordination between users and user groups associated with negotiations around systems operation and individual actions.

Many of the smallholder irrigation schemes are not functional for a number of reasons, including infrastructure deficiencies, inadequate skills and organizational capacity, poor support and inappropriate land tenure system.

In view of the above, the provincial Department of Agriculture and Environment has embarked on a policy of creating an enabling environment through which beneficiaries can take over the schemes and manage them on a sustainable basis (i.e. irrigation management transfer). Irrigation management transfer was initiated for a number of reasons:

- Poor performance of government operated irrigation systems;
- Lack of finances available to manage irrigation systems by government;
- Need for direct involvement of local people in water resource management;

- Encouragement of individuals to take responsibility for water resource management with limited government assistance; and
- Improving agricultural yields.

The objective of irrigation management transfer is to transfer the management and ownership of irrigation schemes to the beneficiaries in a manner that maximizes the chance of self-sustainability and growth. In Limpopo Province, the irrigation management transfer process starts with the rehabilitation of the irrigation schemes. According to Shaker (2000), the provincial Department of Agriculture and Environment has developed a step-by-step process for rehabilitation and handing over of the irrigation schemes. The process of rehabilitation and handing over is implemented in phases and entails the following:

- Initial meeting with target irrigation schemes through existing organizational structures;
- Approach to tribal/local authority;
- Pre-developed survey;
- Technical and economic evaluation of natural resources, infrastructure and the scheme as a whole;
- Formulation of rehabilitation and development plan;
- Establishment of appropriate organizational structure;
- Registration of participants/beneficiaries;
- Establishment of farmer group and development committees;
- Formal notification of farmers by government;
- Training and capacity building of farmers and extension officers;
- Development of scheme management structures;
- Establishment of a demonstration plot;
- Upgrading of infrastructure;
- Establishment of a legal entity (water user association);
- Development of constitution of the legal entity;
- Future government employees agreed upon with their structures;
- Formalization of extension officer's role;
- Formalization of government subsidies;
- Allocation of government equipment to scheme; and
- Formal hand over of the infrastructure and the scheme as a whole.

The first phase (pilot phase) began in 1998 during which 11 irrigation schemes were identified for rehabilitation but only three were affected by the process. The three schemes were Thabina, Boschkloof and Morgan. In 2000, five more schemes (under the Land Care Programme) were included in the rehabilitation programme. These were Dingleydale, New Forest, Metz, Madeira, and Cape's Thorn. In 2002, the second phase of the Land Care Programme introduced 16 more schemes in the rehabilitation programme, namely, 12 schemes in the Ndzhelele Valley, Matshika, Makuleke, Homu and Tswelopele. To date, 28 irrigation projects covering 5616 hectares and involving 3668 farmers are in different stages of revitalization.

<u>Case Study: Thabina Irrigation Scheme</u>

Since 1997, the Limpopo Department of Agriculture and Environment has made efforts to rehabilitate smallholder Irrigation schemes before handing them over to the beneficiaries. The initial phase (pilot programme) involved three pilot schemes and Thabina Irrigation Scheme was one of them. Although the revitalization process is not yet complete to be able to identify the strengths and/or shortcomings of the approach, a study (Perret et al., 2003) was commissioned to look at situation before and after the initiation of the revitalization process. This case study is based on the study report and interviews conducted at the scheme in February 2004 by the research team.

Background to Thabina Irrigation Scheme

Thabina Irrigation Scheme is located at an altitude of 560m above sea level along the Thabina river. The scheme is located 24 km South East of Tzaneen. Annual rainfall averages around 790mm with drastic inter-annual variations, recurrent and severe droughts and long dry seasons with 90 percent of rainfall falling between October and February.

The Scheme started in 1962 to promote development and food security in impoverished rural areas of former Gazankulu and Lebowa homelands. Thabina lies at the southern edges of the Levhubu-Letaba water management area. There are 149 farmers at the scheme cultivating 234 hectares. Initially each farmer was allocated one hectare but reallocation occurred afterwards and average land size per person is now at 1.5 hectares. About 40 percent of the land lies idle/unused in Thabina as the plot holders were not interested in farming.

Land ownership is under PTO with limited prospects for selling or leasing the land to another person. Land can be inherited after the death or immigration of the current occupant.

Infrastructure

The infrastructure for water supply includes the initial gravity-fed system (weir, dams and a main canal) now combined with four pumps (the first and second are diesel pumps while the third and fourth are electric pumps which have been installed to increase water supply to the main canal). The canal starts at a weir along the Thabina river downstream to a dam. The main purpose of the dam was to supply irrigation water but the focus has since shifted to provision of domestic water. Currently, the dam doesn't store water for the scheme. The length of the canal is seven kilometres and about five kilometres thereof lies outside the scheme where it used to be covered with concrete plates which are now broken from place to place.

The main canal supplies secondary canals within each irrigation ward. Water bailiffs control each ward's water supply. There are four wards, (A, B, C & D) and within each ward some farmers are allowed to irrigate while the rest are to wait for the next turn according to the schedule. Farmers admitted that all wards experience water shortages with ward D being the most exposed as it lies at the end part of the main canal. Electric pumps are vandalized on a regular basis to the extent that it takes a long time for them to be repaired at which time farmers stop farming. This has become a major source of concern in the scheme. Three to four farmers own private small pumps, extracting water from the riverbed, especially in winter.

Management of the Scheme

Management of the scheme is by the Irrigation Management Committee and the Provincial Department of Agriculture. Farmers were requested to form management groups from the ward level onwards and choose representatives from wards to the management committee. The management committee has now been converted to a WUA. The scheme is the first where a WUA has been officially established. However, the WUA still does not have a certificate of registration as it is held by DWAF in Pretoria.

Farmers are aware of what a WUA is and have a fair knowledge of what it does. However, the concept of Catchment Management Agencies (CMAs) was not understood by farmers including the resident extension officer. Currently, the WUA is responsible for water issues, irrigated land issues, and cost recovery on pump operation. Other issues are attended to by farmers as individuals. The WUA is still at its infancy and it is highly unlikely that it will be able to handle the roles of a well established WUA in the near future. In the absence of the current leadership of WUA at Thabina, farmers admitted that there would be no leadership in the association raising questions about the type of training provided to farmers during the transition phase.

Rehabilitation of Infrastructure

According to the contractors and interviews with farmers, the following were completed as part of rehabilitation:Installation of two electric pumps:

- Repair of existing diesel pumps;
- Refurbishing / upgrading the weir, the main canal and one of the storage dams; and
- Levelling of irrigated plots.

Farmers acknowledge the improvement in water supply through the pumps but complain about the resulting costs. According to the farmers, R0.5 million (not confirmed by the Provincial Department of Agriculture) was spent on rehabilitation. Farmers felt that more could have been done with this money. The other complaints included:

- The lack of levelling which is direly needed to improve furrow irrigation at plot level and subsequently water sharing at scheme level. Farmers contented that levelling would have ensured efficient use of water.
- The need for canal upgrading and heightening to increase its capacity. Farmers claim that they told the consultants that what was needed was the expansion of the canal so that it can carry more water and not simply the repair of the canals. The canal was built for a smaller farming population but now more people are using the water. Farmers reported that there are still leakages in the sub-canals even after repairs were done.
- The need to upgrade the secondary canals, most being in poor conditions, and resulting in water and time lost during irrigation.

Farmers also indicated that one of the diesel pumps was replaced with a smaller electric pump which has not worked since its installation. According to the farmers, if the dam were to be enlarged, it would store more water for irrigation purposes. About 52 percent of the farmers were not satisfied with the outcomes of the rehabilitation process and felt that the process was not transparent. The committee of observers that worked with consultants was chosen by the consultants and these individuals from the community did not even know how to interpret/read map plans. Farmer participation in the rehabilitation process was highly questioned. Although farmers made their rehabilitation needs clear, these were not taken into account by the consultants. Farmers claim that the situation with the main canal had worsened because the concrete slabs that were used to cover the canal along the five-kilometre distance passing through the community outside the scheme are easily broken by the community. These slabs then block water as they fell into the canal and make it easier for water to be diverted into the community leading to less water flowing into the scheme.

Mechanization Services

Access to mechanization services is a thorny issue. Most of the smallholder irrigation schemes used heavy equipment before the withdrawal of the government from managing the scheme. When government withdrew, the equipment fell into disrepair. Farmers believed that the rehabilitation process should have provided at least some equipment in good working condition for them to start well as autonomous farmers. Since this was not done (though promised), farmers resorted to hiring from private contractors. This proved to be the very expensive. About 92 percent of the farmers hire contractors who provide tractors and implements for ploughing, disking and furrowing. Asked about changes that have taken place since the revitalization process started, farmers lamented that "the scheme is now like a small Kruger National Park". Most of the farms are bushy indicating that limited farming has taken place recently due to lack of funds to hire tractors for ploughing but also because of the limited water supply. They appreciate the training they have received on maize production and the setting up of an experimental plot for demonstration purposes. However members of the management committee complained that no training on management skills had taken place so far.

Extension Services

A male extension officer is permanently stationed at the scheme but is expected to provide services to three other schemes. The extension officer does not have transport and therefore he cannot effectively serve all the schemes. The extension officers generally have limited training in irrigation let alone on water user associations.

The training and support that the extension officer can provide will be limited to the individual farmer level and not at the WUA level. The usual technical functions performed by the extension officer do not match the new needs expressed by the management committee. Hence, the management committee's complaint that the government had forsaken them. There is no plan for the government to help them get even the 'basics right'. According to the Vice-chairman of the committee "the government is making an embarrassment of the management committee and this is very painful". There is limited leadership in the committee because of lack of training in leadership, management of water, financial and managerial skills. The technical, social and economic training needs of the scheme are not likely to be met by the current extension officer unless he is trained in those aspects that will turn the scheme around.

Input Supply, Credit and Markets

The WUA has established relationships with the NTK for seeds, input supply and small implements. A small shop was established at the scheme's facilities to facilitate access to inputs at reasonable prices without transport costs. Unfortunately the shop has already been robbed. With limited prospects of reopening the shop, farmers who need inputs will have to travel 24 kilometres to Tzaneen to buy inputs. Lack of funds prevents farmers from intensifying on input use and this leads to low yields and incomes. Currently farmers pay R10 per ha per month (as irrigation fees), a total of R120 per year. This amount covers only 68 percent of the total operational and personnel costs and does not cover maintenance costs. Since the fees paid are low, the electricity bill has been very high and the inability to pay the bill led to ESKOM disconnecting the electricity supply to the scheme.

The profitability of farming at Thabina hinges on adequate water supply. Currently, the annual farm profit per ha (effectively cropped) averages R675 which is low.

Perret et al. (2003) created different scenarios which would allow the scheme to make profits. Among the scenarios are increased water supply, (three-fold increase in water supply) increased vegetable production, reallocation of unused land and best water charging system. These scenarios assume that other variables are in perfect balance (e.g. availability of inputs, markets, prices etc).

Although farmers are willing to pay extra for fees, it is not likely that the above scenarios will be achieved. According to DWAF, further improvements on water infrastructure are not likely to occur in the near future. This then paints a bleak future for the scheme. Although the scheme is considered to be commercial oriented, a lot of beneficiaries see farming as an aside, food providing occupational activity while non-farm activities and welfare grants provide the bulk of the livelihood. Only 20 percent of the farmers use land and only 27 percent of the main crop (maize) is marketed.

It is noted that marketing arrangements at Thabina lack organization and sustainability. Only a few farmers engage in contract marketing with buyers and most marketing is done through hawkers. Input supply is a common problem including high cost and lack of transport facilities.

In summary, the following can be mentioned:

- Thabina Irrigation Scheme has been exposed to IMT and a WUA has been established even though it does not have a license/registration certificate.
- The rehabilitation of the irrigation infrastructure did not meet the rehabilitation needs of the farmers.
- The rehabilitation process did not adequately involve the beneficiaries who are dissatisfied with the outcome of rehabilitation.
- Although farmers pay management fees, it is considered too low to even cover operational and maintenance costs.
- The electricity bill has been too high and ESKOM has disconnected electricity, pumps do not operate and hence no irrigation takes place.
- Water shortages are a major concern including unlawful tapping of water and broken slabs block the flow of water into the scheme.
- Productivity is low, leading to low income.
- Support service provision (extension, input supply, marketing and credit, and mechanization) is poor and disorganized;
- The Management Committee is inadequately prepared to perform its role effectively.
- The majority of the farmers derive a higher proportion of their income from non- farming activities -- farming is still for subsistence.
- Forty percent of the land remains unutilised and tenurial arrangements dominate ownership of the land.

In spite of government intervention (IMT) in Thabina Irrigation Scheme, the “downward ratchets” are evident in the scheme. There is total dependence on government; dilapidated water supply infrastructure; ineffective water management (weak WUAs); low production levels; little knowledge of crop production or irrigation as well as leadership skills; ineffective extension; lack of markets and credit; and expensive and ineffective mechanization services (Crosby, 2000).

3.4.2 Irrigation Management Transfer: International Experience

Irrigation management reforms have occurred in many countries over the last five decades and have taken different forms. However, since the mid-1980s, the transfer of management of irrigation systems to WUAs or NGOs has been the centerpiece of irrigation management reforms. The transfer of irrigation management has been accompanied by the downsizing or withdrawal of government role in the provision of services such as operation and maintenance, fee collection, water management and conflict resolution (Shah et al., 2002). IMT involves the handing over of a number of responsibilities from the government to WUAs. These responsibilities may include:

- Distribution of water;
- Setting charge rates;
- Collecting fees;
- Implementing repairs and rehabilitation of canals.

The main motivation for the transfer of irrigation management was the need for government to reduce its recurrent expenditure for irrigation. Van Koppen et al. (2002) list four key assumptions underlying the irrigation reforms:

- Government management is neither a viable nor an ideal and sustainable approach to managing irrigation projects;
- Most irrigation schemes are, in principle financially and economically viable or have the potential to be so under reasonable management;
- Transferring the management of irrigation systems partly or wholly to WUAs would result in better operation and maintenance of the systems; improved water management; conflict resolution; improved fee collection; enhanced productivity of land; and contribute to food and livelihood security of the farmers in the schemes; and
- Management transfer takes time and requires capacity building, and succeeds to the extent the enabling conditions are in place to ensure their success.

Global experience on IMT impacts has been far from uniform and reassuring especially in low-income countries. A review of IMT impacts in several countries by Vermillion (1996) conveyed a mixed picture. IMT programs in Turkey, USA, Mexico and New Zealand are considered as successful examples. In less developed countries, the picture is less clear. Major reductions in government staff were reported in the Phillipines, Columbia, and Mexico. In some countries, operational and maintenance charges have increased especially in pump-operated schemes. Improved cost effectiveness of irrigation, improved collection of water fees and diversification of income sources by WUAs have also been reported. However, major maintenance of irrigation infrastructure has often been deferred. In the Phillipines, the key achievement of 20 years of IMT has been improved performance in fee collection.

IMT impact on agricultural productivity has also been mixed. In the Dominican Republic, farmers realized yield increases of 40 percent. In Mexico, there was no change. In Senegal, there was a decline in cropping intensity and area under irrigation expanded. In India and Nigeria, there has been improvement in water delivery to the farmers at the tail end of the canal. In Java, where agricultural production was high even before transfer, IMT did not increase irrigation costs to farmers nor lead to a decline in the quality of irrigation service but significant improvements in productivity were not achieved.

IMT has tended to be smooth, relatively effortless and successful where:

- Irrigation is central to a dynamic high performing agriculture;
- Average farm size is large enough for a significant proportion of farmers in the command area to operate like businessmen;
- Backward linkages with input supply systems and forward linkages with output marketing systems are strong and well developed; and

- The costs of self-managed irrigation are an insignificant part of the gross value of the product of farming.

These conditions prevailed in Mexico, USA, Turkey and New Zealand where IMT has been a success. Some of the above conditions are also found in South Africa in two main areas:

- The former irrigation boards - WUAs par excellence have managed irrigation schemes successfully. However, these boards were managed by white commercial farmers who did not feature in smallholder irrigation schemes. The farms operated by these farmers were large, profitable and highly mechanized. The success of irrigation boards in South Africa and Turkey is due to 40 years tradition of farmer participation in maintenance of the canal system through informal village level organizations. In Turkey irrigation fees are two percent or less of the value of production per hectare.
- The smallholder sugarcane industry in KwaZulu-Natal and Ka-Ngwane regions.
  The smallholder sugarcane industry, though it involves smallholder black farmers, has been able to implement IMT successfully because it enjoys access to broad based credit, input supply and markets. A bottom-up farmer organization called the Small Grower Development Trust has evolved a unique way of financial, training and other support services which account for the success of 42 000 smallholder sugarcane growers.

In Asia, IMT resulted in yield increases, area under cash crop increased, increase in farmer participation in decision making and management at all levels. The increase in irrigation performance in the hills of Nepal may be attributed to the tradition of collective self-management of irrigation that prevailed there for several hundreds of years. Overall, the impacts of IMT are positive. There has been an increase in productivity, improvement in the collection of water fees, improved effectiveness of irrigation, diversification of incomes and increased participation of farmers in decision-making. On the negative side, it may lead to staff retrenchments. Some international experiences with IMT suggest that four conditions must be met before a farming community makes a success of IMT intervention:

- It must hold out the promise of a significant net improvement in life situations for a significant proportion of farmers;
- The irrigation system must be central to creating such improvement;
- The economic and financial cost of sustainable self management must be an acceptably small proportion of improved income; and
- The proposed organizational design must have and be seen to have low transaction costs.

All these conditions were met by South African irrigation boards as well as irrigators in USA, Turkey, Mexico and New Zealand.

IMT faces problems in smallholder communities because most of them are not full fledged farmers and because management costs of a government-built irrigation system like most service organizations increases more rapidly with the number of customers than with the volume of business.

It is clear from the above review that there are successful IMT models in South Africa that we can learn from but we have not taken advantage of the situation. Although it may be argued that the irrigation boards are controlled by large white commercial farmers and that their social technology may not be relevant to smallholder irrigation farmers, some elements of success could be adapted to the smallholder environment.

The case of smallholder sugarcane growers could provide relevant lessons for the restructuring of smallholder irrigation schemes in Limpopo Province despite the fact that smallholder farmers in the province cultivate different crops. A thorough review of the experience with IMT in the smallholder sugarcane industry of KwaZulu-Natal and the former Ka-Ngwane homeland was, therefore, necessary before IMT was implemented in Limpopo Province. One of these lessons is that access to support services is crucial to the success of IMT.

Case Study: Institutional Innovations and Water Management in Office du Niger (1900-1999)[2]

This case study was chosen because it has similar characteristics to the management arrangements which existed in the irrigation schemes where the ARDC was responsible for management of irrigation schemes in Limpopo Province.

Office du Niger in Mali which had similar characteristics to the ARDC in South Africa has been a state run irrigation scheme. It was highly subsidized and operated in an 'estate mode' – centralized input supply and output marketing functions, farmers were reduced to being workers on their land. Irrigation was fully subsidized, mechanization, including planting, ploughing and fertilizer application was also organized by the scheme – farmers made no major capital investment and did not make decisions related to farm management. After many years of failure, restructuring began in the 1970s. Restructuring was deemed important because of the strategic role of the scheme which produced half of the rice output in the country. The average farm size was three hectares per family.

The elements of restructuring of Office du Niger are described below.

Strong Political Commitment

Because of the strategic importance of the scheme to the nation, the restructuring process had a strong support base from the government. Without food the nation would not survive and would have had to import half of its food needs. The Office of the Prime Minister provided political support and ensured that the process was smooth and successful.

Coordination of Donors

Because of strong government commitment, positive signals were sent to the donors who also viewed the situation in a positive manner. The donors forged a common vision which provided financial support to the process. The donors included the World Bank, the Dutch government and a number of French NGOs.

Office du Niger

Before restructuring, the management office had a staff complement of 4000. This was reduced to almost 300 after restructuring. The Office du Niger was given a new mandate which focused on the following three key areas:

- Water services – collecting water fees and water distribution.

[2] Based on Coulture et al. (2002)

- Maintenance of primary and secondary networks.
- Land administration.

Other functions were privatized or transferred to farmers' organizations. Performance contracts were the main tools in the relationship between Office du Niger, the state and farmers. These contracts define the quantitative and qualitative goals to be achieved within the contract period and the commitments of the different actors. The contracts were for three years and reviewed after each term ends.

The Technical Package, Economic Environment and Institutional Reforms

The above defined the success of the IMT in Office du Niger. Price incentives for rice were introduced, access to credit was ensured through farmers' organizations and the National Bank for Agricultural Development and land tenure issues were addressed adequately. At the time of the restructuring, the economic liberalization programme which was taking place in other African countries, was also being implemented in Mali. Crop diversification was encouraged through market gardening and livestock keeping. The technical intensification package also included high yielding rice varieties, transplanting techniques and fertilizer application. A training programme was organized to ensure adoption of the technical package. Rice threshers were disseminated to village associations for rice milling leading to value adding.

Formation of Village Associations

Farmer participation was improved through representation in all committees that touched the lives of the beneficiaries. These areas included water management, maintenance and land tenure. Village-based farmers' organizations were created in 1984 on the model of village associations. They were given the responsibilities for rice threshing and milling, credit management, land management, marketing and training.

Fees Collection and Management

Farmers are responsible for tertiary level canal cleaning and maintenance. Village associations organize collective works to clear the canals. Management of secondary canals is under Office du Niger but costs are borne by farmers through water fees. Fee collection rate is around 95 percent. The level of irrigation fees represents between six and ten percent of net farm income.

Land Management/Land Tenure

Farmers who do not repay their loans are evicted. Steps to ensure land tenure security began in 1989. Land management was placed in the village association's field of activity. Two land statutes were created.

- Farmers can only become permanent and given land tenure security if they follow cultivation rules and repay their loans. They can obtain an agricultural land use permit which can become permanent after three years.
- Temporary farmers had only an annual renewable land use contract.

Both categories of farmers can also sign house lease contracts. Farmers' land rights were therefore protected if they:

- cleaned the tertiary networks;
- followed an irrigation schedule; and
- followed and implemented the recommended technical package.

Private or Semi Private Services

Credit to farmers was organized through village associations and the National Bank for Agricultural Development. The Village associations established a Village Development fund which was later converted into a credit union. Farmers can access credit if (a) they are shareholders of the credit union; (b) if the other members stand surety for the borrower; and (c) if a security credit is paid. Other credit unions were established by NGOs. The credit schemes had recovery rates of 90 percent.

Inputs, Seeds and Agricultural Machines

The Dutch donors installed a professional skilled network of 22 assembly shops or cooperatives for the supply of credit, training and other suppliers. Other interest groups that facilitated input supply to farmers also emerged. Threshing and milling are done by village associations allowing farmers to keep most of the added value. Village associations negotiate contracts with traders from the towns. Service centres to provide advice and training to farmers were created by village associations. Economic interest groups also emerged and employed specialized advisers to advice farmers.

Field Monitoring, Research and Development

A research and development unit was established and subsidized as part of the public service mission of Office du Niger. The research and development unit deals with the dynamics of the farming systems and cultural techniques for rice and vegetables. Agronomic research results are available in irrigated rice, fruits and vegetables, cattle breeding and forestry. The research unit played an important role in generating solutions to farmers' problems.

3.4.3 Lessons for Limpopo Province's Irrigation Management Transfer Process

- IMT that only involves rehabilitation of the infrastructure and capacity building does not work. IMT must go beyond the irrigation sector to include the provision of farmer support services and other factors which will improve agricultural productivity and increase incomes of the beneficiaries. These are some of the "basics" which must be addressed before IMT takes place.

- Better support services and readily available markets are key to successful IMT of smallholder irrigation schemes.

- Government commitment and political will are necessary for IMT to be successful. Such commitment will motivate the private sector to buy into the IMT process. The role of the private sector in IMT in the Limpopo Province has been limited.

- The general economic environment must be favourable for IMT to work (e.g. economic liberalization, free emergence of private businesses, etc.)

- There is a lot of emphasis on WUAs in IMT. The mandate of these associations rarely goes beyond the water/irrigation sector. Often, for provision of other services a separate organization is created. This rarely works under smallholder irrigations schemes. A single organization needs to be created to provide a range of services needed by the schemes. In the schemes being rehabilitated in Limpopo Province, support services are provided by a range of organizations in an *ad hoc* manner.

- Irrigators need to take responsibilities in IMT after a suitable environment has been created. An incentive and carrot approach could be used to get commitment from farmers, e.g. you can only have land rights if you fulfill certain obligations.

- There are simple innovative approaches to providing credit and land rights that have rarely been tried in South Africa. Surety from the group and being a shareholder of a credit group have contributed to success in credit provision in Office du Niger. This arrangement should be considered for smallholder irrigation farmers in Limpopo Province.

The irrigation management transfer process in Limpopo Province appears to have started on a wrong footing. The dependency syndrome created by the government over the last thirty years of managing smallholder irrigation schemes has been destructive in two ways:

- It has destroyed/eroded the entrepreneurial spirit/traits that farmers might have had before they joined the irrigation schemes.
- The indigenous social organizations that provided support to the community have been uprooted.

A vacuum was created by government withdrawal from support service provision without any support mechanism in place. Success elements for IMT were not in place when restructuring started. The following should have been in place prior to restructuring:

- Irrigation schemes should have been profitable through improved productivity, training, access to support services and markets.
- The issue of making it possible for farmers to sell or rent their land or irrigation infrastructure should have been addressed.
- Negotiations with irrigators to determine those seriously interested in farming to pave the way for discussions on organizational structures and infrastructure suited to irrigation needs of the actors.
- All the support services for smallholder farmers should have been restructured. To date, little has been done to transform support services such as extension, marketing and mechanization.

CHAPTER 4: RESEARCH METHODS

This chapter describes the methods used to collect and analyze the data. The methods are described according to the objectives of the study. It should be mentioned that not all the study objectives required the use of specific research methods for their achievement. Hence, the description of research methods by objectives will only be done for some of the original objectives of the study. These include the following: (a) assessment of productivity, profitability and food security; (b) identification of cropping and irrigation management practices; (c) determining the effects of irrigation practices on soil salinity; and (d) documentation of social organization of smallholder irrigation. The remaining study objectives were dealt with as follows:

Extent to which poverty alleviation and empowerment of farmers can be achieved through self-management of irrigation systems. The approach here was to examine the irrigation management transfer process both in Limpopo Province and in other countries. Based on this analysis, some lessons were drawn and observations made that enable the research team to arrive at a conclusion on whether the irrigation management transfer process in Limpopo Province is likely to empower farmers and, thus, contribute to poverty alleviation.

Identify economic, social, institutional and policy issues affecting smallholder irrigation water use. This objective was addressed through the review of literature as presented in chapter three of the report.

Identify organizational designs that ensure a reasonable amount of equity among stakeholders. This objective was addressed by studying the organizational arrangements affecting smallholder irrigation in Limpopo Province, identifying shortcomings and making recommendations to address the shortcomings. The organizational arrangements are described in chapter three while recommendations to address the identified shortcomings are presented in the final chapter of the report.

Support action research to test the proposed strategies; and facilitate capacity building for carrying out practical and applied research. These were essentially some of the anticipated benefits flowing from the research and, thus, did not require any specific research methods.

4.1 DATA SOURCES

Since the study was conducted by a team of technical and social scientists, a multidisciplinary approach to data collection and analysis was required. On-farm (smallholder farms in the irrigation schemes) and off-farm (university experiment station) trials were the main source of data for the technical aspects of the study. Socio-economic data collection involved the use of participatory approaches and the administration of questionnaires to smallholder farmers in the irrigation schemes.

Data collection for the study started in 1999 in five irrigation schemes in the Olifants river basin selected according to the criteria outlined in chapter one. These were Adriansdraai, Sepitsi, Strydkraal, Veeplaats and Wonderboom. Data collection was preceded by a problem analysis to establish what the farmers in the irrigation schemes considered to be their major production constraints. At each irrigation scheme, a meeting was organized with farmers in which problems were identified, discussed and prioritized. The researchers acted as facilitators during the meetings. Some solutions to some of the identified problems were suggested at the meetings. Those problems whose solutions could not be provided on the spot formed the basis for the on-farm and off-farm agronomic experimental trials that were conducted to collect technical data used to address the identified problems. Details of the constraints and experimental trials are outlined in Appendix One. For the socio-economic data, farmers in each irrigation scheme were randomly selected and a total of 138 farmers were included in the sample. Data were collected from the farmers through interviews using questionnaires and participatory approaches. Both technical and socio-economic data collection processes involved university researchers and students.

For the reasons outlined in chapter one, Elandskraal irrigation scheme replaced Veeplaats. However, the data already collected from Veeplaats before the decision to replace it were included in the report. The data collection methods used in the other irrigation schemes were applied at Elandskraal. While Veeplaats was familiar to the research team, Elandskraal was not and the team had to start afresh establishing rapport with farmers -- a process that took a long time.

Other problems encountered during data collection included:

- Some irrigation schemes becoming inactive due to irrigation pipes and pumps being broken or electrical transformers being stolen (Adriansdraai and Strydkraal). This had a negative impact on the data collection process.

- The withdrawal of government from service provision in the irrigation schemes compelled some of the farmers to stop cultivating their crops. When data collection started in 1999, farmers were being asked to recall what their production levels were two to three years ago resulting in recall problems which may have affected the quality of the data. However, where possible, secondary data was used to cross-check the validity of the information provided.

- The resignation of key personnel from both the research institution and provincial department of agriculture had a negative effect on the data collection process.

4.2 ANALYTICAL METHODS

4.2.1 Productivity and Profitability

Productivity

Productivity was measured primarily in terms of crop yield per unit area as well as per unit of irrigation water (water productivity). Information on crop yield was gathered by means of both questionnaires and actual measurement on farmers' fields. Yield samples for maize were determined from four farmers spread over the entire maize production field. Two adjacent one-metre row lengths from three representative sites were sampled from each farmer's field and the number of plants within the harvested areas was also counted. The harvested maize cobs were shelled, dried in the laboratory to 14 percent grain moisture and weighed to determine grain yield.

Wheat yield was estimated from six farmers' fields using a one-square metre quadrant. The quadrant was placed at four randomly but representative sites within a farmer's field. The total number of heads within each quadrant were harvested and combined per farmer's field. The heads were oven dried at $60^{o}C$ to constant weight and threshed manually to release the grains. The grains were then weighed and yield calculated on hectare basis.

Vegetable crop yield was estimated from three farmers at each scheme during the time of harvest. Since the vegetable plots are generally small, an area of 1m x 1m square was used to measure yields from each farmer. This dimension generally corresponds to two to three rows of crops depending on the inter-row spacing used. Cabbage yield was estimated based on the number of heads obtained from the harvested area. For onion, beetroot, and spinach, the number of bunches (based on farmers standards), per harvested area was recorded. The fresh weight of the harvested part of all the vegetables was also recorded using a battery-operated scale so as to measure yield in tons per hectare.

To determine the level of productivity as expressed in terms of output per unit of irrigation water, it was necessary to measure the amount of irrigation water used. The amounts of water applied were estimated using rain gauges for the sprinkler systems and the bucket method for the furrow irrigation system. Optimum levels of application were estimated using the wetting front detectors.

Wetting front detectors were used to ascertain whether farmers were over irrigating with their current irrigation practices. The detectors were inserted at different depths on the farmers' fields and farmers were allowed to continue with their normal irrigation water application rates. The appearance of a rod in a detector after water application indicates that the irrigation water applied has reached the depth in the soil profile at which the instrument was placed. The free draining water was also collected wherever the detector was inserted. This water indicates the amount of water that will have drained beyond the depth of placement of the detector. The amount of water also gives an indication of potential leaching problem. Information on land area allocated to different crops was obtained from records within the schemes as well as validation from actual measurements.

One issue of interest was to establish whether there was any relationship between plot (farm) size and productivity. Data from Elandskraal were used for this purpose. Correlation coefficients between output and plot size were calculated to determine the relationship between farm size and productivity.

Profitability

To determine the level of profitability, gross income (total sales) for each crop was computed and total costs were deducted to obtain net income or profit. The first step involved calculating net farm income without taking into account charges for irrigation water. This calculation was done for each crop across three irrigation schemes (Elandskraal, Sepitsi and Wonderboom). The calculation, therefore, provides an indication of the overall profitability of the various crop enterprises in the three irrigation schemes. Due to the problems outlined above leading to some irrigation schemes becoming inactive, data could not be obtained from Adriansdraai and Strydkraal to enable the research team to compute profit figures for the two irrigation schemes. The second step entailed computing net farm income taking into consideration all the costs (i.e. including irrigation water charges). The latter was done for one irrigation scheme (Elandskraal) due to time and financial constraints and difficulties encountered in obtaining relevant data from the other irrigation schemes. The original survey did not make provision for the collection of data on the cost of irrigation water. This omission was rectified later when interviews were conducted at Elandskraal. Information from the second step provides an indication of crop enterprise profitability at both scheme and farm levels.

An important question to address in smallholder agriculture is whether farming provides sufficient income for rural households. This question was addressed in the study using data from Elandskraal as data from the other irrigation schemes were either insufficient or unavailable. The total annual income/profit from farming activities for an individual farmer and other household members at Elandskraal was calculated and this was compared with the minimum basic household income required for subsistence in South Africa. The household subsistence level per adult equivalent for South Africa when the study was conducted was estimated at R250 per month.

4.2.2 Household Food Security

Household food security was assessed on the basis of information supplied by farmers as requested in the questionnaires administered in two irrigation schemes (Sepitsi and Veeplaats) during 1999. Farmers were requested to indicate whether they sometimes experienced food shortages and how often this occurred during 1998. They were also asked to provide information on the contribution of the various sources of income (farm and non-farm) to total household income. Furthermore, the farmers were categorized into small and large-plot holders and “rich” and “poor”. This enabled us to determine whether household food security was affected by farm size. The categorization of households into “rich” and “poor” enabled us to determine whether the role of the various sources of income varied according to the level of household income. The analysis also provides some indication of the role of smallholder agriculture in poverty alleviation.

4.2.3 Effects of Irrigation Practices on Soil Salinity

Determining the effects of irrigation practices on soil salinity entailed measuring the current levels of salinity on irrigated and non-irrigated land; and determining the quality of irrigation water

Salinity levels were determined at Adriansdraai, Strydkraal, Elandskraal, Wonderboom and Sepitsi. Each time soils were sampled at almost the same place starting from the highest point down the slope to the riverbed (summit through the slope). The depth of topsoil sampling was from the surface up to 24 cm while the subsoil sampling was done from 24 cm plus. A total of forty samples were collected at each site except Wonderboom where only twenty samples were collected because of limited area. Irrigation water samples were also collected at the various schemes.

The silt content was determined from water samples taken from flowing river water at all schemes with the exception of Adriansdraai where irrigation water samples were taken from irrigation water already diverted to the irrigation pump.

The total concentration of soluble salts in irrigation water can be adequately expressed for purposes of diagnosis and classification in terms of electrical conductivity (EC). EC was measured at Adriansdraai, Sepitsi, Strydkraal and Wonderboom for both irrigated and non-irrigated land. The EC of soil samples was measured using the filtrate solution from the soil whereas the EC of the water sample was measured directly on the sample.

4.2.4 Documentation of Social Organization of Smallholder Irrigation, Access to Support Services and Aspirations

The survey questionnaire included questions in which farmers were requested to provide information on how they were organized in terms of water allocation and access to support services. The farmers were divided into three groups according to the size of their plots (i.e. 0.12, 1.28 and 5 hectares). The number of farmers responding to the questions asked within each category of farmers was expressed in percentages. The percentage responses were also calculated for the total sample of 138 farmers to obtain the overall picture.

4.2.5 Identification of Cropping and Irrigation Management Practices

Information on cropping and irrigation management practices was obtained through interviews and observation at the various irrigation schemes. The capacity of the irrigation system was determined using information obtained from engineers who installed the irrigation system.

Information on land area allocated to different crops was obtained from records within the schemes as well as validation from actual measurements while cropping patterns and cultural practices were determined through interviews and site visits.

CHAPTER 5: DESCRIPTION AND ANALYSIS OF RESEARCH RESULTS

This chapter presents the results of the study. This is done according to the objectives of the study.

5.1 SOCIAL ORGANIZATION OF SMALLHOLDER IRRIGATION, ACCESS TO SUPPORT SERVICES AND ASPIRATIONS

5.1.1 Organization and Ownership of the Scheme

Farmers have established irrigation committees to manage the irrigation schemes. The irrigation committees are also responsible for the allocation of water within the scheme. Ninety-four percent of the farmers believe that the irrigation committees are doing a good job and, therefore, enjoy their full support (Table 2). Some of the farmers have formed savings groups. On average, 37 percent of the farmers indicated that they were members of savings groups (Table 2).

Farmers were asked to indicate who the owner of the irrigation scheme was and their responses are outlined in Table 2. Only 17 percent of the respondents considered farmers as project owners. The majority of the respondents still regard the chief, community or government as project owners.

The following sections deal with issues of access, rights and aspirations of the smallholder irrigation farmers.

5.1.2 Access to Financial Markets

Access to finance for production, operation, maintenance and infrastructure was provided through the ARDC. These services were phased out in 1998. The Land Bank was transformed to assist smallholder farmers with financial services. The transformation process contributed substantially to the breakdown of activities. Although the Land Bank was mandated to provide production loans to farmers, the interest rate (24%) charged was considered high by farmers. Other compounding problems included the accessibility of the bank to farmers due to limited information and the physical distance to Land Bank branches. Filling application forms is a complex and lengthy process for smallholder farmers most of whom are functionally illiterate.

Alternative sources of credit are emerging among smallholder irrigation farmers. Although only 37% of all the farmers are members of saving groups, a relatively large proportion of food plot farmers (57%) are already members of saving groups that aim to save money for input purchases and irrigation equipment repairs.

Food plot farmers did not receive production loans through ARDC as compared to large plot farmers. They had to rely on alternative sources of credit. However, more and more farmers are increasingly getting involved in forming saving groups (Table 2).

When farmers were asked whether they had requested for credit in the last six years (since 1995), 70 percent of the farmers indicated that they did not ask for credit to finance their farming activities. Of those who asked for credit only 11 percent were successful in obtaining credit. The main reason for not applying for credit included; (1) did not know where to apply for credit; (2) would not be able to repay the loan; and (3) the application would be rejected.

Table 2. Survey findings on organizational arrangements, support services and household characteristics

	Irrigation plot size			
	0.12 ha n = 41	1.28 ha n = 73	5.0 ha n = 24	Total N = 138
Water management				
The project's water committee has farmers' support (% agreeing)	90	94	100	94
Farmers' perception about project ownership (who is the project owner? (%) of respondent(s))				
Don't know	10	15	0	11
Government	17	14	29	17
Chief	22	57	17	40
Community	17	10	25	15
Farmer	31	4	29	17
Information				
Have information on input markets (% of respondents)	61	70	83	70
Extension officer being major source of information on input markets (% of respondents with access to information on input markets)	79	67	70	71
Have information on output markets (% of respondents)	12	38	83	38
Extension officer being major source of information on output markets (% of respondents with access to information on output markets)	75	74	72	73
Financial Market				
Received production loan through managing agency in the past	No	Yes	Yes	
Member of saving group (%)	57	22	28	37
Interested to form saving group (%)	15	41	50	35
Land tenure				
Satisfied with land ownership status (% of respondents)	85	91	100	90
Miscellaneous model variables				
Household monthly off-farm income (Rand, 1 Rand = US$7.56)	870 (900)	682 (645)	1005 (1326)	797 (876)
Gender of the household head (% female headed households)	29.3	43.8	20.8	35.5

Figures in brackets are standard deviations.

Source: Hedden-Dunkhorst et al. (2002)

5.1.3 Access to Information

The extension service is the major source of information for smallholder farmers in Southern Africa. With the withdrawal of ARDC from support service provision, extension agents became less available to farmers due to curtailed operational expenses and lack of motivation. In the absence of limited 'other sources of information' and farmers' lack of skills to acquire information from elsewhere, extension agents still remained the major source of information.

As Table 2 indicates, 74 percent of the respondents considered the extension agent as the major source of information related to production with an even higher percentage (86%) of small vegetable producing plot holders depending on the extension agent for production related information.

Information on the marketing of agricultural produce is a major problem among smallholder irrigation farmers. Most food plot holders (88%) lack information on output markets (Table 2). The extension agent remains the major source of information for farmers with information on output markets (38%). Other information sources included neighbours and input suppliers. A good proportion of farmers have access to information on input markets with the extension agent again being the major source.

Although the extension agent is the major source of production related information, his/her training rarely includes marketing, posing a problem on the quality of information provided. To overcome the problem of access to information and other marketing constraints, farmers are beginning to develop alternatives such as forming marketing groups. About 30 percent of the farmers suggested the formation of farmer groups in order to market jointly and to get involved in contracts with commercial buyers.

5.1.4 Land Tenure

Current communal tenure arrangements which prevail in smallholder areas limit tenure security and also hamper the exchange of land for productive use. Farmers have PTO with usufruct rights only. They may not sell, mortgage, lease or subdivide the land. This arrangement hinders access to commercial credit. Despite this limitation, research indicates that the majority of smallholder farmers (91%) are largely satisfied with the current ownership arrangements (Lahiff, 1999).

5.1.5 Access to Appropriate Technology

Research on agricultural technology development has in the past focused on commercial agriculture which was the domain of white farmers. This approach has deprived smallholder farmers of appropriate technologies for their farming systems. To determine whether smallholder irrigation farmers were aware of some of the organizations responsible for developing and/or making new technologies available, they were asked to indicate whether they had heard of such organizations. The responses are outlined in Table 3. Higher education institutions in Limpopo Province are the most well known, followed by parastatals and government departments. Most farmers seem to know little about research organizations such as the Agricultural Research Council.

The adoption of new technology is hampered by the design of the irrigation infrastructure on the irrigation schemes. The design of the infrastructure makes it difficult for farmers to irrigate their plots according to their own individual requirements. Thus, farmers are compelled to cultivate the same crops and this limits the adoption of new crop technologies and land use practices that suit the farmer’s individual objectives and market opportunities.

Table 3. Farmers who have heard about delivery organizations

Organization	Number of farmers who have heard of the organization	Percentage
Agricultural and Rural Development Corporation	93	67.4
Agricultural Research Council	21	15.2
Department of Water Affairs and Forestry	67	48.5
Land Bank	81	58.7
Provincial Department of Agriculture	83	60.1
Tompi Seleka College of Agriculture	100	72.5
University of the North	99	71.1

5.1.6 Access to Water

During the apartheid era the control of water was unequally divided between the white Republic of South Africa and the black homelands. Whites controlled the bulk of water through riparian rights which were granted to high volume users by the Department of Water Affairs. The introduction of the National Water Act (1998) sought to redress the race and gender inequities of the past in the arena of water management and thereby contribute to poverty eradication (van Koppen et al., 2002). According to de Lange (1998), as much as 95 percent of water for irrigation is used by large-scale farmers while smallholder farmers only have access to the remaining five percent.

Before ARDC withdrew from the provision of support services, it operated and maintained irrigation pumps in addition to paying for electricity. Since 1998 the responsibility for maintenance and repairs of irrigation equipment and electricity payment was vested with farmers themselves. Farmers were given this responsibility even though they lacked both the experience and financial resources to maintain and repair irrigation equipment. As a result, cropping activities decreased to 15 percent of capacity.

The allocation of irrigation water within irrigation schemes is done mainly by irrigation committees composed of farmers (Table 4). About 82% of the respondents indicated that irrigation committees were responsible for allocating irrigation water. The figures in Table 4 also suggest that there is little interference from government in the allocation of irrigation water. The irrigation committees seem to work relatively well as 94 percent of the respondents indicated their satisfaction with the performance of the committees (Table 2). The high level of satisfaction with the performance of irrigation committees may also suggest that farmers are generally satisfied with the level of access to available irrigation water. However, it was not possible to establish from the respondents whether there was any difference in access to irrigation water between male and female farmers.

Table 4. Allocation of irrigation water in the scheme

	Elandskraal	Sepitsi	Wonderboom	Total (%)
Committees	72.4 (21)	88.9 (24)	85.7 (18)	81.8 (63)
Government	24.1 (7)	7.4 (2)	14.3 (3)	15.6 (12)
Other	3.5 (1)	3.7 (1)	0.0 (0)	2.6 (2)
Total (%)	100 (29)	100 (27)	100 (21)	100 (77)

Pearson Chi-Square=7.99; df=6; n=77. Figures in brackets indicate counts.

5.1.7. Farmer Interests and Aspirations

Before the withdrawal of support by government and the ARDC, project managers employed by the ARDC and the Provincial Department of Agriculture decided on production and marketing issues including crop choice. With freedom of choice, irrigation farmers are interested in changing land use and cropping patterns. They want to introduce alternative cropping patterns. The survey indicated that 66 percent of the farmers would be interested to intensify their land use pattern through the cultivation of high value vegetables and groundnuts. Others wanted to grow sunflower and include sugarbean in their rotation. This shift to alternative cropping is hampered by constraints relating to water management, access to credit, information and land.

In an attempt to overcome marketing constraints, irrigation farmers aspired to process some of their produce (value adding), particularly tomatoes. To this end, they entered into a partnership arrangement with one of the white commercial farmers who promised to process their tomato and then used these farmers to obtain a loan from the Land Bank. Farmers were tricked to sign loan agreement papers from the Land Bank but they never collected the money. At the time of writing this report, the matter was being addressed by the Provincial Department of Agriculture.

5.1.8 Access to Training

Training in this study refers to the management of supply equipment required to repair and maintain equipment such as pumps, reservoirs, etc. and general farm management of crop enterprises. Table 5 provides information on the provision of training to farmers on the irrigation schemes. The results show that extension officers are the most important provider of training to farmers in all the projects surveyed.

Training forms part of a successful irrigation management system. However, there are limited opportunities for smallholder farmers to access formal training. Farmers are often located in remote areas, funding is not available and in general farmers have low levels of education to make use of written information.

Table 5. Provision of training in irrigation scheme

	Elandskraal	**Sepitsi**	**Wonderboom**	**Total (%)**
Extension Officer	70.0 (21)	37.0 (10)	47.6 (10)	52.6 (41)
Committee	3.3 (1)	7.4 (2)	0.0 (0)	3.8 (3)
Private	6.7 (2)	0.0 (0)	33.3 (7)	35.9 (28)
No training	20.0 (6)	55.6 (15)	19.0 (4)	7.7 (6)
Total (%)	**100 (30)**	**100 (27)**	**100 (21)**	**100 (78)**

Pearson Chi-Square= 15.485; df=6; n=78. Figures in brackets indicate counts.

5.2 CROPPING AND IRRIGATION MANAGEMENT PRACTICES

5.2.1 Cultivated Crops at the Schemes

Diverse vegetable and field crops are cultivated in the different irrigation schemes studied. The type of crop cultivated in a particular scheme is related to the plot size available to a farmer. Farmers with access to smaller plots focus primarily on vegetable crops whereas larger field sizes are devoted to field crops. Table 6 gives a detailed description of the crops grown and the proportion of farmers involved in the production of the crops.

Maize (*Zea mays*) and cotton (*Gossypium hirsutum*) are the main summer crops grown at Veeplaats, Adriansdraai, Strydkraal and Elandskraal irrigation schemes. Farmers decide on one of the two crops to plant in the summer season and this is primarily based on a market contract with private companies. Wheat (*Triticum aestivum*) is the only winter field crop planted by farmers which results in a maize-wheat or cotton-wheat rotational system season after season. However, at Elandskraal, the farmers have adopted the practice of alternating the two crops during summer production since 2003.

There had not been any production of these crops at Strydkraal since this study was initiated. The main reasons for inactivity at Strydkraal included financial constraints, pump breakdowns, inadequate water supply and other logistical problems. However, there were few informal vegetable gardens and also a private company's production under leased contract at Strydkraal.

With the exception of small quantities of sugarbean produced at Adriansdraai and cowpea at Elandskraal and Wonderboom, cultivation of leguminous species is generally not part of the cropping systems at these schemes. Legumes are, however, important crops for building up soil fertility due to their ability to convert unavailable molecular nitrogen to plant-usable forms and, hence, minimize the reliance on more expensive inorganic fertilizers. Identification of appropriate legume species that could be incorporated into the system will be essential. Farmers expressed interest in the cultivation of sugarbean (*Phaseolus vulgaris*) and groundnut as cash crops.

Vegetable crop production occurs at Sepitsi, Wonderboom and Elandskraal. The choice of the vegetable crop to plant is made by the farmer and is not based on any market contract. Vegetable sales occur mainly at the local markets. Farmers at Sepitsi are currently focusing on the production of tomato and butternut with only a small proportion of the farmers producing other vegetables.

5.2.2 Description of Irrigation System and Amounts of Water Used

The results obtained on irrigation practices and pump information for the different schemes are presented below:

Elandskraal

The overhead sprinkler, centre pivot, funnel (umbrella) sprinkler and the furrow are the irrigation systems used by farmers at Elandskraal. The overhead sprinkler system is used on the one to five-hectare fields for maize, cotton and wheat production while the funnel sprinkler type is used on the vegetable units (Table 7). The use of the centre pivot only commenced in summer 2003 after a lease contract with a private company expired and is currently being used by ten farmers.

Table 6. Crops grown in different seasons at each irrigation scheme and the proportion of farmers engaged in production of each crop

Scheme	**Number of farmers**	**Crop**	**Season**	**Proportion of farmers producing the crop (%)**
Veeplaats (1999-2000)	25	Maize or cotton	Summer	100
		Wheat	Winter	100
Adriansdraai (1999-2000)	18	Maize or cotton	Summer	100
		Sugarbean	Summer	5.5
		Wheat	Winter	100
Elandskraal (2001-2003)	82	Maize	Summer	100
		Cotton	Summer	100
		Sugarbean	Summer	3.7
		Cowpea	Summer	6.1
		Sweet potato	Summer	6.1
		Wheat	Winter	100
		Vegetables: Spinach, cabbage, carrot, beetroot and onion	Winter	34.1
		Tomato	Summer	34.1
Strydkraal* (2002-2004)	85	Maize or cotton	Summer	100
		Wheat	Winter	100
		Vegetable	Summer and winter	< 5
Sepitsi (2000-2002)	62	Tomato	Summer	100
		Butternut	Summer	100
		Tomato	Winter	100
Wonderboom (2000-2002)	16	Maize, cowpea, sugarbean, pepper, sweet potato, sugarcane	Summer	100
		Onion, beetroot, spinach, peas	Winter	100

* Scheme is not active but when active the crops indicated are cultivated.

The funnel sprinkler rotates among the farmers and, if at the time of irrigation, the sprinkler happened to be unavailable, they resort to the furrow system. The duration of water application with the funnel sprinklers in vegetable production is not consistent. Farmers irrigate until the soil surface is wet according to their own judgments. A small fraction (less than ten percent) of the vegetable farmers use the furrow system to irrigate their crops.

The pump system at Elandskraal is powerful and in good working condition. The majority of the farmers are using new overhead sprinklers and they are generally happy about the water supply at this scheme. The difference in the amount of water applied per application using the overhead sprinkler is mainly due to variation in the time of water application rather than inefficiency of the sprinklers. Some of the farmers, however, were not satisfied with the manner in which the water overlaps on the field during application. The normal practice for the overhead sprinkler is to water for four hours per application. Some selected people within the community, not necessarily farmers are expected to adhere to this period but this is not always the case. Farmers on the five-hectare plots complained about the inadequacy of the irrigation pipes and requested additional pipes for them to be more efficient. Different types of pumps are used for different enterprises at the Elandskraal irrigation scheme (Table 8).

Information on water productivity at Elandskraal is provided in Table 9. Water productivity is consistently higher in wheat than in maize at Elandskraal. However, there had been a considerable improvement in maize water productivity from the 2001/02 growing season to the 2002/03 growing season (Table 9). The highest crop water productivity is obtained under the center pivot system for both maize and wheat. This is attributed to better distribution of water per application and more efficient application of fertilizers.

Sepitsi

The only irrigation system at Sepitsi is the furrow system, which is used for the production of different vegetable crops. The amount of water applied by farmers at the scheme is the same irrespective of the growth stage and this ranged from two to three times per week (Table 10).

A number of irrigation pumps with a capacity of 250 liters per minute (each) were installed at Sepitsi to irrigate 37 hectares of vegetables and 50 hectares of field crops. These pumps were installed more than ten years ago by the erstwhile Lebowa government but only one is currently functional. The cost of repairing a pump is about R7000 and the replacement cost is about R20000.

Wonderboom

Furrow irrigation is the only system utilized at Wonderboom and the amount applied per irrigation does not depend on growth stages of the crops grown (Table 11).

There is no pump at the Wonderboom irrigation scheme. Water is carried from the Olifants River, directly to the farmers' field by gravity flow through canals. There is a mother canal of about two meters deep flowing directly from the river and sub canals that distribute the water to the farmers’ fields. The canals are fitted with shutters to control the inflow of water to the farmers’ fields.

Strydkraal

The main water supply system to the Stydkraal irrigation scheme is via the same canal system that feeds the Wonderboom scheme (Table 12). In Strydkraal, five 55kw pumps were installed along the canal to pump water to the fields. None of the pumps is in good condition.

Table 7. Irrigation type and gross amount of water applied per irrigation at different growth stages at the Elandskraal irrigation scheme

Crop	**Irrigation Type**	**Growth stage**	**Gross amount per application (mm)**	**Frequency of application per week**	**Number of days of application**	**Total application (mm)**
Vegetable	Sprinkler (funnel)		11	Once	12	132
Maize	Sprinkler (overhead)	Planting to 4-leaf stage	16	Twice	8	128
		4-leaf to tasselling stage	16	Once	8	128
		Reproductive stage	16	Twice	14	224
					Total	480
Maize	Centre pivot	Planting to 4-leaf stage	14	Twice	8	112
		4-leaf to tasselling stage	14	Once	8	112
		Reproductive stage	14	Twice	15	210
					Total	434
Wheat	Sprinkler (overhead)	Planting to 4-leaf stage	16	Twice	8	128
		4-leaf to panicle emergence	16	Once	10	160
		Reproductive stage	16	Twice	15	240
					Total	528
Cotton	Sprinkler (overhead)	Planting to seedling establishment	16	Twice	8	128
		Vegetative stage	16	Once	8	128
		Reproductive stage	16	Twice	14	224
					Total	480
Cotton	Centre pivot	Planting to seedling establishment	14 – 16	Twice	Once a week	Twice a week
		Vegetative stage				
		Reproductive stage				

Table 8. Pump information at Elandskraal

Scheme	Pump type	Power (kw)	Total area (ha)
5 Ha	B1	110	60
5 Ha	B2	110	70
1 Ha	C	55	34
1 Ha	A1	37	11
Vegetable	A2	30	

Table 9. Water productivity of selected crops at Elandskraal

			2001/02				2002/03			
Crop	**Irrigation type**	**Total irrigation water application (mm)**	**Total rainfall (mm)**	**Total water (mm)**	**Crop yield kg ha^{-1}**	**Water Produ-ctivity Kg mm^{-3}**	**Total rainfall (mm)**	**Total water (mm)**	**Crop yield kg ha^{-1}**	**Water Prod-uctivity Kg mm^{-3}**
Maize	Sprinkler	480	452	932	3300	0.354	483.3	866.2	5500	0.63
Maize	Centre Pivot	-	-	-	-		434.0	816.9	8000	0.99
Wheat	Sprinkler	528	0	528	4500	0.850	0	528	4500	0.85
Wheat	Centre Pivot	-	-	-	-		0	514	5000	0.97

Table 10. Irrigation type and water application practices at Sepitsi

Enterprise	Irrigation Type	Gross amount per application (mm)	Frequency of application	Number of days of application	Total application (mm)
Vegetable	Furrow system (30-m length x 0.15m depth x 1m spacing)	260-370	2 to 3 times a week	16	4160

Table 11. Irrigation type and water application practices at Wonderboom

Enterprise	Irrigation Type	Gross amount per application (mm)	Frequency of application	Number of days of application	Total application (mm)
Vegetable	Furrow system (15.5m length x 0.15m depth x 1m spacing)	290	Once a week	15	4350

Water supply to the scheme is inadequate mainly due to the following:

i. Capacity of the canal is not adequate. This is evident from the inadequate amount of irrigation water reaching the plots as pointed out by farmers.
ii. The canal is most often blocked by algae growth and needs constant cleaning using chemicals. This is not affordable by the farmers.
iii. There are illegal diversions of irrigation water for small garden irrigation along the canal before reaching Strydkraal which reduce the volume of water available to the farmers.
iv. The source of water for the canal is a dam in the Olifants River which is re-charged by flow from the Arabie dam. When the level of the Arabie dam drops, water supply through the canal also diminishes.

In addition to the canal supply at Strydkraal, there are two backup 20kw submersible sludge pumps drawing water from the Olifants river to supplement the canal supply. One of the pumps was not working. Water supply into the backup system is not adequate during the winter months. However, during rainy seasons, farmers believe that if the two submersible pumps are functional to supplement the canal supply, there will be adequate water to meet crop needs during the season. One 20kw pump is expected to irrigate a total area of about 60 hectares.

The centre pivot section is leased to a private company cultivating mainly maize or cotton in summer and wheat in winter. According to the production manager of the company, cotton is the preferred crop in summer compared to maize due to high levels of theft in maize production. The cotton cultivar is Bolguard, which is genetically modified.

Table 12. Irrigation type and water application practices at Strydkraal

Section	Irrigation type	Total area (ha)	Water source
	Centre pivot*	56	Canal
A	Overhead sprinkler	38	Canal and Olifants River
B	Overhead sprinkler	43	Canal and Olifants River

* Currently under lease with a private company

Table 13. Irrigation type and water application practices at Strydkraal by a private company

Enterprise	Irrigation type	Gross amount per application (mm)	Frequency of application	Number of days of application	Total application (mm)
Maize	Centre pivot	10	Four times a week	64	640
Cotton	Centre pivot	10	Four times a week	64	640
Wheat	Centre pivot	10	Four times a week	64	640

To ensure adequate water supply to the pivot, the canal is cleaned every six weeks by a private company to remove algae. It takes a 24-hour cycle to irrigate the entire 56 hectares under the centre pivot, releasing 10-12ml of water per application. Irrigation is about four times a week (Table 13).

Adriansdraai

Farming activities at Adriansdraai resumed in mid-2003 after a two-year break due to financial constraints, pump breakdown and vandalism. The irrigation system is only overhead sprinklers for a 90-hectare land area. Table 14 provides information on the irrigation system used and irrigation practices.

A number of irrigation pumps are used at the scheme. A major constraint at Adriansdraai is inadequate amount of irrigation pipelines to apply water more frequently. Information on water productivity is provided in Table 15.

Table 14. Irrigation type and water application practices at Adriansdraai

Enterprise	**Irrigation Type**	**Gross amount per application (mm)**	**Frequency of application**	**Number of days of application**	**Total application**
Cotton	Overhead sprinkler	18	Once a week	16	288
Maize	Overhead sprinkler	18	Once a week	16	288
Wheat	Overhead sprinkler	18	Once a week	20	288

Table 15. Water productivity of selected crops during the 1999/00 season at Adriansdraai

			2001/02			
Crop	**Irrigation type**	**Total irrigation water application (mm)**	**Total rainfall (mm)**	**Total water (mm)**	**Crop yield Kg ha^{-1}**	**Water Product-ivity Kg mm^{-3}**
Maize	Sprinkler	192	664.5	856.5	1600	0.187

5.2.3. Levels of Irrigation Water Application

The response of wetting front detectors to irrigation practices in the different schemes is presented in Table 16.

Elandskraal

The applied irrigation water in wheat and maize drained up to 30 cm down the soil profile but not at 60cm when 23mm of water was applied. Eighteen and twelve mililitres of drained water was collected in wheat and maize respectively after four hours of application. The implication is that the soil profile around the 30 cm depth is well watered but the application rate is not adequate to reach the 60 cm depth. Wheat roots can extract water beyond the 60 cm depth and maize up to one metre, indicating that farmers could increase the amount of irrigation water applied. The detectors, however, need to be placed at different depths below and above 30cm to gain a better understanding of water movement down the profile. The funnel/umbrella sprinkler irrigation system in vegetables also resulted in free-drained water of 25ml after irrigating the crops to desirable amounts by farmers using own judgment.

Table 16. The response of wetting front detectors placed at different depths at Elandskraal, Sepitsi, Wonderboom and Adriansdraai

Scheme	**Enterprise**	**Soil depth (cm)**	**Appearance of detector**		
			Yes	No	Drained water (ml)
Elandskraal	Wheat	30	X		18
		60		X	
	Maize	30	X		12
		60		X	
	Vegetables	15	X		25
		30		X	
Sepitsi	Vegetables	15	X		75
		20	X		55
Wonderboom	Vegetables	15	X		17
		30	X		23
Adriansdraai	Cotton	30	X		8
		45		X	

Sepitsi

The soil depth is between 15 and 30cm, which is very shallow. The shallow depth could be the result of a hard pan developed over several years of ploughing. The use of a ripper is essential to break this pan. The irrigation water quickly reached 15 and 20cm depth due to the porous nature of the soil at the scheme. Farmers need to apply reduced amounts of water at more frequent times instead of the current large amounts at a time. The result is that applied water builds up at the upper layers of the soil and later escapes either through evaporation or crop removal.

Wonderboom

Applied irrigation water drained up to 30cm after application. The amounts of free-drained water collected at 15 and 30cm depths were 17 and 23ml, respectively. As in the case of Sepitsi, farmers need to apply the water at reduced rates but more frequently. Further information on the use of the wetting front detector needs to be obtained as we were constrained by the limited number of instruments.

5.2.4 Land Area

Information on land utilization for crops in the five irrigation projects is provided in Table 17. On the five-hectare plots at Elandskraal, it was observed that not all farmers managed to cultivate the entire five hectares due to financial constraints. An additional observation was that almost all the wheat farmers produced wheat on a portion of their five-hectare plots since the remainder of the plot was still occupied by maize or cotton from summer planting. The farmers are however making attempts to plant early so that they can utilize the five-hectare fields as well for the winter crop.

5.2.5 Cropping Patterns, Cultural Practices and Constraints

Cropping Patterns

The cropping system generally employed at the schemes is alternate summer and winter cropping for both field and vegetable crops. Maize or cotton followed by winter wheat is the dominant rotation in the one- and five-hectare schemes. Winter vegetables such as cabbage, spinach, beetroot, onions and peas follow summer vegetables, mainly tomato and butternut in the vegetable units. Summer field crops, mainly cowpea and maize, are grown by farmers at Wonderboom.

Cultural Practices

The cultural practices from land preparation to harvesting for the vegetable and field crop production units are similar across the schemes. Table 18 provides a summary of practices for the vegetable and field crop production currently used by farmers.

Land preparation

Farmers at Sepitsi, Adriansdraai, Veeplaats, Strydkraal and Elandskraal use hired tractors to plough and/or disk the land for new planting. Ridges in the vegetable units for furrow irrigation are made with spade, shovel and hoes. At Wonderboom, farmers prepare the land using basic tools such as hoes and spade.

Table 17. Land area allocation at the schemes

Location	Total number of farmers	Enterprise	Land area per farmer
Elandskraal	28	Summer crops (maize, cotton)	5 ha
	54	Summer crops (maize, cotton)	0.5 ha (182 x 28 m^{-2}) to 1ha
	82	Wheat	~0.5 to 1 ha
Veeplaats	25	Summer crops (maize, cotton)	5 ha
		Wheat	5 ha
Adriansdraai	18	Summer crops (maize, cotton)	5 ha
		Wheat	5 ha
Sepitsi	62	Vegetables	30m x 20m (600 m^2)
Wonderboom	16	Vegetables	40m x 6.5 m (260 m^2)
Strydkraal	85	Summer crops (maize, cotton)	0.7 – 1.8 ha
		Wheat	0.7 – 1.8 ha

Fertilization

Compound fertilizer is applied at planting and topdressed with Lime Ammonium Nitrate (LAN) or Urea three weeks after planting in both the vegetable and field crop units. The common compound fertilizers used are 3:2:3, 3:2:0 and 4:3:4. Blanket amounts of the inorganic fertilizers are applied and these are usually marginal, especially for the field crops. The application rates are usually not based on soil fertility analysis and recommendation. Farmers cite lack of information on fertility recommendation and funds as the main reasons for resorting to a low blanket application.

The analysis of soil fertility at the schemes, however, indicates that the soils are fairly adequate in phosphorous and potassium but low in nitrogen (see Appendix One for details on soil fertility at the schemes).

Plant density

Maize

The number of plants per hectare for maize varied greatly from farmer to farmer. The current range is about 55 000 to about 80 000 plants per hectare. These densities are relatively high considering the fact that fertilizer inputs into the system, especially nitrogen, is marginal. Higher plant density also implies higher seed cost.

Table 18. Farmer cultural practices for production of tomato, spinach, beetroot, and onions in the irrigation schemes

Crop	**Soil Preparation**	**Fertilization**		**Planting**			**Pest control**	**Disease control**	**Weed control**
		Type	Method	Date	Density	Method	Chemical	Period	Chemi-cal
Tomato (cultivars: Zelly and Ruttan)	Disk or hoe and spade	Chicken or kraal manure or 2:3:2 and LAN	Band in furrow for fertilizer	Feb: Zelly Aug: Ruttan	15000 Plants ha^{-1}	Transplant	Buldock for insect pests	Selegro, Bravo & Malasol	Hand hoeing
Spinach (cultivar: Fordhoek Giant)	Disk or hoe and spade	Chicken or kraal manure or 2:3:2 and LAN	Band in furrow for fertilizer	Feb	33000 Plants ha^{-1}	Transplant	Buldock for insect pests	None	Hand hoeing
Beetroot	Disk or hoe and spade	Chicken or kraal manure or 2:3:2 and LAN	Band in furrow for fertilizer	Feb	30000 Plants ha^{-1}	Transplant	Buldock for insect pests	None	Hand hoeing
Onion (cultivars: Texas Grano and Pyramid)	Disk or hoe and spade	Chicken or kraal manure or 2:3:2 and LAN	Band in furrow for fertilizer	March	100000 Plants ha^{-1}	Direct seeding	None	None	Hand hoeing
Maize	Plough and disk	2:3:2 and LAN	Broadcast and disk	Nov – Jan.	50 000 to 75 000 plants/ha	Planter	None	None	Hand hoeing
Wheat	Plough and disk	2:3:2 and LAN	Broadcast & disk	April	105 kg/ ha	Broadcast and disk	None	None	None

Wheat

Wheat is planted at a density of 100 to 110 kg per hectare depending on the farmer. This planting density is within reasonable range.

Pest and Disease control

Farmers spray the seedlings with deltamethrin at transplanting to control cutworms and then spray cypermthrin to control aphids and diamond black moth. Karbamil is used to control bagradabugs, while red spider mites are controlled by ripcord, dithane wg, bladbuff and abamee. Farmers spray butternut with malasol once in two weeks, from transplanting until harvest. Disease control is mainly by selegron and bravo.

The major pest and disease problems encountered in the vegetable production units included:

- damage by cutworms while the seedlings are still young;
- wilting and upward closure of the leaves;
- occurrence of black spot under the tomato fruits; and
- bursting of tomatoes.

5.3 EFFECTS OF IRRIGATION PRACTICES ON SOIL SALINITY

5.3.1 Salinity Levels and Irrigation Water Quality

The concentration and composition of dissolved constituents in water determine its quality for irrigation use. Quality of water is an important consideration in any appraisal of salinity or alkalinity conditions in an irrigated area.

The characteristics of irrigation water that appear to be most important in determining its quality are: (1) total concentration of soluble salts; (2) relative proportion of sodium to other cations; (3) concentration of boron or other elements that may be toxic; (4) the silt content; and (5) under some conditions, the bicarbonate concentration as related to the concentration of calcium and magnesium.

The total concentration of soluble salts in irrigation water can be adequately expressed for purposes of diagnosis and classification in terms of electrical conductivity (EC). The conductivity is useful because it can be readily and precisely determined. Nearly all irrigation water that has been used successfully for a considerable time has EC values less than 2250 micromhos/cm.

Salinity refers to the accumulation of salts in the soil and affects productivity negatively. Inappropriate irrigation practices may cause or exacerbate the problem of salinity. Accumulation of salts is common in shallow soils. Saline soils are those in which the conductivity of the saturation extract is greater than four millimhos/cm, or 4000 micromhos/cm. It has been found that the conductivity of the saturation extract of soil in the absence of salt accumulation from ground water usually ranges from two to ten times as high as the conductivity of the applied irrigation water. This increase in the salt concentration is the result of continual moisture extraction by plant roots and evaporation. Therefore, the use of water of moderate to high salt content may result in saline conditions, even where drainage is satisfactory. In general, water with conductivity values below 750 micromhos/cm is satisfactory for irrigation insofar as salt content is concerned, although salt sensitive crops may be adversely affected by the use of irrigation water having EC values in the range of 250 to 750 micromhos/cm.

Water in the range of 750 to 2250 micromhos/cm is widely used, and satisfactory crop growth is obtained under good management and favourable drainage conditions, but saline conditions will develop if leaching and drainage are inadequate.

The soluble inorganic constituents of irrigation water react with soils as ions rather than as molecules. The principal cations are calcium, magnesium, and sodium, with small quantities of potassium ordinarily present. The alkali hazard involved in the use of water for irrigation is determined by the absolute and relative concentrations of the cations. If the proportion of sodium is high, the alkali hazard is high; and conversely, if calcium and magnesium predominate, the hazard is low.

Alkali soils are formed by accumulation of exchangeable sodium and are often characterized by poor tilth and low permeability. In the past the relative proportion of sodium to other cations in an irrigation water supply has been expressed in terms of the soluble-sodium percentage. However, the sodium adsorption ratio (SAR) of a soil solution is simply related to the adsorption of sodium by the soil. Consequently this ratio has certain advantages for use as an index of the sodium or alkali hazard of the water. This ratio is defined by the equation:

$$SAR = Na^{+} / [(Ca^{++} + Mg^{++})/2]^{1/2}$$

where $Na^{+,}$ Ca^{++}, and Mg^{++} represent the concentrations in miliequivalents per litre of the respective ions.

High silt content is not desirable as it may adversely affect the operation of irrigation equipment. Previous studies have indicated that the quality of irrigation water in the Arabie-Olifants river system has remained relatively stable throughout the years (Silt levels have remained below the 1mg/liltre threshold in all seasons and the sodium adsorption ratio of the soils has never exceeded two). However, oral reports from individual farmers and irrigation project managers indicate a rising level of salinity. Cases of soil salinity were reported in the lower part of the irrigation system including irrigation schemes like Mooiplaats and Veeplaats. This indicates that water quality may have deteriorated downstream as the supply of water decreased.

Electrical conductivity was measured at Adriansdraai, Sepitsi, Strydkraal and Wonderboom for both irrigated and non-irrigated land (Table 19). There was no significant difference in the electrical conductivity values between irrigated and non-irrigated soil at Adriansdraai and Sepitsi. This implies that irrigation practices at the two schemes have not resulted in increased levels of salinity. However, for Strydkraal and Wonderboom the difference in the electrical conductivity values between irrigated and non-irrigated soil were significant and the values were much higher than those for Adriansdraai and Sepitsi. The EC values were less than four mmhos/cm at every scheme and thus salinity is not a problem at this stage.

The results of the irrigation water analysis are given in Table 20. The EC values classify this water as medium-salinity water that can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control. The alkali hazard is low to medium, depending on the time of the year. Low sodium water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium. Medium sodium water will present an appreciable sodium hazard in fine-textured soils having high cation exchange capacities, especially under low leaching conditions. This water may be used on coarse-textured soils with good permeability.

The SAR values at Adriansdraai, Wonderboom and Veeplaats are summarized in Table 20 and averaged 11, 8 and 9 respectively. Again these schemes have medium salinity water and low to medium alkali or sodium water. It will be important to monitor the salinity and alkali levels at these schemes, especially on the fine textured soils with high amounts of montmorillonitic clays.

The results of silt-content analysis (Table 21) indicate that water quality is within acceptable levels as the silt content of the irrigation water is below 1mg/l. The water, therefore, does not pose any danger of blocking the irrigation sprinklers.

The EC values obtained in all schemes were influenced by the soil type, age of the irrigation scheme and agricultural practice. The results on water electrical conductivity are presented in Figures 1 to 11.

Salinity levels (as expressed by the electrical conductivity) at all schemes were within acceptable limits and pose no threat as yet (see Table 19). Strydkraal and Wonderboom had somewhat higher EC levels. This is probably due to the fact that both schemes have been in operation much longer than the other schemes. The salt content of the water at Wonderboom is also higher than at the other schemes (Fig. 11) which would result in a higher salt content in the soil. The fact that flood irrigation is practised at Wonderboom might help prevent the build-up of salts in the soil. Sepitsi, Adriaansdraai and Elandskraal have similar salinity levels (Figures 5 to 10). At all schemes the highest EC values were found during January 2001.

5.3.2 Tolerance of Different Crops to Salinity

Salinity is probably one of the most common limiting factors in agricultural production in arid and semi-arid valleys and basins. Crops can be subdivided into the following three groups with respect to their salt tolerance.

Low salt tolerance: these very sensitive crops show yield reduction at conductivity levels of 2 – 4 mmhos/cm. The crops include beans, green bean, radish, celery, pear, apple, orange, prune, apricot, peach, strawberry, lemon, avocado, white and red clover.

Medium salt tolerance: these sensitive to moderately sensitive crops show yield reductions at conductivity levels of 4 to 8 mmhos/cm. Crops included in this category are rye, wheat, rice, sorghum, maize, sunflower, tomato, brocolli, cabbage, pepper, lettuce, potatoes, carrots, onion, peas, fig, olive, and grape.

Tolerant crops: support conductivity levels over 10 mmhos/cm often up to 16 mmhos/cm. Included in this category are barley (16 mmhos), sugar-beet (14 mmhos), cotton (14mmhos), garden-beet, asparagus, spinach (up to 12 mmhos), and date palm.

Table 19. Electrical conductivity in the soil (mmhos/cm)

ADRIANSDRAAI						
	Variable	**n**	**Mean**	**Std. Error**	**Minimum**	**Maximum**
	Topsoil	32	0.08	0.04	0.05	0.15
	Subsoil	32	0.22	0.15	0.05	0.05
	Topcont	12	0.23	0.17	0.05	0.50
	Subcont	12	0.22	0.17	0.10	0.75
SEPITSI						
	Variable	**n**	**Mean**	**Std. Error**	**Minimum**	**Maximum**
	Topsoil	16	0.11	0.08	0.01	0.25
	Subsoil	16	0.16	0.11	0.01	0.40
	Topcont	16	0.13	0.12	0.01	0.50
	Subcont	16	0.08	0.04	0.05	0.15
STRYDKRAAL						
	Variable n	**Mean**		**Std. Error**	**Minimum**	**Maximum**
	Topsoil	13	0.61	0.12	0.50	0.80
	Subsoil	12	0.57	0.13	0.40	0.80
	Topcont	10	0.53	0.10	0.35	0.65
	Subcont	12	0.62	0.16	0.40	0.80
WONDERBOOM						
	Variable	**n**	**Mean**	**Std. Error**	**Minimum**	**Maximum**
	Topsoil	16	0.47	0.09	0.35	0.65
	Subsoil	16	0.54	0.25	0.25	1.10
	Topcont	16	0.56	0.13	0.40	0.80
	Subcont	16	0.56	0.13	0.40	0.80

Topcont = Topsoil control sample
Subcont = Subsoil control sample

Table 20. Electrical conductivity and sodium adsorption ratio of irrigation water

Month	**EC (Micromhos/cm)**	**SAR**
March	410	11.5
June	400	5.9
October	630	10.5

Table 21. Silt content of irrigation water

Irrigation Scheme	**Silt content (mg/l)**
Adriaansdraai	0.4
Veeplaats	< 0.5
Wonderboom	< 0.3

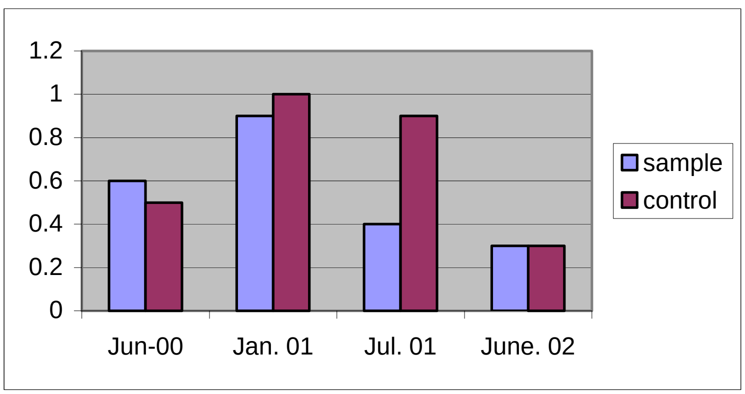

Figure 1. Sample and control topsoil electrical conductivity results for Strydkraal (mmhos/cm)

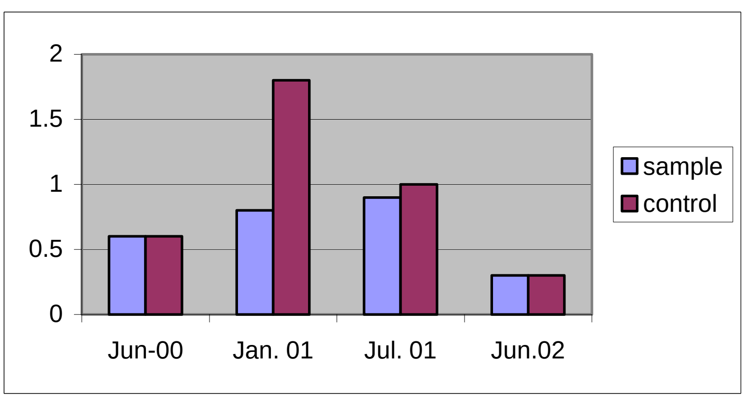

Figure 2. Sample and control subsoil electrical conductivity results for Strydkraal (mmhos/cm)

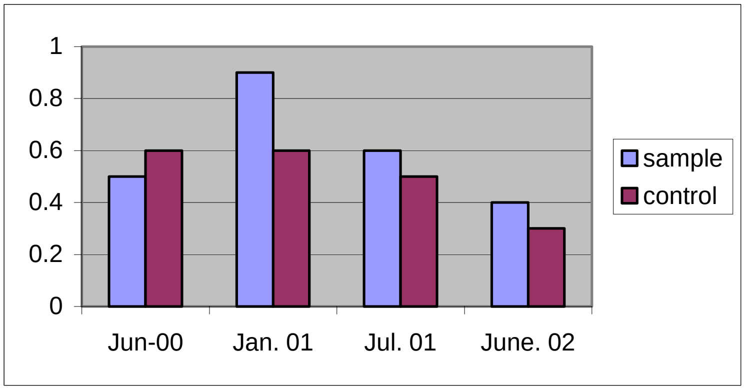

Figure 3. Sample and control topsoil electrical conductivity results for Wonderboom (mmhos/cm)

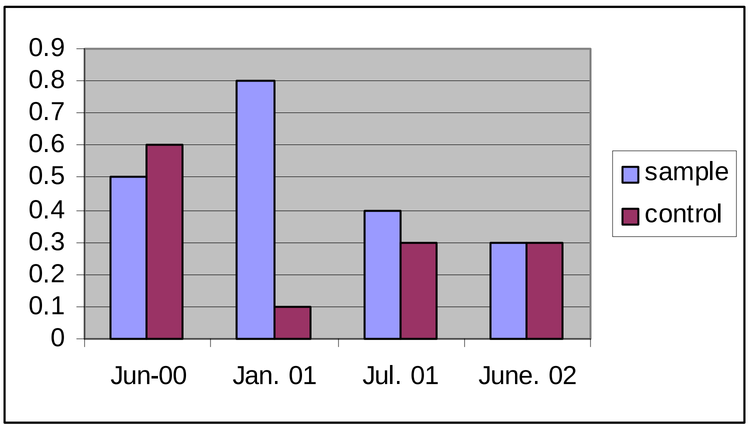

Figure 4. Sample and control subsoil electrical conductivity results for Wonderboom (mmhos/cm)

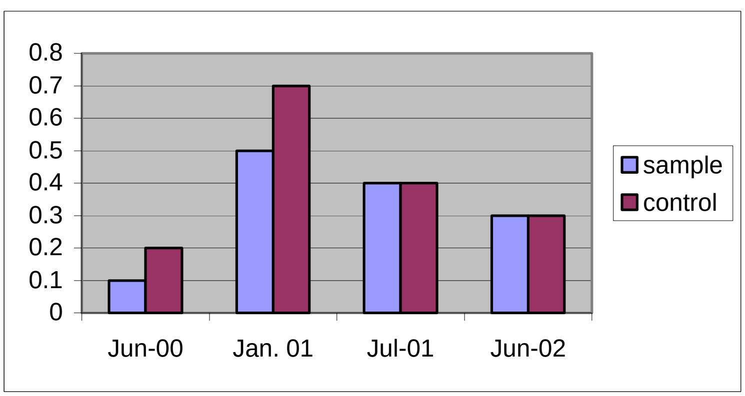

Figure 5. Sample and control topsoil electrical conductivity results for Adriansdraai (mmhos/cm)

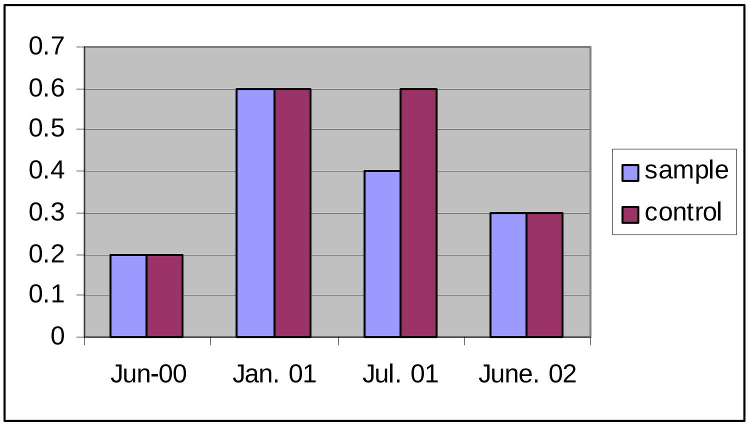

Figure 6. Sample and control subsoil electrical conductivity results for Adriansdraai (mmhos/cm)

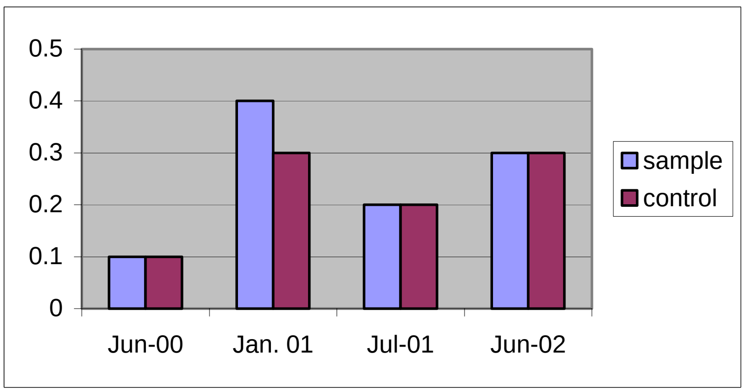

Figure 7. Sample and control topsoil electrical conductivity results for Sepitsi (mmhos/cm)

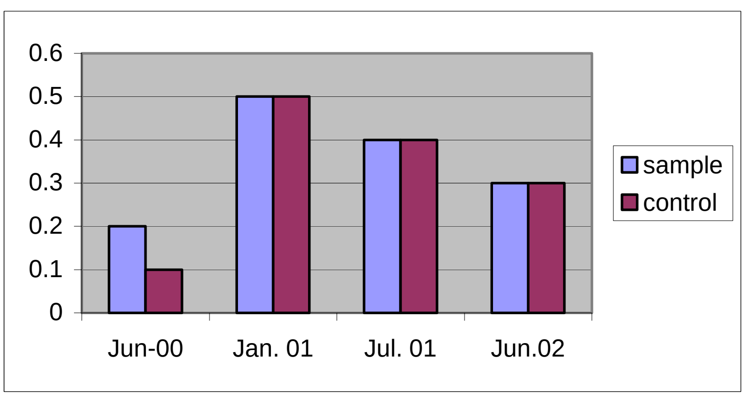

Figure 8. Sample and control subsoil electrical conductivity results for Sepitsi (mmhos/cm)

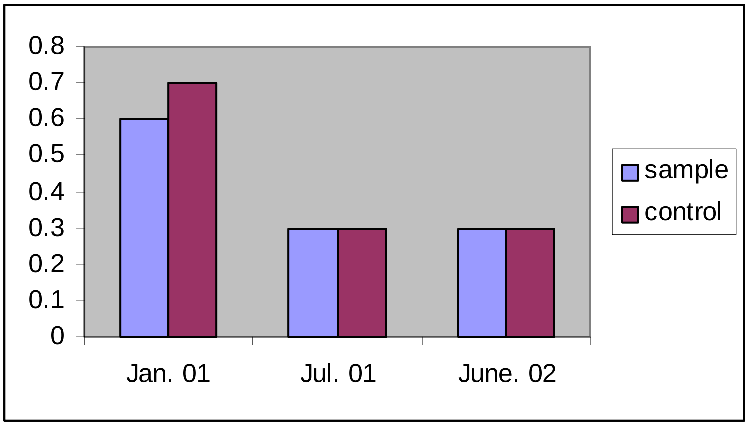

Figure 9. Sample and control topsoil electrical conductivity results for Elandskraal (mmhos/cm)

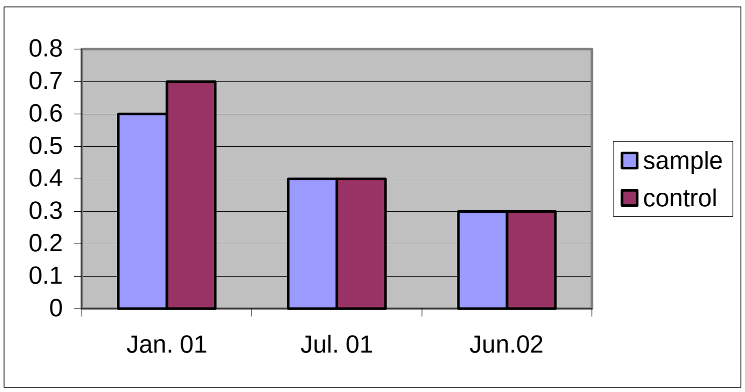

Figure 10. Sample and control subsoil electrical conductivity results for Elandskraal (mmhos/cm)

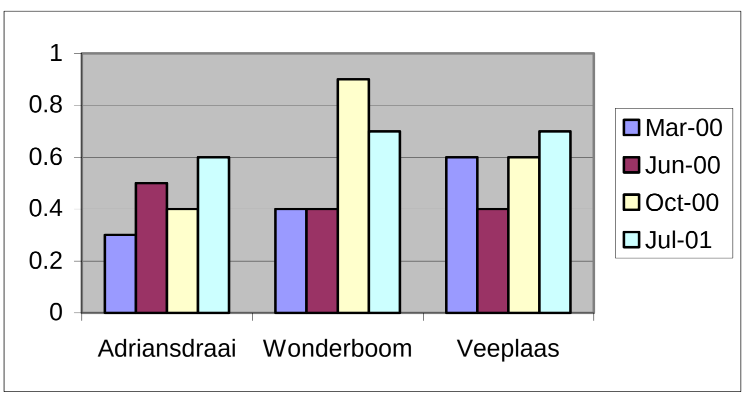

Figure 11. Water electrical conductivity results for Adriansdraai, Veeplats and Wonderboom (mmhos/cm)

Table 22. Guidelines for the determination of the salinity status (mmhos/cm)

Crop type	**Range in degree of limitation**				
	0	1	2	3	4
Low salt tolerance crops	2	2 – 3	3 – 4	4 – 6	6
Medium salt tolerance crops	0 – 4	4 – 8	8 – 12	12 – 16	16+
Tolerant crops	0 - 8	8 –12	12 – 16	16 – 20	20+
Irrigated crops					
Irrigation on coarse to medium textured soils	0 - 8	8 – 16	16 – 20	20 – 30	30+
Irrigation on fine textured soils	0 - 4	4 – 8	8 – 16	16 – 22	22+

The different levels in the degree of limitation are defined as follows:

0 = no limitations: the characteristic (quality) is optimal for plant growth.

1 = slight limitations: the characteristic is nearly optimal for the land utilization type and affects productivity for not more than 20 percent with regard to optimum yield.

2= moderate limitations: the characteristic has moderate influence on yield decrease; however, benefit can still be made and use of the land remains profitable.

3= severe limitations: the characteristic has such an influence on productivity of the land that the use becomes marginal for the considered land utilization type.

4= very severe limitations: such limitations will not only decrease the yields below the profitable level but may even totally inhibit the use of the soil for the considered land utilization type.

Salinity also affects the suitability for irrigation because the amount of water, necessary for leaching, will depend on the salt content of the soil. Table 22 suggests some guidelines for the determination of the salinity status.

The purpose of these guidelines is to provide the farmer with alternative land utilization types if salinity would cause yield reductions in certain crops. Monitoring of the salinity levels will be a requirement.

Discussion

Strydkraal and Wonderboom have the highest electrical conductivity. Amongst the five irrigation schemes, Wonderboom and Strydkraal are the oldest and contain the highest clay content both in top and subsoil horizon. But Strydkraal has the highest EC in control samples since control samples contained high clay minerals as compared to treatment sample. Wonderboom showed the highest EC in the sample probably because of continuous incorporation of inorganic fertilizer and high amount of clay with poor hydraulic conductivity. The flood irrigation where moisture is not controlled at all will dissolve and carry minerals from bottom to topsoil or vice versa.

Sepitsi, Adriansdraai and Elandskraal were established at the same time (quite recent), and, therefore, exhibit the same level of EC with control samples being above the treatment samples probably because of irrigation influencing the leaching status under irrigation while less leaching takes place under control samples. In all irrigation schemes EC values were the highest in January 2001 and the lowest in June 2002 probably as a result of heavy rains experienced in the year 2000. Possibly, high EC values as a result of salts dissolved in heavy rains in the past year. In January 2002, there was less rain but the salts were left on the soil surface. In July and June 2002, there was a decline in EC due to diminishing moisture in the soil.

Sodium adsorption ratio for irrigation water has been determined three times during the year 2000 whereas only once during 2001 with a significant decline which could be a result of low stream in the Olifants river, without additional overland runoff that supplied the stream with salts and minerals.

Conclusions

The level of salinity in the schemes has not yet reached alarming levels. With proper management there will be no harm to crop production especially if fertilizers that would neutralize the salts already in excess are applied and crops that tolerate alkalinity are introduced.

Electrical conductivity in the water samples increased as the water in the river decreased, probably as a result of salt concentration increasing with a decrease in solvent. But SAR is low due to calcium and magnesium increasing and suppressing sodium levels in the water in the 2001 water analysis results.

5.4 PRODUCTIVITY AND PROFITABILITY OF SMALLHOLDER IRRIGATION AND POTENTIAL FOR ACHIEVEMENT OF FOOD SECURITY

5.4.1 Productivity

The productivity of field crops and vegetables measured in terms of yield per hectare for the six irrigation schemes is presented in Tables 23 and 24.

Table 23. Yield of field crops from farmers' fields at the irrigation schemes

SCHEME	CROP	YIELD (Ton ha^{-1})
Elandskraal	Maize (cultivar: Pan)	2.4 - 4.2
	Wheat (cultivar: SST 822)	4.0 – 4.9
Veeplaats	Maize (cultivar: SNK 2147)	2.8
Adriansdraai	Maize (cultivar: SNK 2147)	1.6
Strydkraal	Wheat (cultivar: Inia)	3.4

Maize and wheat productivity for four irrigation schemes, Adriansdraai, Elandskraal, Strydkraal and Veeplaats, is presented in Table 23. Maize productivity ranges from 1.6 to 4.2 tons per hectare with the lowest productivity at Adriansdraai and the highest maize productivity at Elandskraal. The relatively higher maize productivity at Elandskraal may be attributed to better irrigation facilities and consistency in water application to the crops throughout the growing season. Adriansdraai recorded the lowest maize productivity levels largely attributed to the persistence breakdown of the irrigation pump and excessive leakages of the pipelines. Significantly lower application of plant nutrients was also a factor in the reduced yield at Adriansdraai. Another major reason for the lower maize productivity at Adriansdraai was crop damage caused by cutworms and stalk borers. Excessive irrigation water application was also a factor on some of the farmer's fields. The lower maize productivity levels at Veeplaats were mainly due to the inability of farmers to effectively control weeds, particularly the nutsedge and stargrass, as well as lower fertilizer application levels. The levels of maize productivity in the three irrigation schemes are lower than the potential productivity levels of six to ten tons per hectare expected from the cultivars used.

Wheat productivity in two irrigation schemes, Elandskraal and Strydkraal, ranges from 3.4 to 4.9 tons per hectare. These productivity levels are within or exceed the expected range of three to four tons per hectare. This suggests that farmers in the two irrigation schemes can successfully produce wheat provided water supply is not interrupted during the course of crop growth.

Productivity in vegetable production (beetroot, cabbage, onion, spinach, tomato and butternut) at three irrigation schemes, Elandskraal, Sepitsi and Wonderboom, is presented in Table 24.

Vegetable productivity levels are fairly satisfactory in Elandskraal and Wonderboom. However, vegetable productivity levels at Sepitsi are low and this may be attributed mainly to unreliable water supply, poor soil structure and fertility. An additional constraint to higher productivity levels in some of the vegetables, notably tomatoes, is disease that limits the production of good quality products for the market. For example, about 30 percent of the 24-ton yield of tomato at Sepitsi was considered to be of sub-standard in terms of quality. Disease and pest infestations are occasional problems at Elandskraal and Wonderboom.

The potential to increase vegetable crop productivity at Elandskraal, Wonderboom, Veeplats and Strydkraal is generally high. However, farmers need to apply appropriate management strategies (e.g. applying recommended rates of fertilizer, proper pest and disease control, etc.) and also ensure consistent water supply throughout the growing season to realize the full production potential. Some of the constraints at Sepitsi were the relatively low soil depth and, hence, the greater demand for water application, poor soil structure as well as lack of technical know-how in vegetable production.

To determine the relationship between farm size and productivity, correlation coefficients between output and land size for maize and wheat at Elandskraal were determined and found to be -0.05 and 0.05, respectively. In both cases, output and land size are weakly correlated ---- negative and positive correlation for maize and wheat, respectively. The figures, therefore, provide an inconclusive outcome regarding the relationship between farm size and output.

Table 24. Yield of vegetable crops from farmers' fields at three irrigation schemes
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SCHEME	CROP	UNIT	YIELD	
Elandskraal			Unit ha^{-1}	Tons ha^{-1}
	Cabbage	Head	40000	152.75
	Onion	Bunch	25000	38.25
	Beetroot	Bunch	34000	47.12
	Spinach	Bunch	26250	24.78
Wonderboom				
	Onion	Bunch	65000	93.47
	Beetroot	Bunch	33000	81.09
	Spinach	Bunch	22800	25.00
Sepitsi	Tomato	Crate (50 kg)	24	12.00
	Butternut	kg	23	23.00

5.4.2 Profitability

The results on profitability are grouped into two categories.

- *Enterprise Profitability*. Net Farm Income for the various crops (cabbage, onion, beetroot, tomato, butternut, pumpkin, spinach, maize, and carrots) across three irrigation schemes (Elandskraal, Sepitsi and Wonderboom) is presented. The net farm income figure is used to measure the profitability of the crops across the three irrigation schemes without taking into account the cost of irrigation water.

- *Individual Farm and Scheme Profitability*. This category includes net farm income for the main crops (maize and wheat) at Elandskraal and takes into account the cost of irrigation water.

Enterprise Profitability

Table 25 provides an indication of the profitability of the various enterprises at the three irrigation schemes (Elandskraal, Wonderboom and Sepitsi). The figures are average values for all the farmers at the three irrigation schemes and indicate that all the crops are profitable. Vegetables, particularly beetroot and pumpkins, are the most profitable. Maize is the least profitable crop. Profit figures for wheat were not included as some of the irrigation schemes did not cultivate the crop.

Table 25. Profitability of crop enterprises per hectare at Elandskraal, Sepitsi and Wonderboom

CROP	SALES(R)	TOTAL COST(R)	PROFIT(R)
Beetroot	37600	5344	32256
Butternut	24550	5454	19096
Cabbage	16674	5276	11398
Carrots	24300	3606	20694
Maize	10000	4130	5870
Pumpkin	37500	5504	31996
Spinach	24550	5178	19372
Tomato	25534	13022	12512

Individual Farm and Scheme Profitability

Data on profit from maize and wheat production at Elandskraal is provided in Table 26. The data indicate that wheat is profitable while maize is not.

Table 26. Profitability of maize and wheat production per hectare at Elandskraal

CROP	SALES(R)	TOTAL COST(R)	PROFIT(R)
Maize	2264	2977	-713
Wheat	7023	3648	3375

Tables 27 and 28 give an indication of the profitability of maize and wheat production at the farm level. With regard to maize, the majority (76.5%) of farmers are incurring losses – the largest loss is R4034 and the largest profit is R2728 per hectare. All (92.9%) but one farmer producing wheat generate profit – the largest profit is R6413 and the loss is R450 per hectare.

Assuming that the average household size at Elandskraal is five persons, the annual household subsistence level for such a household would be R15000. Plot sizes at Elandskraal are 0.7 hectare, one hectare and five hectares. The annual average profit per hectare for both maize and wheat is estimated at R2662. Thus, the total annual income from farming activities for 0.7-, one- and five-hectare farmers would be R1863, R2662 and R13310, respectively. Therefore, it may be concluded that farmers at Elandskraal cannot make a living from farming alone as their incomes from farming fall below the annual household subsistence level of R15000. Farm incomes of farmers with smaller plots (0.7 and 1 hectare) are much lower than the annual household subsistence level. The figures suggest some positive relationship between plot (farm) size and household income. Thus, the ability of farmers to generate sufficient household income from farming is related to the size of the farm (plot). The implication is that for smallholder farmers to generate sufficient household income from farming, plot (farm) size should be increased. Based on the figures above, the minimum plot (farm) size required for smallholder farmers to generate farm income equivalent to the annual household subsistence level is 5.6 hectares.

5.4.3 Household Food Security

Irrigation is considered as one of the best technologies for ensuring household food security and for sustainable rural development within Africa's large semi-arid zone. Hence, in times of increasing unemployment and household food insecurity, irrigation schemes can play a significant role in improving household food security.

The household food security situation at two irrigation schemes (Veeplaats and Sepitsi) was assessed using data collected in 1999 and the results are presented in Table 29. The results indicate that farmers owning five-hectare plots did not experience any food shortages. However, farmers owning food plots and 2.5 hectare plots experienced food shortages for 7.5 and 7.1 weeks, respectively. These results, like those outlined in section 5.4.2, suggest that the ability to achieve household food security is related to farm (plot) size.

Since farmers can achieve food security from various sources of income, it is worthwhile analyzing the sources of household income for the farmers at the irrigation schemes. This analysis will also give an indication of the role of agriculture in household food security and poverty alleviation. Tables 30 to 34 present the results of the analysis.

Table 27. Frequencies of profit per hectare for maize production at Elandskraal

Profit/ha (R)	**Cumulative Percent**
-4034.00	5.9
-2292.14	11.8
-2190.01	17.6
-1952.00	23.5
-1772.00	29.4
-1714.50	35.3
-1398.00	41.2
-936.00	47.1
-916.81	52.9
-517.75	58.8
-460.00	64.7
-456.55	70.6
-374.36	76.5
725.00	82.4
1333.04	88.2
2099.97	94.1
2728.70	100.0

Household income sources are divided into two broad categories of farm and non-farm sources. Farm income includes income derived from the sale of farm produce (no livestock income is included as the households did not have any livestock). Non-farm sources include old-age pension, remittances, wages, family business and other sources. Table 30 outlines the various household income sources and the contribution of each to total household income for the 138 households included in the survey conducted in 2000.

Table 30 indicates that farming is the greatest contributor to household income -- more than forty percent of total household income is generated from farming. Old-age pension is the second most important source of household income with a contribution of about 25 percent to

Table 28. Frequencies of profit per hectare for wheat production in Elandskraal

Profit/ha (R)	Cumulative Percent
-450.00	7.1
111.20	14.3
1140.00	21.4
2022.50	28.6
2056.00	35.7
2470.00	42.9
2882.00	50.0
4303.78	57.1
4465.80	64.3
4687.60	71.4
4968.00	78.6
5640.00	85.7
6296.00	92.9
6413.00	100.0

Table 29. Household food security situation in selected irrigation schemes (Veeplaats and Sepitsi)

	Food plot farmers (n=41)	2.5 hectare farmers (n=22)	5 hectare farmers (n=3)
Proportion of households experiencing food shortages (%)	53.7	50	0
Period over which food shortages are experienced (weeks)	7.5	7.1	0

Table 30. Sources of income and contribution to total household income

Income source	Average monthly income (R)	Contribution as % of total household income
Farming	545	41.0
Pension	329	24.8
Wages	258	19.4
Remittances	165	12.4
Family business	19	1.4
Other non-farm income	13	1.0
Total	**1329**	**100**

total household income followed by wages contributing about twenty percent to household income. This finding contradicts the results of other studies (Ardington and Lund, 1996; Carter and May, 1999) which indicate that wages, remittances and transfers are more important sources of income for rural households than farming[3]. Non-farm income sources as a category contribute more to household income than farming – about 60 percent of total household income comes from non-farm sources.

Categorizing the households into "poor" and "rich" and analyzing the contribution of the various sources of income to total household income provide some interesting results. This is done in Table 31 using the median income to divide the households into "poor" and "rich". "Rich" households include those with total household income above the median income for all households while those whose income falls below the median income are considered to be "poor".

Table 31. Sources of income and contribution to total household income for poor households (using median income for categorization)

Income source	**Average monthly income (R)**	**Contribution as % of total household income**
Farming	62	27.7
Remittances	53	23.6
Wages	52	23.1
Pension	37	16.5
Family business	19	8.2
Other non-farm income	2	0.9
Total	**225**	**100**

Table 32. Sources of income and contribution to total household income for richer households (using median income for categorization)

Income source	**Average monthly income (R)**	**Contribution as % of total household income**
Farming	745	42.9
Pension	395	22.7
Wages	344	19.8
Remittances	215	12.4
Family business	21	1.21
Other non-farm income	17	0.98
Total	**1737**	**100**

Farming is the most important source of income for "poor" rural households – contributing approximately 28 percent to total household income. Remittances (i.e. income received from members of the household employed in urban areas) and wages are the second and third most important sources of income, respectively, for poor households -- contributing just over 23

[3] The contradiction stems from the fact that the smallholder farmers included in the survey are all irrigation farmers. Therefore, they tend to devote more of their time to farming than other smallholder farmers.

percent each to total household income. These results are similar to those presented above for all households as they also indicate that non-farm sources of income contribute more to household income than farm sources. However, farming contributes more to household income than all individual non-farm sources of income.

A breakdown of income sources and their contribution to total household income for "rich" households is provided in Table 32. Although farming is the most important source of income for "rich" households, non-farm sources as a category contribute more to total household income. Table 32 also indicates that "rich" households depend more on farming for their income than "poor" households. Furthermore, pension and wages are the most important non-farm sources of income for "rich" households. These results also confirm the important role of farming as a contributor to household income. The results further indicate that the role of agriculture as a source of household income is more pronounced in the case of "rich" households than it is for "poor" households.

Table 33. Sources of income and contribution to total household income for richer households (using household subsistence level of R250 per month/person)

Income source	Average monthly income (R)	Contribution as % of total household income
Farming	1821	56.4
Wages	553	17.1
Pension	452	14.0
Remittances	359	11.1
Family business	28	0.9
Other non-farm income	18	0.6
Total	**3231**	**100**

Table 34. Sources of income and contribution to total household income for poor households (using household subsistence level of R250 per month/person)

Income source	Average monthly income (R)	Contribution as % of total household income
Pension	297	37.0
Farming	191	23.8
Wages	175	21.8
Remittances	111	13.8
Family business	17	2.1
Other non-farm income	11	1.4
Total	**802**	**100**

The households were also divided into "rich" and "poor" using the household subsistence level of R250 per adult equivalent per month. This is done in Tables 33 and 34. The results indicate that farming is the most important source of income for rich households while pension is the most important source of income for “poor” households. Farming plays a more dominant role as a source of household income for “rich” households and its contribution to household income exceeds the total contribution of all non-farm income sources combined. Non-farm sources contribute more to household income for “poor” households than farming. Except for the results indicating that pension is the most important source of income for “poor” households, the results are similar to those presented in previous sections. Even in “poor” households, farming is the second most important source of income confirming its importance as a contributor to household income.

The above analysis indicates that agriculture plays a key role in poverty alleviation and food security in rural areas. Agriculture is not only a major contributor to total household income but the contribution seems to increase as households become richer.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions and recommendations of the study according to the study objectives.

6.1 PRODUCTIVITY, PROFITABILITY AND FOOD SECURITY

6.1.1 Productivity

Agricultural productivity, expressed in yield per hectare, in the irrigation schemes included in the study is generally not satisfactory. This is especially so with crops such as maize where productivity is below the expected average for the country. However, productivity in wheat and vegetable production can be considered satisfactory but could be improved. Crop water productivity, expressed in yield per amount of water, maize is also low but improved significantly between 2002 and 2003. Crop water productivity for wheat is higher. The highest crop water productivity for both crops was obtained under centre pivot irrigation system.

There is some relationship between the quality of irrigation infrastructure and productivity. Productivity is higher in those schemes with better irrigation infrastructure. Schemes that consistently experienced problems such as irrigation pump malfunctioning achieved lower productivity levels.

6.1.2 Profitability

Most maize farmers in the irrigation schemes are not making profit from maize production. An important reason for this is that farmers receive low prices for the maize they sell. The fact that maize productivity was low also contributed to many farmers experiencing losses. Wheat and vegetable production, particularly tomato and pumpkins, generates a profit for almost all farmers. In some of the irrigation schemes (e.g. Sepitsi), the quality of vegetables was low due to pests and diseases resulting in lower profits.

6.1.3 Food Security

Farmers with larger plots were generally found to be food secure while the majority of those with smaller plots were generally found to be household food insecure. This suggests that farmers with larger plots produce enough or more food than is required for home consumption. Furthermore, this may also suggest that these farmers derive additional income from other non-agricultural sources of income.

While agriculture plays a dominant role in poverty alleviation and food security in the irrigation schemes, farming alone is not a sufficient source of household income for all farmers regardless of farm (plot) size. However, the study results suggest that those with larger plots have higher levels of household income derived from farming.

The above suggest that farmers need to be encouraged to pay more attention to the production of cash and vegetable crops to increase their profits and improve food security. This is especially important in view of the new responsibilities of farmers to pay for services such as electricity and water. Shifting to high value crops would also contribute to farmers with small plots achieving household food security provided markets and price levels for these crops are favourable. Since most of the cash crops currently grown in the schemes are classified as “medium tolerant” to salinity conditions, increasing their production should not pose a major problem. Most farmers have actually expressed interest in changing their enterprise mix to include high value vegetables, groundnuts, sugarbean and sunflower. This shift to alternative crops was, however, hampered by problems such as access to credit, information, land and irrigation water scheduling. These problems would need to be addressed for farmers to shift to the production of high value crops. In addition, further research should be conducted to determine the socio-economic and financial implications of shifting to the production of high value crops. In particular, the availability of markets and price levels for these high value crops should receive attention. The Provincial Department of Agriculture in collaboration with other stakeholders such as universities should assist in this regard.

Consideration should be given to increasing the amount of land per farmer if farming is to generate sufficient household income. However, raising the productivity of current crops and/or changing the enterprise mix as suggested above could increase household income significantly. This would require among other things paying special attention to improving the quality of irrigation infrastructure and, thus, improve the reliability of irrigation water supply. As land is a constraint in many cases, attention should also be given to creating opportunities for smallholder farmers to generate more income from nonfarm sources to augment their farm income.

6.2 CROPPING AND IRRIGATION MANAGEMENT PRACTICES FOR IMPROVED WATER PRODUTIVITY

6.2.1 Cropping Practices

The main crops cultivated in the irrigation schemes are maize, cotton, wheat and vegetables. Although farmers practice crop rotation, leguminous crops are generally not included in the crop rotation. Incorporating leguminous crops in the crop rotation would add nitrogen to the soil and this would result in increases in crop productivity and production.

6.2.2 Irrigation Management Practices

Farmers in the irrigation schemes tend to apply as much water as they can when their turn to irrigate comes. This practice often leads to the application of excessive amounts of irrigation water and is motivated by (a) the uncertainty about the availability of irrigation water; and (b) the belief that application of more irrigation water necessarily leads to increases in crop productivity and production. The application of excessive amounts of irrigation water results in low in-field water productivity. Furthermore, the same amount of irrigation water is applied regardless of plant growth stage. The above suggest that there is limited knowledge of irrigation water management and scheduling among both farmers and extension officers.

The following are recommended to address the above:

- Practical training in water management and irrigation scheduling should be provided to both farmers and extension officers to address the problem of low water productivity. Such training could take the form of farmers' days for farmers. Training for extension officers could include short courses and specially designed diploma courses offered at universities.

- Farmers should be encouraged to include leguminous crops in their crop rotation system and be provided with appropriate information on leguminous crops that fit their rotation system. Farmers' days have already been presented at the irrigation schemes by the research team to demonstrate the advantages of including leguminous crops in their crop rotation system. However, indications are that farmers have not yet included leguminous crops in their cropping plans. The reasons for this seem to be related to the limited awareness of the advantages and importance of including legumes in the cropping system. Therefore, the research team needs to return to the irrigation schemes to provide more information on leguminous crops and also investigate other factors which might be responsible for farmers not to include leguminous crops in their cropping plans despite information provided to them during farmers' days. In addition, organizations such as the Agricultural Research Council should be brought on board.

- Special attention needs to be given to the elimination or alleviation of problems leading to unreliable supply of irrigation water. The savings clubs that have emerged in some of the irrigation schemes could play a significant role in solving the above problems. In addition, capacity building of farmers to repair irrigation equipment should be implemented.

6.3 EFFECTS OF IRRIGATION PRACTICES ON SOIL SALINITY LEVELS

Salinity levels at all the schemes are within acceptable levels (below 4mmhos/cm). Water quality is also within acceptable levels and does not pose any danger of blocking irrigation sprinklers. The above suggest that, at this stage, measures need to be put in place to avoid any deterioration in salinity and water quality levels.

The following are recommended:

- A programme to monitor soil salinity levels should be drawn up with full participation of the farmers. Such a programme should include training farmers to take soil samples for analysis.

- Information on the tolerance of different crops to salinity should be provided to farmers to assist them to make decisions on what crops to grow in future depending on salinity levels in the soil.

- The research team should draw up guidelines on irrigation practices and provide farmers with a table indicating the various crops that can be grown in the schemes together with their salinity tolerance levels.

6.4 SELF-MANAGEMENT OF IRRIGATION SCHEMES AND EMPOWERMENT OF FARMERS FOR POVERTY ALLEVIATION

The transfer of irrigation management to farmers is based on the belief that the transfer will result in better management of the irrigation schemes and, thus, enable farmers to enjoy a higher standard of living than before the transfer. The irrigation schemes in the former homeland areas have been supported and run by the government with little farmer participation in the management of the schemes. A dependency syndrome has, thus, developed among smallholder irrigation farmers. Furthermore, the irrigation schemes were designed and constructed as if they were to be operated by individual commercial farmers. However, most of the farmers in the irrigation schemes are not commercially oriented and the quality of infrastructure in most of these schemes has deteriorated. The above scenario suggests that a number of challenges will have to be addressed for irrigation management transfer to result in true empowerment of the farmers and, thus, contribute to poverty alleviation.

The following options need to be considered:

- Since the irrigation schemes are being rehabilitated, the Provincial Department of Agriculture should ensure that farmers are actively involved in the process to adapt the schemes to their irrigation needs.
- Capacity building through training and provision of appropriate farmer support services is needed to transform smallholder irrigation farmers to commercial farmers. Key stakeholders such as DWAF, National Department of Agriculture, Provincial Department of Agriculture, Local Government, Irrigation Committees and WUA will need to work together to ensure that irrigation management transfer leads to genuine empowerment of farmers. The formation of a Coordinating Committee at the national level (Coordinating Committee on Small-scale Irrigation Support) involving government departments involved in the delivery of infrastructure and services to the rural poor is an encouraging development.

6.5 ACCESS TO SUPPORT SERVICES AND FARMER ASPIRATIONS

Smallholder irrigation schemes were dependent on government and parastatals for support services. The withdrawal of government and parastatals from the provision of these services has made it difficult for farmers to access the services and resulted in a breakdown of activities (e.g. some farmers have stopped cultivating their land or cultivate only a portion thereof).

6.5.1 Credit

Despite measures that have been taken to improve access to credit for smallholder farmers (e.g. transformation of the Land Bank and reorientation of its services to address smallholder farmers' credit needs), many smallholder farmers in the irrigation schemes have no access to credit. Some of the reasons for lack of access to credit include the current land tenure arrangements, lack of information on where to access credit, fear of failing to repay loans and inaccessibility of credit organizations due to long travel distances.

With government and parastatal withdrawal from support service provision, savings clubs are becoming increasingly important in the irrigation schemes. Some farmers have formed savings groups to save money for purchasing and repairing irrigation equipment.

6.5.2 Information

Farmers in the irrigation schemes have limited access to important information relating to production, sources of credit and markets. Extension agents remain the major source of information to smallholder irrigation farmers on production, processing and marketing aspects. However, the extension agents themselves do not seem knowledgeable enough to provide sufficient and good quality information needed by the farmers.

6.5.3 Appropriate Technology

Access to information on appropriate production technology remains a major problem in the irrigation schemes. Many farmers are not aware of both the technology and the organizations involved in technology development and dissemination.

6.5.4 Training

There are limited opportunities for training for farmers in the irrigation schemes. Extension agents are the main provider of training to farmers. The remoteness of the areas where farmers are located, lack of funds for training purposes and the inability of farmers to use written information due to low levels of education are some of the major problems.

6.5.5 Aspirations

This section considers the issue of whether there is interest among smallholder farmers or rural people to farm. Our observation from some of the irrigation schemes leads to the conclusion that, given access to support services and well-functioning irrigation schemes providing reliable supply of irrigation, smallholder farmers and rural people are keen to farm. In well-functioning irrigation, it is unlikely that land will be left idle and farmer absenteeism is rare.

Makuleleke Irrigation Scheme was designed to accommodate 27 farmers on five-hectare plots. However, 52 farmers were eventually settled on these plots to produce cash crops, vegetables and fruits. At Boschkloof Irrigation Scheme, after the implementation of the rehabilitation programme, the number of farmers increased from the original 36 to 380 and this has resulted in problems of over-irrigation. There are indications that some of the people who were working in urban areas have returned to their rural villages to take advantage of better farming opportunities which arose after the implementation of the rehabilitation programme.

The following are recommended to address problems related to access to support services:

- Capacity building for extension agents to become effective sources of information on aspects such production and marketing should be provided. The Provincial Department of Agriculture together with training organizations such as the University of the North should play a key role in this regard.
- Workshops aimed at sharing information with farmers on credit sources and types of credit available, available technologies and where these may be obtained, and markets for both output and inputs should be held as soon as possible. Representatives from relevant organizations (e.g. Land Bank, Agricultural Research Council, Provincial Department of Agriculture, University of the North, etc.) should participate in such workshops. The Research Team and Provincial Department of Agriculture should take the lead in arranging such workshops.
- Savings groups that have been formed in the irrigation schemes should be strengthened. Relevant financial organizations (private, parastatals, and NGOs) should be identified and requested to provide the necessary training and information to strengthen the capacity of the savings groups. Both the Provincial Department of Agriculture and the Research Team should assist in this regard.

6.6 ORGANIZATIONAL DESIGNS THAT ENSURE A REASONABLE AMOUNT OF EQUITY AMONG STAKEHOLDERS

The smallholder irrigation schemes included in the study are currently managed by irrigation/steering committees. The committees are comprised of men and this does not auger well for meeting equity considerations given that most of the farmers in the irrigation schemes are women. This arrangement could lead to inequitable distribution of water. Furthermore, the extension service which facilitates the implementation of extension programmes, including irrigation, is mostly staffed by men and often provide extension advice to their male counterparts who may not necessarily share it with women farmers.

The process leading to the establishment of WUAs and CMAs is flawed in many ways. This raises concerns about the involvement of disadvantaged groups including women and the prospects of these organizations meeting the water needs of such groups. Some of the shortcomings identified in the process of establishing WUAs and CMAs include:

- The process is driven by a few individuals with limited involvement of the disadvantaged groups.
- The local government has a limited role in the process.
- There has been limited coordination and communication between the key stakeholders.

In ensuring equity in smallholder irrigation, the following are recommended:

- In the process of the rehabilitation of the smallholder irrigation schemes, the Provincial Department of Agriculture and DWAF need to ensure the participation of beneficiaries to ensure that their irrigation needs are taken into account, possibly adapting schemes to meet the irrigation needs of smallholder farmers.

- Through educational campaigns and workshops, the Provincial Department of Agriculture, local government and DWAF should inform farmers about their roles and responsibilities in maintenance and operation of the schemes once IMT takes place.

- The process of establishing WUAs must be transparent and involve all stakeholders who have a stake in water use and management. DWAF should ensure that public awareness and public education/dialogue take place. WUAs must recognize the irrigation rights of the community as a whole. The disadvantaged groups must feel that there are advantages to being a member of a WUA.

- DWAF and local government in collaboration with the Coordinating Committee on Small-scale Irrigation Support should ensure that WUAs have the capacity to mobilize adequate resources to meet the costs of operation and maintenance of irrigation infrastructure. This arrangement could lead to equitable distribution of water.

- Above all, the composition of WUAs and CMAs should take into account gender representation to increase the membership of women.

- The extension officers working in the irrigation schemes should be assisted to be more gender sensitive. This can be achieved through gender sensitive training organized by the Provincial Department of Agriculture in partnership with universities and the private sector.

- Civil society representation on the Coordinating Committee on Small-Scale Irrigation Support should include women to ensure targeting of women in the provision of assistance.

6.7 SYNTHESIS

The main goal of this study was to contribute to poverty alleviation in smallholder irrigation in Limpopo Province. This was to be achieved mainly by improving crop productivity, profitability, gender equity and environmental sustainability. Although not explicitly stated in the original overall goal of the study, contributing to the achievement of household food security was an important goal of the study. Improving crop productivity and profitability was the main vehicle through which household food security could be achieved.

A number of interrelated activities need to be undertaken to improve crop productivity and profitability. These are discussed under the following topics: crop production and productivity; cropping and irrigation management practices; social organizations and access to support services; and empowerment of smallholder farmers through irrigation management transfer. The discussion also touches on issues of gender and environmental sustainability.

Crop Production and Productivity

Increasing crop production and productivity at the farm level should form an important part of any efforts to improve profitability, household food security and poverty alleviation. However, such efforts should promote environmental sustainability. The results of this study indicate that production and productivity levels in field crops such as maize and wheat are low. This suggests that, if appropriate steps can be taken to address the factors responsible for the low production and productivity levels, significant improvements can be achieved in the production and productivity of these crops. Such steps might include helping farmers to improve crop production practices involving the adoption of improved production technologies, application of sufficient levels of fertilizer, and acquiring improved farming skills. As regards vegetable crops, production and productivity levels are considered to be satisfactory suggesting that there is room for improvement. While raising the production and productivity of vegetables should be pursued to increase their contribution to food security and poverty alleviation, it seems that more attention needs to be given to non-production aspects such as marketing. Vegetable production in the irrigation schemes included in the study is more profitable than field crop production. However, access to good markets offering good product prices appears to be a major problem.

Cropping and Irrigation Management Practices

Ensuring that farmers select the appropriate combinations of crops could contribute to increased production and productivity. For example, the study results show that farmers do not include leguminous crops in their crop rotation which would raise the level of nitrogen in the soil. Furthermore, including cash crops in the production plans would improve the financial position of farmers.

There are indications that the irrigation practices used in the irrigation schemes may result in low water productivity. Some of these practices (e.g. applying as much water as possible while irrigation water is still available) are adopted to deal with problems of unreliable irrigation water supply. In addition, such practices do not promote environmental sustainability as problems of salinity which currently do not exist may occur. Therefore, training farmers in irrigation management practices and ensuring a reliable supply of irrigation water should receive attention.

Social Organizations and Access to Support Services

Lack of access to appropriate farmer support services is one of the major constraints to improved crop production and productivity in South Africa. Therefore, little will be achieved in terms of improving household food security and poverty alleviation unless the problem of lack of access to farmer support services is adequately addressed. While farmers themselves can do much to address the problem, government involvement remains crucial if the problem is to be resolved. The results of the study indicate that smallholder irrigation farmers experience serious problems in accessing support services such as marketing, credit and extension. These problems have been exacerbated by the withdrawal of government and parastatals from the provision of support services.

The withdrawal of government from management of irrigation schemes left a big gap in the provision of support services. The dependency on the government did harm to the smallholder farmers by not making skills available and strengthening existing informal organizations. However, smallholder farmers in the irrigation schemes studied have started forming saving groups to assist each other with production loans. These efforts need to be supported by the government. The establishment of cooperatives and/or farmers' associations has also received attention in some irrigation schemes.

WUAs that have been established in the irrigation schemes need to be strengthened so that they may play a meaningful role in the provision of support services. A well structured WUA or farmers' cooperative would be able to organize for inputs, credit, markets and other support services required to increase productivity. A well-functioning WUA can also contribute to empowerment by ensuring that smallholder irrigation farmers produce quality products. This can be achieved through (a) proper management of farming operations, and (b) ensuring proper management of the irrigation scheme, including provision of irrigation water and technical and other support services by coordinating the activities of service providers.

Organizational structures that are established in the irrigation schemes are required to be representative of all the stakeholders involved in smallholder irrigation. While government policy is well designed in terms of process and outcome to ensure equity, what is implemented on the ground can hardly achieve the desired policy outcomes. What should be done to ensure that the desired policy outcomes are achieved is described exhaustively in section 6.6 of the report. One of the major weaknesses is in the monitoring of policy implementation.

Current efforts in the revitalization of smallholder irrigation schemes in Limpopo Province include the building of partnerships between the government and private sector and the undertaking of joint ventures to address issues of market access and credit. At policy level, the establishment of farm equity schemes is being pursued. As these efforts include capacity building and/or training of smallholder farmers, they are likely to impact positively on access to farmer support services.

Empowerment and Irrigation Management Transfer

Irrigation management transfer is meant to transfer the management and ownership of irrigation schemes to farmers. This process should ultimately result in improvement in the livelihood of smallholder irrigation farmers. Therefore, an important question to ask is "Will irrigation management transfer in Limpopo Province enhance the livelihood of smallholder farmers?" In other words, are smallholder farmers better of *with* than *without* irrigation management transfer? These questions cannot be adequately addressed in the case of Limpopo Province because the irrigation management process is ongoing. Therefore, the focus here is on what needs to be done to achieve success in the implementation of revitalization and irrigation management transfer of smallholder irrigation schemes. The question being asked is "To what extent have the conditions for successful irrigation management transfer been achieved in Limpopo Province?"

Irrigation management transfer before irrigation schemes are at a stage where productivity and income have improved to enable smallholder farmers to derive decent livelihoods is unlikely to be successful. Therefore, government policy should give priority to the following:

- adoption of improved farming practices;
- strengthening access to markets and credit; and
- reforming irrigation management agencies and strategies.

The government has developed a framework through which empowerment and irrigation management transfer can take place. For example, a favourable environment has been created for public-private partnerships to develop. The Agricultural Research Council has been restructured to address smallholder farmers' technological needs, financial organizations such as the Land Bank are being transformed to make loans available to smallholder farmers, and the National Water Act is being implemented to ensure that WUAs that are established are equitable.

The implementation of existing policies needs to be monitored through the development of monitoring mechanisms on the ground. Based on the results of this study and observations, including international experience, irrigation management transfer will make sense when productivity and income from smallholder irrigation farmers enable them to derive a decent livelihood and irrigation schemes are considered profitable. Productivity and profitability will occur if farming practices are improved through high value crops accompanied by improved access to support services. Irrigation management agencies will also need to be reformed.

Improving farming practices should entail the following:

- introduction of high value crops;
- improving extension and technical services;
- adoption of appropriate smallholder technologies; and
- land tenure reforms.

The crops being produced in the schemes are wheat, vegetables, maize and cotton. Farmers have requested information on new cash crops such as sunflower, groundnuts and beans. Some high value crops are already being produced and plans are underway to introduce others through joint ventures.

The level of provision of extension services and technical support needs to be improved. There are ongoing efforts to introduce an appropriate extension model for South Africa.

Appropriate smallholder technologies are yet to be developed. This will be possible when the ARC has a thorough understanding of the smallholder irrigation context. Some efforts have been made to restructure the ARC to focus on smallholder irrigation.

Although farmers seem to be satisfied with the current land tenure arrangements, there are certain limitations to PTO which need to be addressed at the policy level.

Strengthening access to markets and credit should entail:

- forming partnerships with the private sector;
- establishment of cooperatives/farmers' associations; and
- establishment of farm equity schemes.

Joint ventures are being negotiated with the private sector but little progress has been made. There are also limited achievements in developing farm equity schemes and the establishment of farmers' organizations. Where farmers' organizations have been established, they are still weak. Marketing problems are experienced in almost all the schemes. The Land Bank's services have been reoriented to serve the needs of smallholder farmers but access to credit is still a major problem.

Reforming irrigation management agencies and strategies should entail the following:

WUAs have been formed or are in the process of being formed in the irrigation schemes. None of the schemes has a registered WUA or a certificate of registration. In most cases, the functions of WUAs are limited to irrigation-related issues and are not diversified to address marketing, credit, input supply, training/support services, etc.

From the above, it may be concluded that significant progress has been achieved towards meeting the conditions for successful irrigation management transfer. However, a lot remains to be done for conditions to be conducive to increased productivity and income, and true economic empowerment for smallholder irrigation farmers.

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APPENDIX ONE

ESTABLISHMENT OF EXPERIMENTAL TRIALS TO ADDRESS PRODUCTION CONSTRAINTS

A number of production constraints were identified at the irrigation schemes through problem analysis. The constraints are described below for each scheme. Experiments were designed in order to find ways of addressing the identified constraints.

Veeplaats

Maize is the dominant crop followed by wheat. Cotton is considered to be an occasional crop grown primarily on experimental basis for income generation. However, due to the unfavourable experience with cotton, primarily from low yields and profitability, the farmers were not considering this crop in subsequent years. There are plans to introduce groundnut and sugarbean in the cropping system. The current cropping system is dominated by summer maize production and winter wheat in rotation with no leguminous species as part of the system.

Soil Preparation

Tariffs on use of tillage implements have increased by as much as 25% relative to the previous year. Farmers were therefore concerned that this might be too expensive for profitable field crop production. Thus, the need to develop affordable land preparation options for the farmers is eminent.

Crop choice

Farmers were unaware of potentially adapted field crops under the prevailing environmental (climatic and soil) conditions at Veeplaats and will be very grateful if this information is available to enable them to make choices in future. Identification of alternative crops of high economic returns will be essential to diffuse the cereal-cereal rotation. Legumes in particular will be attractive in this situation due to their ability to convert atmospherically inert nitrogen to plant usable forms in the soil.

Soil Testing

Farmers were eager to know the status and potential of their soils through proper laboratory analysis. According to the farmers, soil samples have been collected in the past but no results had ever been presented to them. It is important that any future analysis be effectively communicated and clearly explained to the farmers.

Salinity

The problem of soil salinity through visual observations on production sites was mentioned by some of the farmers as a potential constraint to productivity

Weeds

Two main weeds were cited as problematic on some farmers' fields: nutsedge (*Cyperus rotundus*) known as *Lekankane* in Sotho language, and stargrass. The nutsedge is reported as being a severe yield depressant since it is almost impossible to control. The herbicide, Servion, is an effective control of nutsedge. The stargrass is an invasive weed which was initially introduced on a nearby pastureland as livestock feed. The grass could be controlled by herbicide and physical removal through raking. The weed is only problematic on selected fields in the scheme and not widespread.

Fertilization and seeding rate

Optimum fertilization rates for the crops grown are not known. The current practice is the blanket application of 3:2:0 or 3:2:3 compound fertilizer followed by LAN topdress. Whether these nitrogen and phosphorous application rates are adequate or not was not known. Farmers want to obtain some recommendations on rates of inorganic fertilizer applications for the various field crops required for maximum growth rates and seed yields in the scheme.

Farmers also indicated the desire to know about the optimum seeding rates for their crops. Seeding rates are currently based on general recommendations derived from commercial farming enterprises elsewhere rather than on any research findings within their environment.

Both inorganic fertilization and seeding rates in addition to water are paramount yield determinants in crop production and therefore need to be critically assessed, if production and profitability of the dominant crops are to be improved.

Waterlogging

The uneven nature of the soil surface on farmers' plots, leakage from irrigation pipes and probably excessive water application result in severe and frequent waterlogging on some parts of the field. Farmers are anxious to know the effect of waterlogging on crop growth and yield.

Other problems

Farmers identified insufficient funds to repair broken pumps and irrigation pipelines as a problem. Availability of water per se is not considered to be a problem. The rate of water application appears to be on once daily to once in three days basis depending on availability of electricity to pump the water. These rates of application appear to be excessive for crop production. Such application rates not only exert considerable pressure on the irrigation pumps and hence frequent breakdowns, but may also result in accelerated leaching of mobile nutrients in the soil and possibly enhance salt problems on the production field, all leading to soil degradation.

Marketing of agricultural produce was cited as a major problem in the enterprise of this scheme. Seed companies sometimes travel to the scheme to purchase the produce but farmers are not satisfied with this procedure since they do not have the ability to negotiate the price.

The above is the major information generated during the several visits to the Veeplaats irrigation scheme. The information is also applicable to two other irrigation schemes specializing in field crop production in the Olifants river basin, namely, Andriansdraai and Strydkraal.

Adriansdraai

Maize is the dominant summer crop though cotton also has a potential in this scheme due to a more favourable experience with the crop compared to Veeplaats. Wheat continues to be the major winter crop. Farmers expressed high interest in producing sugarbean as an alternate summer crop. Some farmers are already producing sugarbean. The current cropping system is dominated by summer maize production and winter wheat in rotation or cotton-wheat rotation.

The production problems are similar to those encountered at Veeplaats.

The farmers in this scheme occasionally experience pump breakdown but may not be as severe as at Veeplaats. The rate of water application is once a week for three hours per application. The marketing of agricultural produce was cited as a major problem at the scheme.

Elandskraal

The Elandskraal irrigation scheme consists of three groups of farmers, 5ha, 1.0ha and 0.5 ha or less farmers. The 1 and 5 ha farmers focus mainly on field crops whereas the farmers with 0.5 or less hectares are involved in vegetable production. The field crop farmers face similar challenges as the those encountered at Veeplaats and Adriansdraai in terms of crop choice, land preparation, soil fertility and fertilizer recommendations, planting density and weed control. The farmers are however satisfied with their irrigation systems and marketing arrangements.

The major constraints cited by vegetable farmers include: information on appropriate cultural practices on production, soil fertility recommendations, diseases and pest control and marketing. The vegetable produce is mainly sold locally within the community but farmers are willing to explore other markets, which could bring higher income.

Strydkraal

Maize and groundnuts were cited as the dominant crops and following a meeting with farmers and extension personnel working in the scheme, the desire to continue with the production of these two crops was emphasized. It is unclear whether these two crops are produced in rotation or as sole culture on different sites on farmers' fields. Winter wheat is the crop selected for production in the winter season.

The production problems are similar to those encountered at Veeplaats and Andriansdraai.

The pump is currently broken which has inevitably halted all production activities. The rate of water application according the extension personnel is on daily basis as per recommendation in the 1980s under the ARDC programme and farmers are not willing to compromise unless proven otherwise. Again this rate appears to be excessive and research interventions are required to justify or modify this.

The marketing of agricultural products was cited as a major problem. Currently, the marketing of grain crops per se is not a constraint as several grain crops are purchased by grain milling companies. The problem is selling the produce at a price which is reasonable to the farmers. The grain supply needs of Progress Milling Company cannot be met from production in Limpopo Province and, therefore, the company has to import grains from other provinces, mainly Northwest and Free State. The company is, however, committed to purchasing grains from farmers in Limpopo Province at satisfactory prices in an attempt to boost the local economy.

Sepitsi and Wonderboom

The main activity at Sepitsi and Wonderboom irrigation schemes is vegetable production, though small amounts of maize and cowpea are produced at Wonderboom. The major constraints cited by the vegetable farmers include: information on appropriate cultural practices in production, soil fertility recommendations, disease and pest control and marketing. Poor soil organic matter and low retention of moisture in the soil for a significant period of time in particular were also identified to be a major constraint at Sepitsi. The vegetable produce is mainly sold locally within the community but the farmers are willing to explore other markets which bring higher income.

Based on the general information gathered from the visits and interaction with farmers, it was decided to do a soil analysis and establish a number of experiments to address the identified constraints in the schemes.

Soil analysis at the schemes

Table A1. Soil analysis at Elandskraal

Particulars of Samples	**Wheat experiment**	**Farmer**			
		Farmer 1	Farmer 2	Farmer 3	Farmer 4
PH	7.10	7.10	7.15	6.67	7.06
Resistance (Ohms)	688	565	605	446	612
Miligram/kg					
N	4	10	7	10	14
P	68	32	55	34	52
K	253	240	130	350	300
Ca	1240	1130	1870	2670	1170
Mg	468	430	580	950	450
Na	70	93	103	120	73
Cl	20	24	18	21	10
Zn	7.40	3.68	5.08	3.80	2.80
S - SO4	13	17	16	16	12
*S value	11.021	10.223	14.925	22.620	10.656
Ca %	56.3	55.3	62.6	59.0	54.9
Mg %	35.1	34.8	32.1	34.7	34.9
K %	5.9	6.0	2.2	4.0	7.2
Na %	2.8	4.0	3.0	2.3	3.0
Organic C%	0.77	0.62	0.72	1.62	0.61

Soil pH readings are close to neutral (7.0), which is good for crop production. At these pH values, most nutrients are readily released from the soil for crop use.

The levels of soil nitrogen from the experimental plot and those of the different farmers ranged from 4 to 14 mg kg^{-1}. These values are very low and require additional inputs of nitrogen fertilization. Minimum amounts of about 25 to 30 mg kg^{-1} are required to produce yields of about 3 tons per hectare, provided other factors are not limiting. An amount of 14 mg kg^{-1} is equivalent to about 56 kg N ha^{-1}, which will give a yield of less than 1.0 ton per hectare in this soil with low organic matter content (Table A1).

Phosphorous and potassium are in adequate amounts in the soil to support satisfactory yields of maize and wheat. Phosphorous levels of 0 to 12 mg kg^{-1} are considered to be deficient, 12 to 24 mg kg^{-1} is minimal, and amounts of 25 mg kg^{-1} or just above are considered ideal as plants will not respond to any added P fertilizers. The minimum amount of phosphorous for maize production is about 20 to 25 mg kg^{-1}. Since all the P levels at this irrigation scheme are above 30 mg kg^{-1}, addition of phosphate fertilizer on the farmers' fields will only contribute to the amount of phosphorus existing in the soil, which could be utilized in subsequent cropping. It should be noted that phosphate toxicity could occur when the concentration in the soil exceeds 90 mg kg^{-1} (Table A1).

Potassium is non-limiting in the soil at this scheme and therefore no K fertilizer, whether straight or compound should be applied. A minimum amount of 80 mg kg^{-1} potassium is required for crop growth and development.

The levels of calcium, magnesium and zinc are high in the soil. An ideal Ca% level should be 60 or more and that of Magnesium about 25 or less. A Ca:Mg % ratio of about 2.5:1.0 is ideal. Calcium percentage should always be higher than Magnesium percentage. The ratio in the scheme is fairly good (Table A1).

Table A2. Soil analysis at Sepitsi

Particulars of Samples	Farmer 1	Farmer 2
PH	6.89	7.35
Resistance (ohms)	618	2000
Miligram/kg		
N	8	4
P	31	27
K	88	105
Ca	460	568
Mg	143	170
Na	70	23
Cl	57	1
Zn	3.12	2.36
S - SO4	25	6
*S value	4.012	4.614
Ca %	57.3	61.5
Mg %	29.5	30.4
K %	5.6	5.8
Na %	7.6	2.2
Organic C%	0.55	0.47

Resistance gives an indication of salinity problems. Low resistance implies potential salinity problems. Minimum resistance levels should be about 300 Ohms.

Organic carbon (matter) levels are low in the soil. This could be built up by the incorporation of significant amounts of crop residue (grasses and legumes) into the soils.

Similar to Elandskraal, the soil pH levels at Sepitsi are satisfactory as they are close to neutral. Nitrogen levels are very low whereas levels of phosphorous and potassium are just adequate. Continuous cultivation of crops without P and K application will quickly result in deficiency of the nutrients. Calcium and magnesium levels are adequate and the ratio of Ca and Mg % is ideal. Organic matter is however low in the soil and needs to be built up (Table A2).

Table A3. Soil analysis at Wonderboom

Particulars of samples	**Farmer 1**	**Farmer 2**
pH	7.47	7.67
Resistance (ohms)	759	435
Miligram/kilo gram		
N	10	11
P	96	52
K	153	188
Ca	985	1990
Mg	345	620
Na	40	173
Cl	5	43
Zn	3.76	4.40
S - SO4	9	32
*S value	8.342	16.308
Ca %	59.0	61.0
Mg %	34.2	31.4
K %	4.7	3.0
Na %	2.1	4.6
Organic C%	0.62	0.86

Table A4. Total soil pH and nutrient content during 1999/2000 growing season for Adriansdraai and Veeplaats

Location	**Depth**	**PH$_{(H20)}$**	**PH$_{(KCl)}$**	**Total N**	**P**	**K**
	Cm			**…………mg kg^{-1}…………..**		
Adriaansdraai	00-15	7.2	6.4	15.0	18.5	188.3
	15-30	7.4	6.5	20.0	25.9	99.5
Veeplaats	00-15	6.6	6.5	19.5	22.8	195.3
	15-30	7.0	6.6	20.0	25.9	103.5

The pH level of the soil at Wonderboom is slightly basic but close to neutral. Like all the other schemes, the level of nitrogen is very low and hence, nitrogen fertilization is essential to increase productivity. This could be obtained from inorganic fertilizers, poultry and livestock manure or legume green manure. The phosphorous and potassium levels are very high and no fertilization is required. Calcium and magnesium levels are also high and the ratio of Ca and Mg % is relatively good (Table A3).

Similar to the other schemes, soil pH at Adriansdraai and Veeplaats is close to neutral and suitable for crop production. Soil nitrogen is slightly higher than at the other schemes but is still low and requires N fertilization. Phosphorous fertilization is also required as the soil is low in P. There is no need for potassium fertilizer application (Table A4).

Specific Research Trials

(a) Growth and grain yield response of maize(Zea mays) to nitrogen and water at Veeplaats and Adriansdraai

Introduction

Maize (*Zea mays*) is a cereal crop, widely grown by smallholder farmers in South Africa and other developing countries of the world. In the Limpopo Province, maize is a staple crop and a livestock feed among rural communities. Despite its dominance among cultivated crops and its paramount importance, maize grain yields are still variable and generally low on smallholder farmers' fields. Major causes of low productivity are specifically water and nitrogen limitations. Water availability in the irrigation schemes is a severe constraint to productivity since these schemes lack flexibility to allow farmers to water at will. Water is usually available only at set times in a given area as water is passed systematically through the whole scheme. Farmers tend to over-irrigate when they have access to the water as evidenced by severe runoff during irrigation. Despite access to some amounts of water, crop productivity is still remarkably low in the smallholder irrigation schemes. This suggests other production factors in addition to water as yield-limiting constraints in the schemes.

Apart from water, agricultural soils in the province are low in nitrogen and phosphorous which constitute a serious constraint to crop production. Efficient management of both water and nitrogen will not only improve grain yield but also enhance the fertility status of the soil. The main objectives of this research were to determine optimum nitrogen fertilizer levels under two irrigation levels and assess the impact of reduced irrigation on maize growth, grain yields and components in smallholder irrigation system.

Objective

To determine optimum nitrogen fertilizer application level for maize dry matter accumulation and grain yield under varying irrigation levels in smallholder irrigation schemes.

Materials and methods

Field studies were conducted during 1999/2000 cropping season at Adriansdraai and Veeplaats irrigation schemes in the Olifants river basin in the Limpopo Province. the trials were conducted on farmers' fields with full participation of the farmers from experimental set until harvest. Prior to planting, soil samples were taken from 0-15 cm and 15-30 cm depths within each block and analysed for pH, nitrogen, phosphorus, and potassium. The initial soil analysis indicated the following: pH (water) of 7.40, and 18.70 mg kg^{-1} phosphorous and non-limiting levels of potassium at Adriansdraai. Maize variety, SNK 2147 was planted on 11 November and 6 December 1999 at Adriansdraai and Veeplaats respectively in a split plot arrangement with four replications at each location. The main plot treatment consisted of two irrigation levels: full irrigation (12mm per application) and half level (6mm per application). Phosphorous was applied at 30 kg P ha-1 to all plots at planting.

Irrigation water application occurred once a week for three hours for both full and half irrigation. However, at Adriansdraai, almost four weeks elapsed during the early grain filling stage and two weeks in the vegetative stage where no water was applied due to break down of the pump. Two rain gauges were placed in a block at each location and average gross amounts of water applied to the fields were determined. Under full irrigation, plants were watered for four hours releasing an average of 12 mm of water and then for two hours for half irrigation treatment at 6 mm per application. The total amount of irrigation water applied throughout the experiment at Adriansdraai including preplant application was 192mm and 96mm for the fully and half irrigated plants, respectively.

At Veeplaats, the total amount of water applied to the plots was 240mm for full application and 120mm for half application. The subplot treatment consisted of nitrogen fertilizer application at four levels, 0, 50, 100, 150 Kg N ha^{-1}. Each experimental unit consisted of 8 rows of 8m length at inter row spacing of 90 cm. Plant population was maintained at 45000 plants per hectare, the recommended density for irrigated maize. Dry matter samples were taken thrice during the growing season at 56, 78 and 146 days after planting (DAP) as an assessment of crop growth. At harvest maturity, plants from a 25-m2 area in the middle rows of each experimental unit were harvested to determine grain yield.

Results and Discussion

<u>Grain Yield at Adriansdraai</u>

Maize grain yield was not influenced by the amount of irrigation water applied at Adriansdraai and the interaction with nitrogen fertilizer was also non significant. Thus, average grain yields across nitrogen fertilizer were similar for fully and half irrigated crops. Considering the influence of nitrogen fertilizer, highly significant differences were observed in grain yields irrespective of water application. The yield range was 2.43 to 3.30 tons ha-1 under full irrigation and 2.58 to 3.62 under half irrigation (Table A5). From the levels of nitrogen fertilizers applied in this study, the peak grain yield of 3.62 tons ha^{-1} was obtained at 100 kg N ha^{-1} nitrogen fertilizer application under full irrigation but when plants received half of the water application, the peak yield (3.30 tons/ha^{-1}) appeared to be at 150 kg N ha^{-1}.

Statistically, maize grain yield at 100 Kg N ha^{-1} was the highest when plants were fully irrigated, but under reduced irrigation, yield at both 100 and 150 Kg ha^{-1} were similar. The implication is that, nitrogen fertilizer application of 100 Kg N ha^{-1} appears sufficient for maximum maize yields in this irrigation scheme. The high yield at 100 kg N ha^{-1} could partly be attributed to an increased number of cobs per hectare and the number of kernels per square metre recorded from the trial.

Comparing fertilized plants to unfertilized ones, differences occurred only when nitrogen was applied at a rate of 100 Kg N ha^{-1} or more. Thus, the grain yield at 50 Kg N ha^{-1} was similar to that of unfertilized crops. The average yield increase at 100 and 150 Kg N ha^{-1} relative to unfertilized plants was 25.8 percent and 33.8 percent under full and half irrigation, respectively. Unfertilized plants yielded an average of 2.5 tons ha^{-1} which was still higher than the average yield of **1.6 tons ha^{-1}** determined from the farmer's field under full irrigation conditions. The lower yield from the farmers field indicates the need to train farmers to adhere to proper cultural practices for their maize production. Farmers were however eager to improve their practices following observations from the experiment.

Table A5. The influence of irrigation and nitrogen on grain yield, yield per applied water and stover yield at Adriansdraai

Irrigation	**Nitrogen**	**Grain yield**	**Grain yield per applied water**	**Stover 146 DAP**
	Kg ha^{-1}	Tons ha^{-1}	Kg mm^{-1} ha^{-1}	Tons ha^{-1}
Full	0	2.43	12.7	9.67
	50	2.79	14.5	10.64
	100	3.20	16.7	11.80
	150	3.30	17.2	10.29
Half	0	2.58	26.9	12.79
	50	3.00	31.3	11.81
	100	3.62	37.7	11.13
	150	2.87	29.9	13.06
Significance		**		Ns
CV (%)				22.7

Full = 12mm of water per application; Half = 6mm of water per application.
DAP = Days after planting; ns = non-significant difference.

Table A6. The influence of irrigation and nitrogen on grain yield, yield per applied water and stover yield at Veeplaats

Irrigation	**Nitrogen**	**Grain yield**	**Grain yield / applied water**	**Stover**
	Kg ha^{-1}	Tons ha^{-1}	Kg mm^{-1} ha^{-1}	Kg ha^{-1}
Full	0	-	-	6397
	50	-	-	8272
	100	-	-	8883
	150	-	-	8428
Half	0	3.61	33.4	7717
	50	4.23	39.2	7889
	100	4.56	42.2	9033
	150	4.71	43.6	12299
Significance		*		Ns
CV %		2.26		16.52

Full = 12mm of water per application; Half = 6mm of water per application.
DAP = Days after planting; ns = non-significant difference.

Grain Yield at Veeplaats

The effect of irrigation at Veeplaats could not be determined due to premature harvest of the fully irrigated treatment by a participating farmer. The report therefore focuses on only the influence of nitrogen fertilizer on maize grain yield under reduced irrigation level. There was a significant effect of nitrogen fertilizer rate on grain yield at this irrigation scheme (Table A6).

The yield range at Veeplaats was 3.61 to 4.71 tons per hectare with the highest yields occurring at 100 and 150 kg ha^{-1} application. The effect of nitrogen fertilizer at 50 Kg N ha^{-1} was similar to that of unfertilized control plots. Thus, similar to the results at Adriansdraai, the grain yield of maize responded to nitrogen and therefore, farmers need to apply at least 100 kg N ha^{-1} to obtain the maximum maize yields, giving the low N status of the soil. An average yield increase of 28.3% was obtained by applying 100 and 150 kg N ha^{-1} relative to zero N application.

Yield per applied water

The yield per water applied was estimated as the total grain yield harvested divided by the total amount of irrigation water (gross) applied throughout the growing season and it is a measure of the efficiency with which the applied irrigation water is used in the production of grain. Grain yield per applied water ranged from 12.7 kg mm^{-1} to 17.2 kg mm^{-1} under full irrigation application and from 26.9 to 37.7 under reduced application at Adriansdraai (Table A5). The highest values were recorded under reduced irrigation. At Veeplats, the values ranged from 33.4 to 43.6 kg mm^{-1} (Table A6). These values may be over estimated since low efficiency and some leakages of the irrigation pipes might have contributed some water in the field, which was not captured by the rain gages.

Stover yield

No significant effects on stover yield due to irrigation and nitrogen were recorded at both locations.

Conclusions

No differences in grain yield between plants receiving full amount of irrigation and those receiving half the amount were observed at all sites, which could probably be attributed to, a relatively higher rainfall received during the experimentation. Regarding the importance of nitrogen, application of nitrogen is required for improved maize growth and grain yields in the irrigation schemes. An application rate of 100 Kg N ha^{-1} is recommended. Subsequent studies should focus on demonstration trials on farmers' fields where large blocks of maize, fertilized at 100 Kg N ha^{-1} are compared with unfertilized controls under both irrigation regimes before final recommendations are made on nitrogen fertilization.

(b) Variety and density effects on growth and grain yield of maize (Zea mays) at Adriansdraai and Veeplaats

Introduction

Maize is a dominant crop widely cultivated in South Africa and, in the Limpopo Province, the crop is a staple food especially in rural communities. Observing appropriate planting density in the field is an important cultural practice for successful maize production.

Planting density influences solar radiation interception, dry matter accumulation and eventual grain yield. Currently, the optimum density for commonly grown maize variety in the smallholder irrigation schemes along the Olifants River is not yet documented.

Objective

To determine the density that will result in optimum grain yield of two varieties of maize

Materials and methods

Field trials were conducted at Adriansdraai and Veeplaats during 1999/2000 cropping season. Maize cultivars SNK 2147 and Pioneer Hybrid (PHI) were planted on 11 November and 06 December 1999 at Adriansdraai and Veeplaats respectively as RCBD in a 2 by 4 factorial arrangement with four replications at each location. The factors consisted of variety and planting density, 15000, 25000, 35000, 45000 and 55000 plants per hectare. Each experimental unit consisted of 8 rows of 8m length at inter row spacing of 90 cm. All plots received 100 Kg N ha^{-1} as urea and 30 Kg ha^{-1} as Superphosphate. At harvest maturity, plants from a 3-m length in the middle four rows of each experimental unit were harvested to determine grain yield.

Table A7. Grain yield and dry matter accumulation of maize as influenced by variety and planting density at Adriansdraai during the 1999/2000 growing season

Variety	Population	Grain Yield	Yield $Plant^{-1}$	Yield per applied water
	Plant ha^{-1}	Tons ha^{-1}	Gram $plant^{-1}$	Kg mm^{-1} ha^{-1}
SNK 2147	15000	2.4	160	12.2
	25000	2.9	116	14.8
	35000	3.8	109	19.4
	45000	3.7	82	18.9
	55000	3.6	65	18.4
PIONEER (PHI)	15000	2.4	160	25.0
	25000	3.1	124	32.3
	35000	4.7	134	49.0
	45000	4.3	96	44.8
	55000	4.1	75	42.7
$LSD_{(0.05)}$		1.4		

Results and discussion

Results are presented only for Adriansdraai because the farmer who participated in the experiment at Veeplaats harvested the maize cobs before ant yield could be determined.

No significant difference in grain yield between cultivars SNK 2147 and Pioneer Hybrid (PHI) was observed. Cultivar SNK 2147 is the popular variety among the farmers in the irrigation scheme whereas Pioneer was recently introduced. Differences were however observed in planting density (Table A7).

There was a definite quadratic response of grain yield to density at Adriansdraai with the maximum yield occurring between 35000 and 45000 plants per hectare irrespective of cultivar. The average yields at these densities were 3.8 and 4.5 tons ha^{-1} under SNK 2147 and PHI respectively. These constitute 14 and 22% yield increase over the average cultivar yields respectively across plant densities. Since no significant differences occurred between these two optimum densities, plant population of 35000 plants per hectare is recommended for the farmers in this irrigation scheme as this will help minimize the cost of purchasing seeds.

<u>Grain Yield per Plant</u>

Growth of individual plants decreased as density increased (Table A7). This is an indication of plant plasticity, a natural phenomenon where individual plants tend to grow bigger in the absence of significant competition for growth resources to produce yields similar to those under severe competition and vice versa. However, in this study, the extent of plasticity at low plant population was not sufficient to compensate for the final grain yield as indicated by the higher grain yields with increasing plant population.

<u>Yield per applied water</u>

Yield per applied water at Adriansdraai was generally higher in Pioneer hybrid than in SNK 2147. Within each variety, the highest efficiency was obtained under 35000 plants per hectare followed by 45000 plants per hectare. This efficiency might have contributed to the observed yields obtained at these densities.

Conclusions

Planting density was observed to play a significant role in maize grain yield at the Adriansdraai irrigation scheme. Yield response to population density was quadratic with the maximum yields and efficiency of applied water use occurring at 35000 and 45000 plants per hectare. Grain yield of the two varieties SNK 2147 and Pioneer Hybrid PSI were rather similar and farmers are likely to use the former, which they are already accustomed to. However, before final conclusions are drawn on planting density for the farmers, it is recommended that demonstration plots be established on farmers using the variety SNK 2147 under the densities of 15000, 35000 and 45000 plants per hectare.

(c) Yield and growth response of diverse groundnut (Arachishypogaea) varieties at Adriansdraai and Veeplaats

Introduction

Currently, continuous cereal production is the dominant practice in smallholder irrigation schemes at Veeplaats and Andriansdraai, a practice that is generally not sustainable. Farmers have already expressed the desire to utilize alternative field crops in addition to the cereals. Incorporation of legumes into the existing cropping system may be beneficial. Legumes are superior to non-leguminous crops in adapting to poor soil conditions as they provide a substantial amount of biologically fixed nitrogen into the agro-ecosystem and, thus, contribute to maintenance of soil fertility. They also provide a relatively inexpensive dietary source of protein for humans and livestock and serve as organic nitrogen fertilizer for cereal crops grown either in intercropping or as rotational crops.

A major problem experienced by farmers in the irrigation schemes is low production and quality of crops, which do not generally meet the demand of potential commercial farmers. High input costs and uncertainty of markets and prices are additional problems. Groundnut is the least expensive protein source and increased production and quality of this crop in the irrigation scheme has the potential of addressing some of these problems.

Currently, the most important constraint to groundnut production is the incidence of foliar diseases, notably, early leaf spot (*Cercopora arachidicola*), late leaf spot (*Phaaeosariopsis personata*) and rust (*Pucinia arachidis*) as well as pod diseases. For increased production, it is necessary to select high yielding groundnut cultivars that are resistant to diseases and harsh environmental conditions of the Limpopo Province.

Table A8. Response of groundnut yields to cultivar at Adriansdraai during the 1999/2000 growing season

Cultivar	**Grain yield ($Kg\ ha^{-1}$)**	**Grain yield per applied water ($Kg\ mm^{-1}\ ha^{-1}$)**
Akwa	886	4.6
Anel	1569	8.2
Hartz	554	2.9
Jasper	653	3.4
Kwartz	951	4.9
Pan 9212	836	4.4
Robbie	605	3.2
Sellie	985	3.6
$LSD_{(0.05)}$	443	

Objective

To determine grain yield and protein content of the eight varieties of groundnuts.

Materials and methods

Field experiments were conducted at Adriansdraai and Veeplaats irrigation schemes during 1999/2000 cropping season. Eight commercially available groundnut cultivars serving as treatments were established in a randomised complete block designs with five replications at each irrigation scheme. Planting occurred on 25 November 1999 at Adriansdraai and on 4 December at Veeplaats. Each experimental unit consisted of 4 rows of 4m length at inter row spacing of 90 cm. All units received 60 Kg P ha^{-1} as superphosphate at planting. At harvest maturity, plants from a 3.6 m^{-2} area in the middle rows of each experimental unit were harvested to determine grain yield.

Results and Discussion

Significant response of groundnut seed yield to cultivar was observed at the Adriansdraai irrigation scheme. Yield among the cultivars were generally similar except for Anel, which yielded higher than all the other cultivars (Table A8).

The yield of Anel was 1569 kg ha^{-1}, which constituted a 100 percent yield increase relative to the average cultivar yield. The overall yields among the cultivars were generally low since under high potential environment, thus, adequate moisture, good nutrient status and good management, most of the cultivars are expected to produce yields of more than 3000 $Kgha^{-1}$. The low yields could be attributed to the occurrence of several interruptions in water supply and partly to late season attack by foliar disease complex.

Anel, the highest yielding cultivar is reported to produce the most stable yields in the Mpumalanga province under dryland even though variable yields of about 500 to 1824 kg ha^{-1} have been observed under dryland. The choice of groundnut cultivar is however not solely dependent on yield, quality of the seed is also a determining factor. The final decision will be based on the presence of black pod rot, pod nematode or scab disease. No yield was recorded at Veeplaats due to untimely harvest of the crop by a participating farmer.

Conclusion

Groundnut cultivar, Anel, could be recommended for farmers in the irrigation scheme. Further studies are however required on these varieties before final recommendations are made.

(d) Wheat cultivar for growth and yield at Elandskraal

Introduction

Cultivar selection is an important management consideration in crop production for superior crop growth and yield. Yield of a ciultivar is influenced by the environment as well as management practices employed by farmers. Thus, it is important for farmers to select cultivars that are adaptable to their local environment in order to attain maximum productivity. Several wheat cultivars are available in South Africa but suitable varieties for the Elandskraal irrigation scheme is not yet identified. This experiment was established to determine grain yield and straw production of four superior wheat cultivars in the irrigation scheme.

Materials and methods

A field experiment was established at the Elandskraal irrigation scheme on 17 June 2002 in a randomized complete block design with 4 replications. The treatments examined were four wheat cultivars, namely: INIA, SST 806, SST 822 and SST 876. Each cultivar was planted within a plot size of 14 by 22m. The initial soil analysis indicated that the soil had 10 mg kg^{-1} nitrogen, 32 mg kg^{-1} phosphorous and 240 mg kg^{-1} potassium (Table A9). All plots received 30 kg P ha^{-1} as superphosphate and 100 kg ha^{-1} as urea. Nitrogen was applied as split application, at planting and at 4 weeks after planting. The total amount of irrigation water applied from land preparation till physiological maturity was 371.3 mm. The cultivars were planted by hand by broadcast at a density of 105kg ha^{-1}. Flowering of the cultivars were determined when 50% of the plants in an experimental unit had revealed panicles. At harvest maturity (mid October), above-ground sample was taken from a representative 1-m^2 area from each plot using a quadrant. Samples were separated into grain and straw and were oven-dried at 65^{o}C to about 13% grain moisture. The dried grain and straw samples were weighed to determine yield and growth of the cultivars. Thousand seed weight was also measured to assess differences in kernel size.

Results and discussion

Grain yield was statistically similar in all the SST cultivars with a range of 4.69 to 5.14 tons per hectare. This is a relatively higher yield compared to national average of about 3.5 tons per hectare. Thus, with proper management, the farmers should be able to produce satisfactory yields of wheat using any of the SST cultivars examined in the trial. SST876 is however an attractive one since it is the highest numerically and could result in the highest profit. The lower yield of INIA could be attributed to its high susceptibility to bird damage.

Table A9. Cultivar and straw yield of four wheat cultivars at Elandskraal

Cultivar	**Flowering**	**Grain Yield**	**1000 seed mass**	**Straw Yield**
	DAP	tons ha^{-1}	Grams	Tons ha^{-1}
INIA	83	2.90	42.1	7.74
SST806	85	4.69	37.9	6.56
SST822	87	4.76	40.4	7.00
SST876	81	5.14	38.1	6.49
$LSD_{(0.05)}$	Ns	0.93	3.6	ns

Considering the kernel size, INIA appears to produce large kernels and hence a great potential to produce higher grain yield if birds could be effectively controlled. All the cultivars produced similar amounts of straw statistically, but there was a tendency of higher straw production in INIA and SST822.

Conclusions

Cultivars SST806, SST822 and SST876 are suitable for cultivation in the Elandskraal irrigation scheme due to their high grain and straw production and can therefore be recommended to farmers. Cultivar INIA also has a potential for high productivity but its high susceptibility to bird damage in the area renders it too risky for recommendation to farmers unless effective methods are employed to control the birds.

APPENDIX TWO

REPORT ON CAPACITY BUILDING

The project was envisaged to contribute to capacity building of smallholder irrigation farmers, the School of Agriculture and Environmental Sciences at the University of the North, and the Department of Agriculture and Environment (Limpopo Province). The above stakeholders were expected to benefit as follows:

Smallholder Irrigation Farmers

Smallholder irrigation farmers are expected to benefit from improved policies, technologies and support systems once they have been adopted and put in place. Women farmers are expected to be the main beneficiaries.

The benefits to smallholder farmers are of short- and long-term nature. In the short term, smallholder farmers will gain knowledge of how to use irrigation water efficiently. Currently, there are indications that farmers are not irrigating their crops efficiently. The results of experiments that were conducted indicate the appropriate amounts of irrigation water to apply. Farmers will also obtain information about where to market their crops.

The results of experiments conducted with farmers in the irrigation schemes were presented at farmers' days and workshops with farmers, graduate students and researchers. This ensured that farmers as full participants in the research process understood the application of the research findings. There were other spin-offs that led to farmer training at the schemes. The following are examples:

- Academic staff in the School of Agriculture and Environmental Sciences developed proposals with farmers' cooperatives which led to the Land Bank granting funds for training of farmers in three irrigation schemes. Farmers were trained on different aspects of vegetable production from planting to harvesting.
- An exchange programme was organized by the Department of Agricultural Economics at the University of the North whereby irrigation farmers from Sepitsi were linked with farmers at Apel to learn aspects of nursery development.
- Through the Centre for Rural Community Empowerment, a group of 22 farmers were trained on marketing, record keeping, development of business plans, etc. This training lasted for a week. Four of the 22 farmers were drawn from Sepitsi and Strydkraal.

School of Agriculture and Environmental Sciences

The project is expected to enhance the research, teaching, and community outreach capacity of the school. In particular, the project is expected to

- enhance the capacity of staff to conduct high quality research on smallholder irrigation through collaborative linkages with leading national and international research organizations;
- improve the research skills of postgraduate students through collaborative work in a multidisciplinary team in experimental design, data collection and analysis;
- enrich the curriculum through the introduction of smallholder irrigation aspects;

- contribute to capacity building through the provision of short courses and workshops on irrigation; and
- enhance the capacity of the School to provide community outreach through improved collaboration with other stakeholders.

Both staff and students have benefited from the research because they have learned new things about smallholder irrigation. The project has assisted two masters students to complete their degrees: one in agricultural economics and one in plant production. A third masters students was about to complete her thesis at the time of compiling this report.

The project has enabled researchers to develop links with the International Water Management Institute who collaborate with the School on different aspects of smallholder irrigation. Links have also been forged with the University of Pretoria.

These linkages are expected to further benefit researchers in different specialization areas of smallholder irrigation. While conducting research in the various irrigation schemes, spontaneous links were forged with Agricultural Research Council scientists, Land Bank personnel (who assist farmers with loans), input suppliers and different NGOs. These encounters enable researchers to develop strong multidisciplinary research teams to address complex rural development problems.

Department of Agriculture and Environment in Limpopo Province

The project is expected to enhance the capacity of the Department to develop appropriate policies related to smallholder irrigation. In addition, extension personnel should improve their knowledge of smallholder irrigation and how to work with smallholder farmers. The Department is also expected to gain knowledge of appropriate methodologies for the transfer of management of small-scale irrigation schemes.

The benefits to the Department of Agriculture will be realized if the recommendations from the research are implemented.

<u>**APPENDIX THREE**</u>

PUBLICATIONS AND OTHER TECHNOLOGY TRANSFER ACTIONS

1. Publications

The following publication was produced as an output from this research project:

Hedden-Dunkhorst, B., Machethe, C. and N. Mollel (2002). Smallholder Water Management and Land Use in Transition: A Case Study from South Africa. *Quarterly Journal of International Agriculture 41(1/2).*

2. Thesis and Articles

A masters thesis was also completed as indicated below:

Modiba, M.D. (2002). Growth and Grain Yield Response of Maize to Water and Nitrogen in Smallholder Irrigation Schemes in Limpopo Province. M. Agric. Admin. Thesis, University of the North.

Thema, P.J. (2004). Farm Size, Profitability and Productivity: The Case of Smallholder Irrigation Farmers in Elandskraal and Sepitsi. M.Sc. Agric. Thesis, University of the North.

A number of articles will be prepared shortly for submission to accredited journals.

3. Future Publications

The results of experiments that were conducted in the irrigation schemes will be published as guidelines for farmers. The publications will be translated into Sepedi but this will be dependent on the availability of funds. A separate funding proposal may need to be developed to accomplish the above.

4. Social Organization Technology

The Centre for Rural Community Empowerment in collaboration with masters students in Extension is assisting farmers at Mafefe Irrigation Scheme to establish a WUA.

APPENDIX FOUR

ARCHIVING OF DATA GENERATED DURING THE PROJECT

The data generated during the project is available on cassette disks, hard copies and on the website (www.unorth.ac.za). The cassette disks and hard copies are available at the following address:

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