EVALUATION OF THE APPROPRIATENESS AND MANAGEMENT REQUIREMENTS OF MICRO-IRRIGATION SYSTEMS IN SMALL-SCALE FARMING

FJ du Plessis • I van der Stoep

WRC Report No. 768/1/01

Water Research Commission

EVALUATION OF THE APPROPRIATENESS AND MANAGEMENT REQUIREMENTS OF MICRO-IRRIGATION SYSTEMS IN SMALL-SCALE FARMING

FJ DU PLESSIS & I VAN DER STOEP

Report to the Water Research Commission
by
MBB Consulting Engineers Incorporated

WRC Report No : 768/1/01
ISBN No : 1 86845 675 7

Printed by Silowa Printers

EXECUTIVE SUMMARY

EVALUATION OF THE APPROPRIATENESS AND MANAGEMENT REQUIREMENTS OF MICRO-IRRIGATION IN SMALL-SCALE FARMING

1. INTRODUCTION

1.1 *Description of project*

The proposal for this research project was submitted in 1995, at a time when irrigation planning and design professionals in South Africa generally knew relatively little about the nature and requirements of sustainable small-scale irrigation, and even less about the basic principles of rural development. At the same time, South Africa was effectively isolated from global research and debates on small-scale farmer development.

Authorities recognised the fact that, in view of future water shortages in SA, micro-irrigation would play an important role, yet, generally speaking, irrigation specialists had reservations as to the appropriateness of micro-irrigation systems under circumstances typically faced by small-scale irrigators. Although there was a growing realisation among individuals involved in small-scale irrigation development that the technical approaches of the past were not yielding development that suited the circumstances, the idea of ignoring or actively discouraging traditional irrigation practices, and replacing it with sophisticated modern systems, were not perceived to be the ideal solution.

These reservations were not unfounded, and were based on the higher level of management required to run and maintain micro-irrigation systems. Small-scale irrigators are often isolated from support services and equipment suppliers, either by distance or absence of transport; they normally lack electricity; many are part-time farmers with other (non-farming) duties that make demands on time and resources.

However, there are small-scale farmers practising micro-irrigation successfully, often making ingenious adaptations to suit their needs. Also, micro-irrigation has some distinct advantages for the small-scale situation when compared to other types of irrigation.

The project comprised of an in-depth investigation into the practical application possibilities of micro and drip-irrigation by small-scale farmers. This was done by installing and monitoring a number of systems, on-farm, under the management and control of small-scale farmers, as well as field visits to a number of existing systems operated by individual farmers, and a number of existing micro-irrigation schemes.

During the project field work, the researchers learnt valuable lessons that will assist them and others in future projects of this nature.

1.2 Objectives of project

The objective of this project was to assess how small-scale farmers experience the concept of micro-irrigation systems and how they cope with problems. The aim was to identify those aspects that eventually determine the success or failure of small-scale crop production under a micro-irrigation system.

Notes:

- For purposes of this report, please note that the term *micro-irrigation* includes both micro-sprayer and drip-irrigation systems.
- The term *farmer* is used to describe any person from the wide range of irrigators who are described in the project (from backyard to commercial).
- Although the masculine form is used in this report, it should be emphasised that this was done to simplify the written text and DOES NOT AT ALL EXCLUDE FARMERS, EXTENSION OFFICERS, DESIGNERS, ETC. WHO ARE WOMEN from the field of study.

2. PRESENT STATUS OF MICRO-IRRIGATION IN SMALL-SCALE FARMING IN SOUTH AFRICA

In the context of this project, the term *micro-irrigation* refers to pressurised irrigation systems which can be used to irrigate part of the field area (as opposed to full surface wetting) in a controlled manner. With this definition, the choice of equipment is reduced to only two types of systems, namely micro-sprayer and drip-irrigation systems. These two

systems are widely applicable, ranging from ultra low application rates on a very limited field area, to high application rates on the full surface area.
Micro-sprayer systems have not changed much since being introduced over twenty years ago. The difference between systems lies mainly in the application rate, the wetted area and the pattern of water distribution properties of the emitter.

Drip-irrigation systems on the other hand, have witnessed, and are still undergoing considerable, even drastic change. Pressure compensated drippers are becoming more popular, because they require reduced design inputs, offer easier management and have less clogging problems. The popularity of subsurface dripper lines is also increasing.

2.1 Micro-irrigation equipment

Information on irrigation equipment suitable for small-scale projects was compiled after discussions with all major equipment suppliers and manufacturers in South Africa. They were briefed about the purpose of this project, and their co-operation requested for the supply of irrigation equipment. In almost all cases manufacturers expressed their willingness to participate by donating equipment for trial plots.

The most advanced equipment in this field is available on the South African market. This is not unexpected, since the South African irrigation industry is an attractive and significant market for irrigation system suppliers.

2.2 Types of small-scale farmers using micro-irrigation

For purposes of this project, small-scale farming was defined as farming taking place on an area equal to or smaller than 20 hectares. Although it was attempted to establish the extent and location of significant small-scale micro-irrigation farming projects in South Africa at the start of the project, the project team became aware of more such projects during the later years of the project.

According to De Lange (1993), small-scale irrigation farmers can be divided into three groups, i.e.:

(a) independent farmers: these are farmers growing crops on land that is not part of an irrigation scheme, but which does not usually belong to them either.

(b) scheme farmers: these are farmers growing and irrigating crops on an irrigation scheme where they share a water source, infrastructure and sometimes irrigation equipment.

(c) vegetable garden (foodplot) farmers: these farmers are usually found in community gardens, having very small plots (for example, 10m x 10m) and sharing a water source and equipment.

Another group of farmers that have been identified during the course of the project, is "backyard" farmers. Farming on the same scale as the vegetable garden farmers, these farmers are not grouped together, but have independent access to water for domestic purposes and allocate some of this for farming.

2.3 A comparison between small-scale micro-irrigation and other irrigation systems in SA

A number of irrigation methods are practiced by small-scale irrigators in South Africa. The irrigation systems (excluding micro) used most often by small-scale farmers are flood irrigation and sprinkler irrigation. A number of center pivots are also used by some farmers, but the other two methods are by far more often found.

As to the extent of existing micro-systems used by small-scale farmers, the systems used by these farmers vary from properly designed micro-irrigation systems, to home-made driplines, to "off the shelf" micro-systems, and they are applied on various crops and soils, some suitable and others less suitable.

2.4 International trends in small-scale micro-irrigation farming

Trends in three areas outside South Africa, namely Sub-Sahara Africa, India and the Middle East, were briefly reviewed by means of a literature study.

The irrigation methods most often found in Sub-Saharan Africa, are flood (in various forms of basins, borders or furrows), and sprinkler irrigation. Probably the most significant development employing the principles of micro-irrigation, is a "bucket drip system" that was developed in Malawi during the 1970's.

In India, with the realisation that the utilisable water sources available are not enough to irrigate the cultivable land, a comprehensive subsidy scheme was introduced in 1982. It was further recognised that the irrigation companies, or dealers, should supply only good quality material of standard specifications, and that they should improve upon their after-sale services. A system to this effect was introduced. The results of these mentioned measures appear to have given the impetus to quicker conversion to drip-irrigation in the country.

In the Middle East during the early seventies, the Israeli Ministry of Agriculture started a campaign to promote drip-irrigation on the western terrace of the Jordan River. Drip and fertigation systems were donated to the farmers by the government, the irrigation industry and non-profit organisations. Advisors to the Ministry of Agriculture were giving extensive guidance on tilling methods and system operation. In 1977 approximately 15% of the fields were converted to drip, and in 1982 this figure had increased to 95%. The donation of systems has since stopped, and farmers are paying for the systems themselves. Yields have increased considerably, and water consumption dropped.

3. METHODOLOGY

3.1 Introduction

The project team originally envisaged the monitoring of 5 trial plots, but after the first season's monitoring, it was realised that this may not be representative of the situation in the country as a whole. The steering committee suggested that the number of trial plots be increased to 15. Though the reasoning behind this idea was better distribution of trial plots, it also proved to be a very sound decision, due to the failure of so many plots during the monitoring period. The additional number of plots added to the project team's workload, but very useful information was gained.

3.2 Identification of candidate trial plots

Potential locations for trial plots were found through consultation with various persons and organisations active in the developing parts of the country. It was realised that making the right decision regarding trial plot sites was crucial to the success of the project, and that this matter had to be handled with great caution.

3.3 Selection of trial plots

Based on the information obtained during interviews with various organisations, a number of areas with significant developing agriculture were identified and visited to obtain on-site information. The conditions, farming practices and management levels varied extensively, emphasising the importance of the procedure by which trial plots for this project should be identified in order to obtain useful information and to make conclusions which are representative of conditions.

Eleven plots were identified to be equipped with micro-irrigation. Seven of the plots were in the Western Cape, one in the Northern Cape and three in the Northern Province.

3.4 Installation and monitoring of trial plots

It proved more difficult than expected to undertake the negotiations required to establish the plots. Unseasonable rain in the Western Cape was a further delaying factor. Consequently the 1997/1998 summer season and the 1998 winter season were the first occasions for full irrigation on all sites.

A topographical survey was done for each of the sites. Designs were based on design standards as specified by the South African Irrigation Institute (SAII). Bills of quantities were compiled and the supply of the material negotiated with irrigation companies.

All sites were visited regularly by the project team, and these visits, together with the original negotiations, resulted in the establishment of significant networking involving small-scale farmers, development specialists, agricultural scientists and the commercial concerns designing and supplying irrigation equipment. This networking has been of great benefit to the project team, and has gone a long way towards providing answers to the questions posed in the original project proposal, while drawing attention to additional aspects which require consideration.

In October 1997 a workshop for the trial plot farmers was held at Elgin. The purpose of the workshop was to give farmers the opportunity to meet one another and to share their experiences with this new technology they had been exposed to. The workshop succeeded in its aims.

Although the regular collection of technical data is important, and can be done according to a checklist, it was found that other relevant issues emerged from informal conversations and objective observations.

By the end of the second season, various difficulties experienced at the trial plots had led to only 6 of the plots being in operation.

3.5 Additional monitoring of existing small-scale farming projects

Following a suggestion made by the steering committee in October 1998, the project team visited existing small-scale micro-irrigation farmers in order to establish how they were performing, and what their irrigation histories were.

3.6 Aspects influencing success and failure of small-scale micro-irrigation farming and development of guidelines on the management requirements

A set of aspects, factors and criteria were developed to evaluate the results of the monitoring procedure (based on the SAPFACT program principles), and from these, guidelines were developed for the successful implementation of micro-irrigation in small-scale farming.

4. OBSERVATIONS ON THE SMALL-SCALE MICRO-IRRIGATION TRIAL PLOTS

The experiences, successes and failures of each farmer's activities on the trial plots during the 4 years research project, and in particular around his micro-irrigation system, are briefly summarised. Observations made on the existing irrigation farms that were visited, are also described.

During the course of the project about 30 sites were visited or monitored where small-scale farmers use micro-irrigation. Of the 23 sites discussed in detail in the report, 11 were newly established for purposes of the project, a further 11 previously existed in South Africa, and the remaining site was the one visited in Israel by a member of the project team.

Of the 11 trial plots established specifically for purposes of the project, only four remained in operation by the end of the monitoring period. The rest all failed at an earlier stage, for various reasons. During the initial stages of monitoring, the reliability of the water-supply was identified as one of the biggest contributing factors to failure of many of the trial plots.

It was encouraging to see the successful enterprises of established farmers in the Northern Province, proving that difficulties can be resolved.

Observations made during monitoring of the trial plots, and the survey of existing systems, together with information obtained through literature studies and discussions with other parties involved in small-scale irrigation, were used to identify six aspects which are considered to be of major importance when evaluating small-scale micro-irrigation farming. A number of descriptive properties are listed for each aspect, and is presented in Chapter 5.

5. INTERPRETATION OF TRIAL PLOT OBSERVATIONS

The number of plots included in this evaluation total 17, consisting of the 11 original trial plots, 2 additional installations, and 4 existing farms.

The SAPFACT program was considered as model for this interpretation, but the aspects, factors and criteria used in the program were found to be not quite suitable, although the broad categories were more or less similar. A new set of these were developed, which should be considered for a new version of the program, aimed specifically at small-scale micro-irrigation farming.

Aspects and factors identified as being important are the following:

5.1 Characteristics of the farmer

Based on observation, one could conclude that the individual characteristics of a farmer could be a determining factor in his success or failure. The level of literacy of farmers was found to be significant in the sense of providing them with access to written information, and for purposes of record-keeping. Farmers with previous irrigation experience and/or formal or informal irrigation training were more likely to succeed with a new system. Another important factor was the farmer's initial attitude towards the new technology, with all the initially skeptical farmers failing to make appropriate use of the systems.

5.2 Circumstances of the farmer

The circumstances under which trial plot farmers operated, differed significantly and with clearly observable consequences, especially on existing farms. Plot owners situated in remote areas experienced problems with access to support services, while those facing harsh climatic conditions, or farmed on marginal or unsuitable soils, were at risk if the irrigation supply proved unreliable.

Farms that were monitored varied from smaller than 0,1 ha, to larger than 20 ha in size, with ownership ranging from schemes and community gardens to individually owned or rented land. Demonstration plots were generally found to have a high risk of failure due to the lack of commitment from the person responsible for the irrigation and maintenance. On the other hand, plots where the farmer was dependent on the income from crop production, seemed more likely to succeed.

5.3 Water supply

Water supply to the farm was clearly found to play a major role in the successful management and operation of a project. If water shortages are experienced on a farm, it is necessary to clearly distinguish between a water supply problem, and a water distribution problem.

A more than adequate water supply benefits farmers and serves as compensation in cases where they schedule irrigation poorly and make mistakes when they start with micro-irrigation, as witnessed in most cases. The reliability of the water supply adds considerably to the ease of managing the irrigation project. If the farmer is personally responsible for his supply system, and he is not adequately trained and well backed up with support services, there is a real risk of his project failing. Irregularity of water supply, together with poor management of the supply system on certain plots, caused serious set-backs for these plots. On the other hand, water supply systems which were well managed contributed much to achievements attained by farmers. None of the trial plots failed due to poor water quality. However, over the longer term, poor quality water may cause problems.

5.4 The irrigation system

The irrigation system includes the pump, filtration and fertigation equipment, and the infield system. The research work showed that all the projects where pumps, operated by the farmer himself, were involved, were seriously disadvantaged due to pumping problems.

Farmers recognised the importance of, and therefore experienced few problems regarding filtration. The infield systems itself proved to be suitable, although with some concern in a few cases. Clear recommendations on appropriate fertigation procedures, and the efficiencies of the different systems, cannot be made, and it is therefore recommended that additional work be done in this regard.

The installation of the system is the first and major step in the training of a farmer. The extension officer should preferably be present. Training was also identified as being inadequate for those farmers who preferred other irrigation systems to micro-irrigation.

5.5 General management

Irrigation systems were under-utilised on most of the trial plots, mainly due to managerial problems. Maintenance of the systems were in most cases limited, although none of the system failures can be contributed to this factor only.

Not much pressure was applied by the project team to schedule accurately, and in general over-irrigation occurred on all sites where sufficient water was available, and under-irrigation where the water supply was limited, or irregular.

Due to the size of the operation, little or no labour and time saving were reported by the majority of the farmers. Despite poor record-keeping, for various reasons, some farmers were nevertheless successful, although the project team is of opinion that good record-keeping is fundamental to sound farming.

5.6 Infrastructural, institutional, extension and social factors

A wide range of facilities are covered under this heading, but only the two considered to have the biggest impact on the appropriateness of micro-irrigation, i.e. input markets and the availability of utilities, are discussed here. A comprehensive overview is given by Van Averbeke et al (1998).

These factors are often linked to the location of the plots, with access to services and communication being more difficult in remote areas.

It was found that the local extension officer (if available) should have a good understanding of the system in order to provide support, and this is probably the group that should be targeted for training.

International experience (India and the Middle East) emphasises the importance of other support mechanisms, such as farmer groups, local government and policy. Failure due to their absence confirms their importance.

5.7 Economical and financial factors

The transformation of water resource inputs to crop production outputs is the basic relationship in the research of irrigation economics (Van Averbeke et al, 1998). The capital cost of micro-irrigation is known to be relatively high compared to other irrigation systems, and this can be an obstructive factor to many small-scale (marginal) farmers. Also, the smaller the system, the higher the cost per hectare seems to be, making development less economically justifiable. Yet it has intrinsic advantages (such as labour demand reductions) which make it viable in other ways.

Few of the farmers encountered were concerned about the cost of water, with some receiving it without payment and others paying a "flat rate", which they accepted as giving them unlimited access. The concept of saving water was foreign to many of them, and this factor should be addressed through training. Although most of the farmers wanted to expand their areas under irrigation, opportunities were limited, mainly due to lack of money, and the increased risk associated with it. Some farmers did, however, obtain credit to expand, most of them without being landowners, but in general small-scale farmers' cash flows were found to be poor. An improvement of marketing skills and opportunities could improve the situation.

6. GUIDELINES FOR SMALL-SCALE MICRO-IRRIGATION SYSTEM DESIGN AND OPERATION

During the evaluation of the data gathered, it was found that most of the issues at stake were generic problems of small-scale irrigation farming, and very few were related directly to micro-irrigation. These aspects are discussed in depth in the previous chapter.

Furthermore, it is recommended that all the technical design considerations used for conventional irrigation design be taken into account, with certain alterations, as discussed here.

Guidelines are presented under six broad headings.

6.1 System planning

A preliminary investigation into the proposed development may present crucial information on the site and persons that could contribute to the success of the project. It is important to gather information on the characteristics and circumstances of the farmer, as well as previous development attempts that have been made in the area, and future expectations of the farmers. Technical information regarding the water supply, soils, crops and management limitations should also be obtained before system planning is done in a participatory manner, incorporating the farmer's needs.

6.2 System design considerations

As previously mentioned, conventional design criteria should be applied, but can be adapted to suit the particular situation. The possibilities of intercropping and a suitable scheduling program should be taken into account. Technology should be in accordance with the farmer's needs, and the necessary support services to provide back-up should be available. Inferior quality material should be avoided.

6.3 System installation and training

Installation of the system must be of a high standard, and the occasion must be appropriated for the training of the farmer. The farmer should be thoroughly introduced to the different components of his irrigation system, and must have access to sufficient and understandable documentation about the system, how it operates and maintenance requirements. The documentation should also include avenues to find help with the different components of the system and how it operates, should the farmer experience problems.

6.4 Management (operation and maintenance)

Regular communication with the farmer is important, not only between the support groups and the farmer, but also among farmers themselves. From information obtained through these discussions, the farmer should be assisted to progress as fast as possible and to improve his skills, and it will be necessary to concentrate on aspects such as the following: record-keeping, utilising support services, maintenance requirements, irrigation scheduling, application of fertilisers and weed control.

6.5 Economical aspects

Ownership of the land is not necessary for a farmer to be successful. Access to financing, however, is important to allow further development and expansion of the farming operations. Cash crops are important for generating the necessary cash flow, but due to risks involved, permanent crops, together with intercropping, should be considered if the size of the farm justifies this. Sound advice on the selection of crops is needed at all times. Normally there is considerable idle time involved with the irrigation system; this should be exploited optimally in order to reduce the cost of the system per unit area.

Under certain conditions municipal water can be used economically for irrigation.

A new official policy on the successful conversion from flood and sprinkler systems to micro-irrigation, which addresses both the financial and technology transfer issues, should be developed

6.6 Training requirements and approaches

One conclusions of the project team, based on monitoring and visits on more than one occasion, is that training (or the lack thereof) is probably one of the main contributing factors in the success or failure of small-scale farmers. Some suggestions are made as to approaches that should be adopted for implementation of successful training.

7. CAPACITY BUILDING

This research project provided opportunities for capacity building mainly with regard to the exposing farmers from previously disadvantaged communities, as well as to their fellow farmers and families, to micro irrigation technology and giving them an opportunity to obtain experience in operating and managing these systems themselves.

The support received through the numerous visits by, and discussions with the project team helped to create an atmosphere in which they could develop confidence in working with the systems and establish a contact with other role-players that may assist them in future.

Capacity building was also done amongst the various extension officers and NGO officials involved with the trial plots. This group of role-players are considered to be very important to the development of emerging farmers, and it is believed that they should be targeted to receive comprehensive training new technologies if it is implemented, in order to be able to provide the farmers with the right support and information.

8. CONCLUSION

The objectives of this project have been well met. The aspects and factors which influence small-scale micro-irrigation projects positively and/or negatively have been identified, and typical problems experienced by the farmer and his way of coping with it, were observed.

Guidelines for the implementation of micro-irrigation in small-scale farming, which are based on all the observations, are practical, and can serve as a checklist for planners, designers and extension officers.

Micro-irrigation can be implemented successfully in small-scale farming, provided a number of support services are in place. Small-scale farmers experience very few problems with the operation of the system, provided it functions properly, and operational guidelines are followed satisfactorily. However, when something fails in the system, especially if it is related to the water supply, a project can come to a sudden standstill, with devastating consequences for the farmer.

The guidelines in this report will help those working in this field to avoid the recurrence of problems and mistakes of the past. Hopefully it will contribute to policy-making on small-scale farming, which will ensure more successful projects in the future.

To date a number of research projects have been carried out on different small-scale farming issues. Definite interfaces exist among the findings of these projects, and it is recommended that an abstract be made from all the findings or reports, containing guidelines on a broad range of aspects.

A number of aspects were identified which need further investigation. These include design norms for small-scale micro-irrigation, the application of fertilizer, the rate of conversion to micro-irrigation systems, and the use of gray water in micro-irrigation systems.

ACKNOWLEDGEMENTS

The research in this report emanated from a project funded by the Water Research Commission, and entitled:
"*The evaluation of the appropriateness and management requirements of micro-irrigation systems in small-scale farming*".

The Steering Committee responsible for this project consisted of the following persons:

Mr DS van der Merwe	Water Research Commission (chairman)
Mr OCE Hempel	Water Research Commission (secretary)
Dr GR Backeberg	Water Research Commission
Prof MC Laker	University of Pretoria
Dr W van Averbeke	Border Technikon
Mr CM Stimie	ARC-Institute for Agricultural Engineering
Mr FB Reinders	ARC-Institute for Agricultural Engineering
Prof S Walker	University of the Orange Free State
Mr AS Roux	Department of Agriculture – Western Cape
Mr JK Murray	MBB Consulting Engineers Inc

The financing of the project by the Water Research Commission and the contributions of the members of the Steering Committee is acknowledged gratefully.

This project was only made possible with the cooperation of many individuals and institutions. The authors wish to sincerely thank the following:

- The small-scale farmers who operated the trial plots
- Department of Agriculture: Directorate of Agricultural Engineering, Elsenburg
- Department of Agriculture: Small Farmer Development Institute, Elsenburg
- Department of Agriculture: Northern Province
- ARDC, Northern Province
- Agricultural Research Council – Infruitec, Nietvoorbij

- LANOK, Paarl
- Informal Business Forum, Johannesburg
- New Farmers Company, Cape Town
- The Land Development Unit (LDU), University of Western Cape
- Various irrigation companies throughout the country:

    Agrinet (Pty)Ltd

    Agriplas (Pty)Ltd

    Andrag (Pty)Ltd

    Intech Irrigation (Pty)Ltd

    M&B Pumps (Pty)Ltd

    Netafim South Africa (Pty)Ltd

    Robor Stewarts & Lloyds (Pty)Ltd

TABLE OF CONTENTS

PAGE

PAGE

PAGE

PAGE

1. INTRODUCTION

1.1 DESCRIPTION OF PROJECT

The proposal for this research project was submitted in 1995, at a time when irrigation planning and design professionals in South Africa generally knew very little about the nature and requirements of sustainable small-scale irrigation, and even less about the basic principles of rural development. At the same time, South Africa was effectively isolated from global research and debates on small-scale farming development.

Authorities recognised the fact that, in view of future water shortages in SA, micro-irrigation would play an important role, yet, generally speaking, irrigation specialists had reservations as to the appropriateness of micro-irrigation systems under circumstances typically faced by small-scale irrigators. Although there was a growing realisation among individuals involved in small-scale irrigation development that the technical approaches of the past were not yielding development suited to the circumstances, the idea of ignoring or actively discouraging traditional irrigation practices, and replacing it with sophisticated modern systems, were not perceived to be the ideal solution.

These reservations were not unfounded, and were based on the higher level of management required to run and maintain micro-irrigation systems. Small-scale irrigators are often isolated from support services and equipment suppliers, either by distance or absence of transport; they normally lack electricity; many are part-time farmers with other (non-farming) duties that make demands on time and resources.

However, there are small-scale farmers practising micro-irrigation successfully, often making ingenious adaptations to suit their needs. Also, micro-irrigation has some distinct advantages for the small-scale situation when compared to other types of irrigation, of which the most important are:

- high irrigation efficiencies, therefore potential water saving;
- relatively low operating pressure required;
- low labour requirements and 24 hour a day operation;
- versatility in field layout and topography; and
- relative ease with which systems (drip) can be moved between fields.

The project comprised of an in-depth investigation into the practical application possibilities of micro and drip-irrigation by small-scale farmers. This was done by installing and monitoring a number of systems, on-farm, under the management and control of small-scale farmers, as well as field visits to a number of existing systems operated by individual farmers, and a number of existing micro-irrigation schemes.

A total of 11 micro and drip-irrigation systems were installed on small-scale farms in the Northern Province, Northern Cape and Western Cape, and monitored to a greater or lesser extent over a period of two and a half years. A number of the trials failed for various reasons, and it was decided to include the monitoring of other existing systems, which added some very important information to the study. During the project field-work, the researchers gained valuable knowledge which will be of benefit to those working on projects of this nature in future.

1.2 OBJECTIVES OF PROJECT

The objective of this project was to assess how small-scale farmers experience micro-irrigation systems and how they coped with the potential problems involved. The aim was to identify those aspects (technical, managerial, financial, etc) which eventually determine the success or failure of small-scale crop production under a micro-irrigation system.

Notes:

- For purposes of this report, please note that the term *micro-irrigation* includes both micro-sprayer and drip-irrigation systems.
- The term *farmer* is used to describe any person from the wide range of irrigators who are described in the project (from backyard to commercial).
- Although the masculine form is used in this report, it should be emphasised that this was done to simplify the written text and DOES NOT AT ALL EXCLUDE FARMERS, EXTENSION OFFICERS, DESIGNERS, ETC. WHO ARE WOMEN from the field of study.

2. PRESENT STATUS OF MICRO-IRRIGATION IN SMALL-SCALE FARMING IN SOUTH AFRICA

2.1 INTRODUCTION

In the context of this project, the term micro-irrigation refers to pressurised irrigation systems which can be used to irrigate part of the field area in a controlled manner. With this definition, the choice of equipment is reduced to only two types of systems, namely micro-sprayer and drip-irrigation systems. These two systems are widely utilised, ranging from ultra-low application rates on a very limited field area, to high application rates on the full surface area.

In most applications micro-sprayer systems are used on tree crops where normally between 50% and 100% of the surface area is wetted, whereas drip-irrigation is used (on suitable soils) for permanent row crops at closer spacing, as well as vegetables and field crops.

Micro-sprayer systems have not changed much since being introduced over twenty years ago. The difference between systems lies mainly in the application rate, the wetted area and the pattern of water distribution characteristic of the emitter.

Drip-irrigation systems, on the other hand, are still evolving. Pressure compensated drippers are becoming more popular, because they require fewer design inputs, offer easier management and have less clogging problems. The use of subsurface dripper lines is also increasing.

2.2 MICRO-IRRIGATION EQUIPMENT

The information on irrigation systems for this study was compiled through discussions with the major equipment suppliers and manufacturers in South Africa. They were briefed about the purpose of this project and their co-operation requested to supply irrigation equipment. In almost all cases the manufacturers expressed their willingness to participate by donating equipment for trial plots.

2.2.1 What is available in South Africa?

The most advanced equipment in this field is available on the South African market. This is not unexpected, since the South African irrigation industry is an attractive and significant market for irrigation system suppliers.

Most of the micro-sprayer and drip-irrigation equipment is fully or partly manufactured in South Africa. Some of the equipment is manufactured under license from companies abroad. The major foreign countries influencing the micro-irrigation equipment market are Israel and the USA.

Israel concentrates more on micro-irrigation, while the USA leads in the field of micro-irrigation. The other role-players, of whom South Africa and Australia are amongst the biggest, develop relatively little new equipment at this stage.

2.2.1.1 Micro-sprayers

Micro-sprayers can be divided into two broad categories, namely static sprayers and mini-sprinklers. Static sprayers normally cover a much smaller area than the mini-sprinklers, which are equipped with rotating swivels, giving a greater throw.

Static sprayers can be subdivided into two groups, namely those which have a full-circle spray coverage, and those spraying water over specific segments spread along the perimeter. The full-circle sprayers have the disadvantage that a mist is produced, and under windy conditions much of this mist is blown out of reach of the plants. The disadvantage of the radial distribution pattern is that it resembles a number of drippers on the periphery of the wetted area of each emitter, rather than a uniformly wetted area.

Pressure regulated micro-sprayers are now becoming available, but the application is still very limited. Similar to pressure compensated drip-systems, the major advantage of pressure regulated micro-sprayers lies in simplified system design and management, especially on very steep topography. Pressure regulated emitters also perform better when clogging is a problem.

There are many unanswered questions on system efficiencies. For design purposes the accepted efficiency is between 80% and 85%. Information gathered by commercial farmers using neutron probe technology in scheduling, show considerable deviations from these figures. Large differences in efficiencies are found between day and night irrigation. With the information available, these differences cannot be accounted for, and there is a definite need to obtain more data through research on this subject.

The typical cost of micro-irrigation in-field systems in commercial fruit orchards in the year 2000 is approximately R 8000 per hectare. The cost of the pumping equipment, main and distribution pipelines, as well as filtration equipment, depend on the size of the project, but normally varies between 10 % and 20 % of the in-field system cost. The cost for smaller size projects will be higher.

2.2.1.2 Drip-irrigation

The variation found in dripper equipment is much wider than in the case of micro-sprayers. Three major categories exist, namely button drippers, in-line drippers, and tape drippers.

Button drippers are pressed into standard polyethylene (P.E.) pipes at the desired interval for the necessary application.

In-line drippers are normally inside the pipe and are molded or inserted into the pipe during the manufacturing process.

Tape drippers are similar to in-line drippers in the sense that the dripper is part of the pipe manufacturing process, but in this case the dripper pattern is not created by a separate piece of equipment, but created in the manufacturing process. As the name implies, tape drippers are made of strips of very thin polyethylene, which are "welded" together to form a pipe.

In-line drippers are available in pipes of varying diameters and wall thicknesses. Wall thickness largely determines the life expectancy and cost of the dripper line and the situation in which it will be applied.

For all three categories of drippers, both pressure regulated and non-regulated emitters are available. With pressure regulated emitters, less clogging occurs due to a diaphragm in the dripper, allowing for movement when blockages occur. Longer lengths of dripper lines (laterals) than conventionally possible can be used with regulated drip, and therefore fewer submains are required. This simplifies system installation and management, and reduces system costs.

For subsurface drip, in-line or tape dripper lines are buried approximately 200 mm beneath the soil surface in the root zone of the plants. The ends of the dripper lines protrude above the surface for regular flushing. Root intrusion into the emitters is prevented by using chemical compounds that repel plant roots as long as these chemicals are present in the soil. The chemical is sometimes impregnated into the dripper or filter rings, from where it is slowly released while irrigation takes place.

A new development in the field of drip-irrigation took shape during the 1997 drought in Mpumalanga. With this system the water from a single dripper is distributed through smaller emitters at closer intervals, resulting in a much lower application rate. The results from these systems are promising with regard to water usage, system management and system cost.

With drip-irrigation there are also some unanswered questions with regard to system efficiencies. For design purposes the accepted efficiencies for normal drip-systems are between 85% and 90%, and for subsurface drip- systems between 95% and 100%.

The cost of button and in-line drip-systems are very similar to micro-sprayer systems for single-line systems. Tape drip-schemes are in the order of 40% cheaper for the in-field system.

2.2.2 Availability of equipment in rural areas

The need for this project is supported by the limited surveys done to date. "Experts" who have to advise the communities are either uncertain about where to start and what kind of system to implement, or believe that there are no or little management limitations to be considered. It does, however, seem as if all are in agreement that micro-irrigation is unaffordable to the small farmer.

The exposure of small farmers to micro-irrigation varies, but in general it is very limited. They have seen it, but do not really know what the advantages are, although they are aware of the high cost of implementation. Some are aware of the harsh practical realities, such as weed control under micro-spray systems.

Indicative of the limited exposure of the average small-scale farmer to micro-irrigation, is, for example, that major problems faced by commercial farmers concerning filtration and mechanical maintenance, are not even mentioned by small-scale farmers when micro-irrigation is discussed.

Experience has shown that small-scale farmers with some knowledge of micro-irrigation are very unsure of results that can be expected. Therefore, although irrigation specialists may feel they know what the right approach should be, much will depend on an interchange of experience and know-how with farmers.

With the limited water resources available in the RSA, micro-irrigation is an important irrigation practice for both commercial and small-scale farmers where it is agronomically and technically applicable. This fact is not as yet fully accepted by all commercial farmers. There are, however, strong indications that new farmers are eager to acquire knowledge, which can help promote the implementation of micro-irrigation.

2.2.3 Suitability of equipment

Initial literature studies indicate that the target group is not so unique that new systems have to be invented; it is rather a case of selecting appropriate systems and applying them to the needs, which may vary from one community/situation to the next.

Micro-irrigation has a wide application potential in small-scale farming, but there are certain basic requirements that need to be in place for successful system operation. The most important of these are the following:

- Clean water is essential: Water has to be filtered in order to reduce maintenance and increase the life of the system. The filter station can be described as the heart of the irrigation system. Normally sand filters are used for drip-irrigation, and mesh or disc-filters for micro-sprayers. The size of the emitter orifice determines the degree to which the water has to be filtered.

- Micro-irrigation requires pressure: Micro-systems normally work at a minimum pressure of 100 kPa, although regulated drip can even be operated at a pressure as low as 60 kPa. However, in addition to the working pressure of the system itself, extra pressure is needed for filtration and friction losses through pipelines and equipment (valves, bends, etc). Friction losses can be calculated, and between 60 kPa and 100 kPa is normally allowed for filter losses. If backflushing of the filters is required, approximately 200 kPa is required at the filter location.

Available pressure may be the single most limiting factor for the application of micro-irrigation in small-scale farming. In areas where electricity is available, it will be more viable, because electrically driven pumps are affordable, and available from very small sizes, e.g. windscreen sprayers in cars. Small petrol and diesel engines are expensive and require much more skill to maintain. Furthermore, the running costs of these engines are three to four times that of electric motors.

- Chemical properties of the irrigation water: There are certain elements which have to be removed from the water, or chemically treated for successful long-term system operation. This has mainly to do with emitter blockages. Chemical treatment requires skill and special knowledge of the problem, and it is doubtful whether the average small-scale farmer will be able to apply the treatment. Relatively expensive equipment is also needed for the treatment.

- Design flow-rate is fixed: The number of emitters per section is determined by the available flow-rate. Once the system has been installed, the design flow-rate to the irrigation system must be maintained for effective operation. This is unlike a sprinkler system where sprinklers can be added or removed according to the water-supply available.

2.2.4 Availability of support services

Support services are essential for successful farming. This is true for commercial farming, and even more so for small-scale micro-irrigation farming.

The typical services which one finds in regions where micro-irrigation is practiced mainly revolves around the selling of agricultural input articles required by the farmer, which include irrigation equipment, and buying of products produced by the farmer. Availability of electricity, communication and transport services are almost taken for granted in the commercial farming environment, while these services are normally poorly developed in the small-scale farming environment. With the usually poor financial status of small-scale farmers, it can be expected that this additional burden makes successful farming under these conditions even more difficult.

In addition to infrastructure, irrigation farming requires specific skills, which either come through experience (normally transferred from father to son), or through training. Commercial farmers acquire this fairly easily (although there are certain reservations as to their ability to deal efficiently with irrigation water). The small-scale irrigation farmer, however, relies heavily on extension services for these skills, and the down-scaling of these services by the government creates almost insurmountable problems for these farmers.

For the rural small-scale irrigation farmer there is seldom enough buying power and market opportunities in his immediate environment to sell his products at "good" prices. He is normally not in a position (financially, lack of communication and infrastructure, undeveloped marketing and organising skills) to take or send his limited produce somewhere else for better prices.

It is, however, recognised that the cost of creating or developing support services is extremely high, and if it has to be built around small-scale (irrigation) farming only, it is doubtful whether it will be affordable in regions that are remote, or even rural.

2.3 TYPES OF SMALL-SCALE FARMERS USING MICRO-IRRIGATION

For the purpose of this project, small-scale farming was defined as farming taking place on an area equal to or smaller than 20 hectares. Although it was attempted to establish the extent and location of significant small-scale micro-irrigation farming projects in South Africa at the start of the project, the project team learned about more such projects during the later years of the project. It must also be mentioned that during recent years a number of small-scale micro-irrigation projects were initiated by various NGOs, most of them with different objectives.

According to De Lange (1993), small-scale irrigation farmers can be divided into three groups, i.e.:

(a) Independent farmers: These are farmers growing crops on land that is not part of an irrigation scheme, but which usually does not belong to them either. They have their own source of irrigation water (dam, borehole, river) and are responsible for the water-supply and infrastructure (obtaining, installing and maintaining pumps, pipelines and irrigation systems). They are not subsidised by government, but may have loans. Farm size varies widely.

(b) Scheme farmers: These are farmers growing and irrigating crops on an irrigation scheme where they share a water-source, infrastructure and sometimes irrigation equipment. These schemes are usually subsidised by government or a funding agency. Farm sizes range from 0.1 ha to 10 ha.

(c) Vegetable garden (foodplot) farmers: These farmers are usually found in community gardens, having very small plots (for example, 10m x 10m) and sharing a water-source and equipment. The gardens often develop close to schemes, sharing the water-source and supply system, but having some of its own equipment to maintain (pump from scheme canal, for instance).

Another group of farmers that have been identified during the course of the project, is *backyard* farmers. Farming on the same scale as the vegetable garden farmers, these farmers are not grouped together, but have access to water for domestic purposes and allocate some of this for farming. The source is often municipal water, which means that the water is clean and needs no filtration. Whether domestic water should be used for growing crops, is, however, a debatable subject.

Although all irrigation farming should ideally be a progression towards commercial farming, and is usually planned to operate as such (especially in the case of schemes), it more often lapses into subsistence farming. This may be due to a multitude of factors, but usually because one or more element of the production cycle is not properly adhered to (for instance, planting on time, fertilising, adequate/timely irrigation, transport, marketing, etc.). This lapse is not limited to a certain type of farming operation or irrigation system, but has been found to be a generic problem in all small-scale irrigation farming systems.

As a consequence, a range of small-scale irrigation farmers are now found, from commercial farmers selling all their produce after harvesting, to semi-commercial farmers who produce for themselves and sell the excess, and finally subsistence farmers producing for their own consumption only.

Another aspect which may serve to differentiate between farmers, is the nature and degree of support services available to them. Scheme and community farmers (or in general subsidised farmers), usually have access to an extension service. This usually includes an extension officer(s) appointed by government or the funding agency to provide advice to farmers on the scheme or in a certain area. These extension officers are not always knowledgeable enough to assist the farmers, or have inadequate resources (transport, time) to attend to all the farmers in their area. Independent farmers may also have access to the public extension service, or make use of the services provided by seed and fertiliser manufacturers or a farmers' co-op.

Bembridge (1996) compiled some figures on small-scale irrigation schemes in South Africa, dividing the country into six areas. The figures, which gives an indication of the extend of small-scale irrigation schemes, are presented in Table 2.1.

TABLE 2.1 SMALL-SCALE IRRIGATION SCHEMES IN SOUTH AFRICA,1996 (BACKEBERG ET AL, 1996)

Province	No of schemes	Area (ha)	No of farmers	No of foodplot farmers	No of comm. Farmers	Main commodities
Eastern Cape	25	9460	7365	3752	2613	Maize, vegetables, citrus, lucerne
Western/Northern Cape	5	487	1004	905	99	Vegetables, deciduous fruit, lucerne
North West	20	3874	880	342	538	Wheat, cotton vegetables, maize, lucerne, fruit
Northern	102	19895	7425	310	7115	Maize, vegetables, groundnuts, wheat, cotton, citrus, fruit
KwaZulu/Natal	33	8341	763	17910	1555	Sugar-cane, maize, vegetables
Mpumalanga	17	5429	1689	740	949	Sugar-cane, vegetables, fruit
Total	202	47486	37108	23239	12869	

2.4 A COMPARISON BETWEEN SMALL-SCALE MICRO-IRRIGATION - AND OTHER IRRIGATION SYSTEMS IN SA

A number of irrigation methods are practised by small-scale irrigators in South Africa. A short summary of methods found in the field will be given here, but more information is available from the WRC project on "The evaluation of the irrigation techniques used by subsistence and emergent farmers" (WRC Report No 578/1/94).

Irrigation systems (excluding micro) used most often by small-scale farmers are flood irrigation and sprinkler irrigation. A number of center pivots are also used by some farmers, but the other two methods are far more widely found.

Flood irrigation includes basin, border and furrow irrigation. Basin irrigation is limited to irrigating fruit trees, and border irrigation is not very common due to the large volume of water needed. Furrow irrigation, and more specifically short-furrow irrigation, is practised widely on schemes. It is an indigenous method of dividing the field into short sets of furrows (5 m to 10 m long) and filling them in sequence under gravity from a concrete canal via an earth supply furrow. This method is labour-intensive, but requires no equipment other than a spade to close furrows. High efficiencies (up to 75 %) can be obtained in theory by correct layout and the right combination of stream size with the soil type and furrow slope, but in practise this is seldom achieved.

A number of forms of sprinkler irrigation are practised by small-scale farmers, and many schemes using draglines or quick-coupling systems are still operational. Farmers often have to share the sprinklers and/or pipes, and this leads to damage (no-one is responsible) and theft. Maintenance of the equipment is often a problem, with nozzles wearing out without being replaced, or hosepipes cracking and leaking.

Small-scale farmers using centre pivots are also found. The circle covered by the pivot is usually divided into segments and each segment allocated to a farmer. Scheduling is difficult, as well as cultivation where different farmers want to plant different crops. Maintenance, repairs and electricity costs have to be shared, making management difficult.

As for the extent of existing micro and drip-systems used by small-scale farmers, there are independent, scheme and foodplot farmers around the country. The systems used by these farmers vary from properly designed micro-irrigation systems, to home-made drip-lines, to "off the shelf" micro-systems, and they are applied on various crops and soils, some suitable and others less suitable. The observations made by the project team with regard to micro-systems is described in detail in Chapter 3.

2.5 INTERNATIONAL TRENDS IN SMALL-SCALE MICRO-IRRIGATION FARMING

2.5.1 Sub-Saharan Africa

The largest part of Sub-Saharan Africa has in general a more favourable climate for crop production than South Africa, where climatic conditions are dry and crops are subject to water deficits during part or all of the growing season.

In many African countries, irrigation systems vary between a few larger-scale government schemes, and a number of very small independent irrigators. The latter practise various "traditional" techniques, employed with hardly any outside financial assistance. Recently these farmers have started incorporating some "modern" (or introduced) equipment, notably small pumps, but their whole mode of financing and operation is very different from that employed on the larger-scale official schemes. These schemes are usually designed from outside, externally financed (in many instances), and usually employ salaried staff. As a consequence, government initiated projects tend to be larger; have a formal organisational structure, and depend upon "introduced" irrigation technologies.

The irrigation methods found most widely in Sub-Saharan Africa are flood (in various forms of basins, borders or furrow), and sprinkler irrigation. Probably the most significant development employing the principles of micro-irrigation is a "bucket drip-system" that was developed in Malawi during the 1970s. The system basically consists of a bucket which is raised about 1 to 1.5 meters above the ground, and one or two lengths of drip-line (usually not exceeding 20 m in length) distributing water from the bucket.

This initiative has now been developed to the extent that the equipment is available as "kits" from an American company called Chapin Watermatics Inc., who sells them on a non-profit basis at $6.00 each. This kit includes a 20 litre bucket, connectors, a small filter and two 15 m lengths of drip-tape. Preliminary information indicates that farmers experience problems with the filter, rodent damage to the drip-tape, and with availability of spare parts.

Not only can a farmer make better use of a small amount of available water, but the system also significantly reduces the labour demand of a small-crop production unit. This means that the farmer now has more time available to do additional tasks, such as clearing more land for more production, and this promotes growth and further development.

2.5.2 India

In 1994 the Indian National Committee on Irrigation and Drainage brought out a comprehensive report on drip-irrigation in India (Drip Irrigation in India, 1994). The idea behind it was to give impetus to faster expansion to drip-irrigation in the country. In view of the fact that the utilisable water-sources available in India are not enough to irrigate the cultivable land, it has been recognised that production per unit of water must be maximised, effecting utmost economy in water-use for agriculture.

Their findings were that their farmers are convinced about the usefulness of the system, but that the adoption is rather slow due to the high investment cost of the system, with recurring operational and maintenance cost. Their studies revealed that water-saving by drip ranges from 40% to 70% over surface irrigation, with a yield increase as high as 100% for some crops in specific locations.

To encourage the use of water-saving devices such as sprinkler and drip-systems their Ministry of Water Resources introduced a centrally sponsored subsidy scheme in 1982. Under this scheme the government (central and state) subsidises the purchase and installation of the devices with 50%. Seventy five percent of the subsidy budget was targeted for small and marginal farmers, with the balance of 25% for other farmers.

Some states in India, however, subsidised the implementation of drip with 100%, resulting in a huge increase of the area under drip in those states.

It was further recognised that the irrigation companies, or dealers, should supply only good quality material of standard specifications, and that they should improve on their after-sale services. In this respect a system was introduced whereby some checks were built into the procedure in order for the subsidy to be paid out. These included the following:

- A system installation report has to be compiled and signed by the dealer, the installer and the farmer and submitted to State Government. In comparison with the irrigation norms applied in South Africa, the report, however brief (it consists of approximately 30 questions), is practical and to the point.
- A warranty letter, which sets out the responsibilities of the irrigation company (proper design, installation and after-sale services, as well as that of the farmer (proper maintenance) has to be signed by the irrigation company and farmer.
- Coupons for free after-sale services, which consist of three free visits by the dealer during the first nine months of system operation.
- A draft for fortnightly reports to be completed by the farmer, giving very valuable information about the system operation, problems experienced, and the need for further guidance.

2.5.3 Middle East

This section refers only to a limited area in the Middle East, namely the western terrace of the Jordan River, and illustrates an approach followed there, from which valuable lessons can be learned. The information was obtained from unpublished reports compiled by a leading irrigation company from Israel.

This semi-arid region, which lies 300 m below sea-level, has an annual rainfall of approximately 200 mm, and irrigation was done through open channels and flood irrigation, served by water from mountain springs. The population consisted mainly of illiterate farmers, producing vegetables, citrus and bananas. Because of the supply system, growers experienced uneven distribution of water, with farms closest to the main canal receiving the most water. Yields were poor, and soil conditions worsened over the years. In the late 1960s a survey showed that per capita income of the 4000 families farming there on 1800 hectares was less than US $200 .

In approximately 1973, after research work by the Hebrew University on irrigation systems and the use of saline water for irrigation, the Ministry of Agriculture started with a campaign to promote drip-irrigation among leading farmers. Although it was soon established that farmers did not experience difficulties with drip-irrigation systems, it was difficult to persuade them to convert to the new system.

A programme then started whereby drip and fertigation systems were donated to the farmers by the government, the irrigation industry and non-profit organisations with a guarantee that farmers *would be compensated if damage was caused. Advisers of the Ministry of Agriculture were giving* full guidance on tilling methods and system operation.

In 1977 approximately 15% of the fields had been converted to drip, and in 1982 this figure was 95%. The donation of systems has since stopped, and farmers are paying for the systems themselves. Yields have increased considerably, and water consumption by vegetable crops dropped from 1 200 mm to 600 mm annually, making it possible to exploit new areas, and producing two yields annually. The vegetable production increased from 15 000 tons in 1970 to 135 000 tons in 1982.

According to developers working in the area, this example demonstrates that it is possible to overcome traditional obstacles in a traditional society, on condition that a comprehensive technological process, which takes agricultural limitations into account, is applied. It appeared as if it was easier to introduce a new crop or method, rather than improve the existing one.

Today the difference between advanced Israeli agriculture and the Arab agriculture in the Jordan Valley is hardly visible. The difference is the size of the fields; the Israeli's have large co-operative fields, whereas the Arabs are still working on small fields.

3. METHODOLOGY

3.1 INTRODUCTION

The project team originally envisaged the installation and monitoring of five trial plots, but after the first season's monitoring, it was realised that this may not be representative of the situation in the country as a whole. The steering committee suggested that the number of trial plots be increased to 15. Though the reasoning behind this idea was the distribution of trial plots, it later also proved to be a very good decision for a different reason, namely the failure of so many plots during the monitoring period. The additional number of plots added to the project team's work-load, but very useful information was gained.

During the initial stages of the project an evaluation of micro-irrigation systems was completed and summarised. This included field evaluations of the major small-farmer projects in the Western and Northern Cape provinces. Three pilot trial plots were identified and irrigation systems were installed on two of these, which could then be monitored. The farmers on the trial plots were given basic training in the implementation of the irrigation system.

In the second summer and winter irrigation seasons (November 1996 to October 1997) of this project, a further eight trial plots were identified, and irrigation systems installed on these plots (five in the Western Cape and three in the Northern Province). Monitoring of the three plots established in the Western Cape during the previous year continued, as well as monitoring of the new plots.

In October 1998 the steering committee decided that existing small-scale micro-irrigation farmers should also be visited by the project team in order to try and obtain information on all the existing systems in the country.

3.2 IDENTIFICATION OF POTENTIAL TRIAL PLOTS

Possible locations for trial plots were identified after consultation with various parties and organisations active in the developing parts of the country. Organisations included:

- Department of Agriculture: Directorate of Agricultural Engineering, Elsenburg
- Department of Agriculture: Small Farmer Development Institute, Elsenburg

- Agricultural Research Council - Infruitec, Nietvoorbij
- LANOK, Paarl
- Informal Business Forum, Johannesburg
- New Farmers Company, Cape Town
- The Land Development Unit (LDU), University of Western Cape
- Various irrigation companies throughout the country

It was realised that making the right decision regarding trial plot sites was crucial to the success of the project, and that it had to be handled with great circumspect. It became clear that locations for trial plots offered a number of possibilities, ranging from individual farmers, to scheme and garden farmers, all with varying degrees of experience.

3.3 SELECTION OF TRIAL PLOTS

Based on information obtained during interviews with the organisations mentioned in paragraph 3.2, a number of areas with significant developing agriculture were identified and visited to obtain on-site information. The conditions, farming practices and management levels varied widely, emphasising the importance of the procedure by which trial plots for this project should be identified in order to obtain useful information, and to make conclusions which are representative of conditions.

The following small-scale farming projects were visited: Genadendal, Suurbraak, Zoar/Amalienstein, Dysselsdorp, Haarlem, Thembalethu, Blanco, Groot Brak River and Friemersheim, Kranskop, Guguletu community garden, Ebenaeser, Kheis, Richtersveld, Hlaneki, Strydkraal and Veeplaats.

There are many variables under which the sites can be categorised. A general summary of the different small-farmer projects visited is presented in Table 3.

TABLE 3.1 SUMMARY OF SMALL-SCALE FARMER DEVELOPMENT PROJECTS IN THE WESTERN AND NORTHERN CAPE PROVINCES FROM PRELIMINARY SURVEY

Variable	Range	
	From	To
Number of plots	1	450
Size of plots	400 m^2	10 ha
Availability of water	Very limited	Abundance
Quality of water	Sewage ("grey")	Purified
Energy source	None	Diesel engines, Eskom power
Water pressure available	Zero	500 kPa

Eleven plots were identified for purposes of micro or drip-irrigation. Seven of the plots were in the Western Cape, one in the Northern Cape, and three in the Northern Province. These were:

Western Cape: Buysplaas Plot
Western Cape: Gugulethu Plot
Western Cape: Ebenaezer Plot
Western Cape: Genadendal Plot 1
Western Cape: Genadendal Plot 2
Western Cape: Haarlem Plot
Western Cape: Thembalethu Plot
Northern Province: Rooifontein Plot
Northern Province: Hlaneki Women's Club
Northern Province: Homu Banana Scheme
Northern Province: Strydkraal Community Garden

3.4 INSTALLATION AND MONITORING OF THE TRIAL PLOTS

It proved more difficult than expected to enter into negotiations required to establish the plots. Unseasonable rain in the Western Cape was a further delaying factor. Consequently the 1997/1998 summer season and the 1998 winter season offered the first opportunities for full irrigation on all sites.

A topographical survey was done for each of the sites. Designs were based on design standards as specified by the South African Irrigation Institute (SAII). Bills of quantities were compiled and supply of material negotiated with irrigation companies.

To establish a reference point, a SAPFACT run (WRC Report No 382/1/96) was performed for the two plot holders at Genadendal where trial plots were to be installed. The data used in the program for this initial run was based on limited contact with farmers and their activities. This is further reported on in Chapter 5.

All sites were visited regularly by the project team, and these visits, together with the original negotiations, culminated in the establishment of significant networking involving small farmers, development specialists, agricultural scientists and commercial institutions responsible for designing and supplying irrigation equipment. This networking has been of great benefit to the project team and has gone a long way towards providing answers to the questions posed in the original project proposal, while drawing attention to additional aspects that require attention.

In October 1997 a workshop was held at Elgin, which was attended by all but one of the Western and Northern Provinces trial plot farmers, an extension officer from the Northern Province and representatives from Infruitec and LDU. The purpose of the workshop was to give farmers the opportunity to meet one another and to share their experiences with this new technology they had been exposed to. The workshop succeeded in its aims.

During the early stages of monitoring it was found that a formal checklist is not the ideal way of getting information on unexpected experiences from farmers, this being of particular significance to the management of the system. Although the regular collection of technical data is important, and can be done according to a checklist, it was found that management issues emerged from informal conversations and observations.

By the end of the second season various problems experienced at the trial plots had led to only six of the plots still being in operation. After discussions with the steering committee, intensive monitoring continued on only five of the sites, while the others were visited occasionally. In addition, the team also visited other existing micro-irrigation systems operated by small-scale farmers in order to obtain additional data (refer paragraph 3.5).

In an attempt to gather more quantitative data, flowmeters and tensiometers were installed on the five sites still operational by the third season.

3.5 ADDITIONAL MONITORING OF EXISTING SMALL-SCALE FARMING PROJECTS

As a result of a suggestion made by the steering committee in October 1998, the project team visited existing small-scale micro-irrigation farmers in order to try and establish how they were performing, and what their irrigation histories were. A number of existing micro-irrigation small-scale farmers were identified, and followed up with field visits, on which occasions discussions were held with the farmers and others involved in the projects.

Location of these projects are as follows:

Free State: Back-yard projects at Koffiefontein and Petrusburg
Free State: Small-farmer schemes at Bethlehem and Harrismith
Northern Province: Masisi (individual farmer)
Northern Province: Nwanedzi (individual farmer)
Northern Province: Buysdorp (individual farmer)
Northern Province: Hlaneki B (scheme)

Through their networking with the Department of Agriculture, Infruitec and the LDU, the project team also became involved with projects in a development stage at Kheis and Leliefontein in Namaqualand, and Blackheath in the Western Cape. The experience gained at these sites were relevant and, together with the information about the other additional plots, are included in Chapter 4 of this report.

During a visit to Israel by one of the project team in October 1999, a brief visit was paid to a small-scale irrigation farming community on the West Bank. Views on this are included in Chapter 4.

3.6 OTHER LITERATURE AND DESKTOP STUDIES

A limited literature study was carried out on the subject, and a number of useful papers and publications, locally and from abroad, were found. Information from these regarded as of relevance is included in this report.

3.7 INTERPRETATION AND PROCESSING OF INFORMATION OBTAINED FROM LITERATURE AND FIELD STUDIES

Based on the SAPFACT program principles, a set of aspects, factors and criteria were developed to evaluate results of the monitoring procedure. This could be used to create another version of the program, specifically aimed at evaluating small-scale micro-irrigation farming.

Aspects identified as being important were then further analysed to develop a set of guidelines for future implementation, as suggested by the steering committee in 1998. These guidelines, as reported on in Chapter 6, are aimed at irrigation planners and officials, and presents the findings of this project regarding the use of micro-irrigation by small-scale farmers.

4. OBSERVATIONS ON SMALL-SCALE MICRO-IRRIGATION TRIAL PLOTS

4.1 INTRODUCTION

In this chapter the events at each of the trial plots for the monitoring period are summarised in chronological order. Instead of giving the summary in table format, a brief "story" is given so that the reader can get a better indication of the experiences of individual farmers. No attempt was made to draw conclusions at this point, or even to speculate about observations made. In the next chapter the analysis of each plot is done according to specific aspects and factors.

The existing (previously established) irrigation farms that were visited are also described.

4.2 TRIAL PLOTS

The 11 trial plots are described in the following paragraphs. Problems abounded on most of the plots, a brief description of which is included.

4.2.1 Buysplaas

The plot at Buysplaas, adjacent to Mossel Bay, was one of the demonstration orchards established by the Agricultural Research Council - Infruitec to facilitate the training of communities in aspects of fruit production. Buysplaas is a church community with a few hectares of irrigation along the banks of the Gouritz River. This area experiences occasional flooding, but an additional approximately thirty hectares of suitable land is available for irrigation. The community is anxious to develop this area, provided funding can be obtained.

For this development water will have to be pumped from the Gouritz River, but in order to get the project off the ground, the Regional Services have permitted the use of household water from a borehole for the first season. Other development and employment opportunities are limited in this area, and agriculture can therefore create much needed job opportunities.

The motivation behind the inclusion of this plot in the research project was that it offered the opportunity to observe a situation where a new supply system is developed from a source where pumping is required. In addition to this, the water quality is poor. Information about the irrigation system appears in Table 4.1 and Figure 4.1

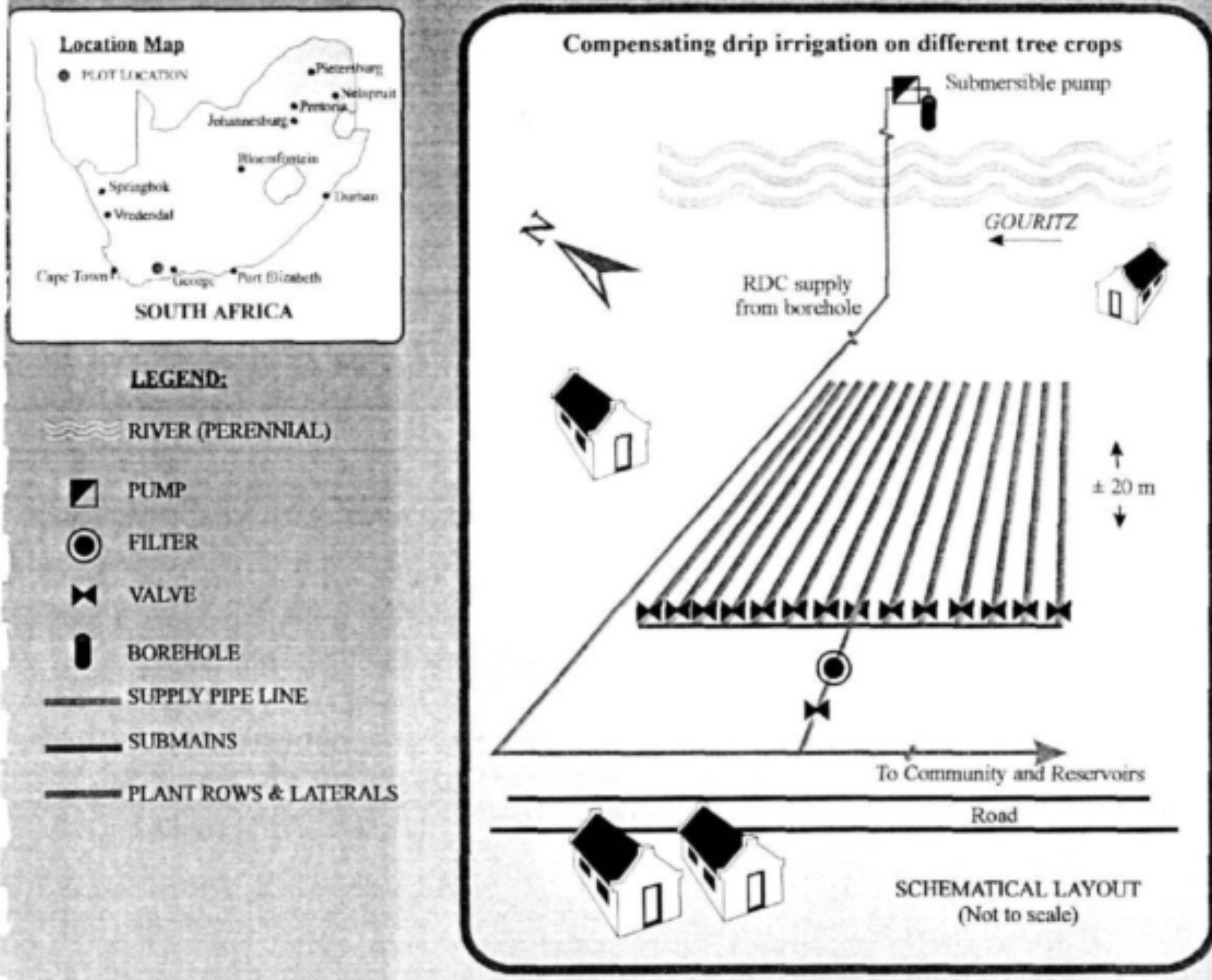
TABLE 4.1 INFORMATION ABOUT THE TRIAL PLOT AT BUYSPLAAS, WESTERN CAPE

1.	Province/Region	Western Cape
2.	District	Mosselbay
3.	Closest town	Mosselbay - 30 km
4.	Ownership	Communal land, individual plot
5.	Farm area	30 ha
6.	Soil texture	Silty loam
7.	Irrigation water source	Borehole, Gouritz River & pump
8.	Trial plot (Experimental plot)	
8.1	Installation date	September 1997
8.2	Crop	Deciduous fruit, different variations
8.3	Size	1 500 m^2
8.4	Irrigation system	Compensating drip
8.5	Lay-out	4,5 m x 1,0 m
8.6	Emitter delivery rate	3.5 l/hr
8.7	Working pressure	10 m
8.8	Scheduling practice	Infruitec guidelines
8.9	Application rate	0,78 mm/hr
8.10	Filtration	Disc filter
8.11	Fertiliser application	By hand
8.12	Irrigation system cost	R1 522,00(~R10 350/ha)
8.13	Material suppliers	Netafim

The in-field system consists of drip-irrigation with laterals spaced at 4,5 m and drippers at 1m intervals. Each lateral is equipped with a control valve, and the system is fed from the main supply line through a disc-filter. The main pipeline runs from tanks on a hill behind the houses and also provides the houses with water for domestic use. The tanks are filled from a borehole, which is managed and maintained together with the pumping operation by Regional Services.

A wide variety of deciduous fruits have been planted, including peaches, nectarines, apricots, plums, apples, and in addition, alternative crops such as prickly pears, figs, pomegranates,

Figure 4.1 BUYSPLAAS TRIAL PLOT (1 500 m²) - Western Cape - Rural/Urban area



olives, quinces and heuningbos tea. Organic and inorganic fertiliser practices are to be evaluated.

Although not generally recommended for deciduous fruit-trees, it was decided on drip-irrigation, because of the poor quality of the water (future water-supply may be from the river) and damage that could be caused by water coming in contact with the leaves. The system was designed to allow for intercropping during the developmental period of the trees.

This demonstration plot is well supported with information and services by the Land Development Unit (LDU) in co-operation with Infruitec. The day-to-day management is under control of a retired teacher who lives on a nearby plot where he grows fruit-trees and vegetables. He uses an adapted "wagon wheel" irrigation-system with home-made drippers for his vegetables, and conventional dripper lines between the vegetable rows to irrigate the fruit-trees.

This farmer's brother, a retired headmaster of the Buysplaas school, is very involved with rural development in the coastal area, and especially with the Buysplaas community. He is the driving force behind creating a better future for these people, and investigates every potential opportunity. Under his guidance a business plan was developed which addresses the agricultural development opportunities at Buysplaas. His objective is to prove to the young people in this community that being a farmer can be a noble and paying occupation.

The system was installed with the help of this ex-teacher and a number of schoolchildren, and scheduling guidelines were provided by Infruitec.

During the first season (1997 summer) onions were planted between the fruit-trees. The dripper lines were moved between the tree-rows and the onions. This worked well, and the onion yield was a success. The onions were noticeably bigger than the onions produced under flood-irrigation.

The fruit-trees (which are still very young) adapted well under the drip-system and no significant problems were experienced with the irrigation.

In January 1998 another farmer, who had had health problems up to that stage, took over the operation of the system, following the instructions given to him by the first farmer.

Due to financial restrictions, the pumping system at Gouritz River could not be implemented before the start of the next irrigation season, and the Regional Council granted permission to Buysplaas to withdraw water from the domestic supply system for an additional season.

During January 1999, however, the Regional Council restricted the community to a maximum of three hours of irrigation per week. Although this was much less than the requirement (less than 10% of the gross peak requirement), they managed to keep the orchard in quite a good condition. The farmers often remarked that if it had not been for the drip-system, the trees would not have survived the water shortage. The grant to use domestic water for irrigation would terminate in May 1999.

However, in May 1999, money was still not available to develop a supply system from the Gouritz River, and the project team assisted the Buysplaas farmers with negotiations for a further extension of the grant. This was approved, and irrigation practices were scaled down to accommodate the new limitations.

The three hours of irrigation was not sufficient to meet the irrigation requirements during peak requirement conditions, and the effect of this became clearly visible.

Apart from occasional damage to the submain and laterals, which was repaired by the farmer, system operations were carried out without problems. When the second responsible farmer left early during the last season of monitoring, the first farmer again took over.

Towards the end of the monitoring process it was noticed that a very small hole, probably made with a needle, could be seen in the dripper lines at most of the tree stems. From this a very thin stream of water (delivery of which is probably less than a single dripper) sprayed towards the trees. Responsibility could not be established, but it would seem as if someone wanted to see a jet of water, instead of drops from the drippers.

A further difficulty now faced by the farmers is to successfully negotiate the construction of a pumping site on their neighbour's property. If this is not successful, the alternative installation will be much more expensive, which may again put further development out of their reach.

The "water rights" of Buysplaas, as a riparian landholder along the Gouritz River, is unclear, and although the project team tried to initiate negotiations in this regard, no progress was made in spite of the facilitating role played by the LDU in this community.

4.2.2 Ebenaezer

This farmer was suggested as trial plot candidate by the extension office of the Department of Agriculture at Vredendal. He was considered to be a successful farmer and also to take part in the research project. An interview with him confirmed the Department's view. He is down to earth, in his late fifties, cautious about accepting new ideas, but prepared to take advice. He completed Standard 2 in school.

He farms a 1,7 ha plot on this flood irrigation scheme in the Vredendal district. The Department of Agriculture plans to develop an additional fifty plots, and their policy is to bypass an evolutionary approach and to apply advanced technology with intensive training and extension, so that the farmers can become financially independent as soon as possible. The intention is to provide each farmer with filtered and chlorinated water under pressure. The Department's officials welcomed this drip-irrigation "pilot" project.

The drip-irrigation system was installed in December 1996 on approximately 0,4 ha of paprika. The balance of the farm of 1.7 ha consists of 0,6 ha of paprika and 0,7 ha of lucerne, all under flood irrigation.

Information about the irrigation system is presented in Table 4.2 and Figure 4.2

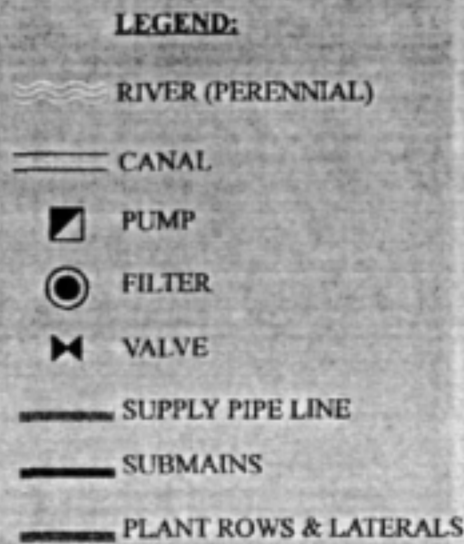
TABLE 4.2 INFORMATION ABOUT THE TRIAL PLOT AT EBENAEZER, WESTERN CAPE

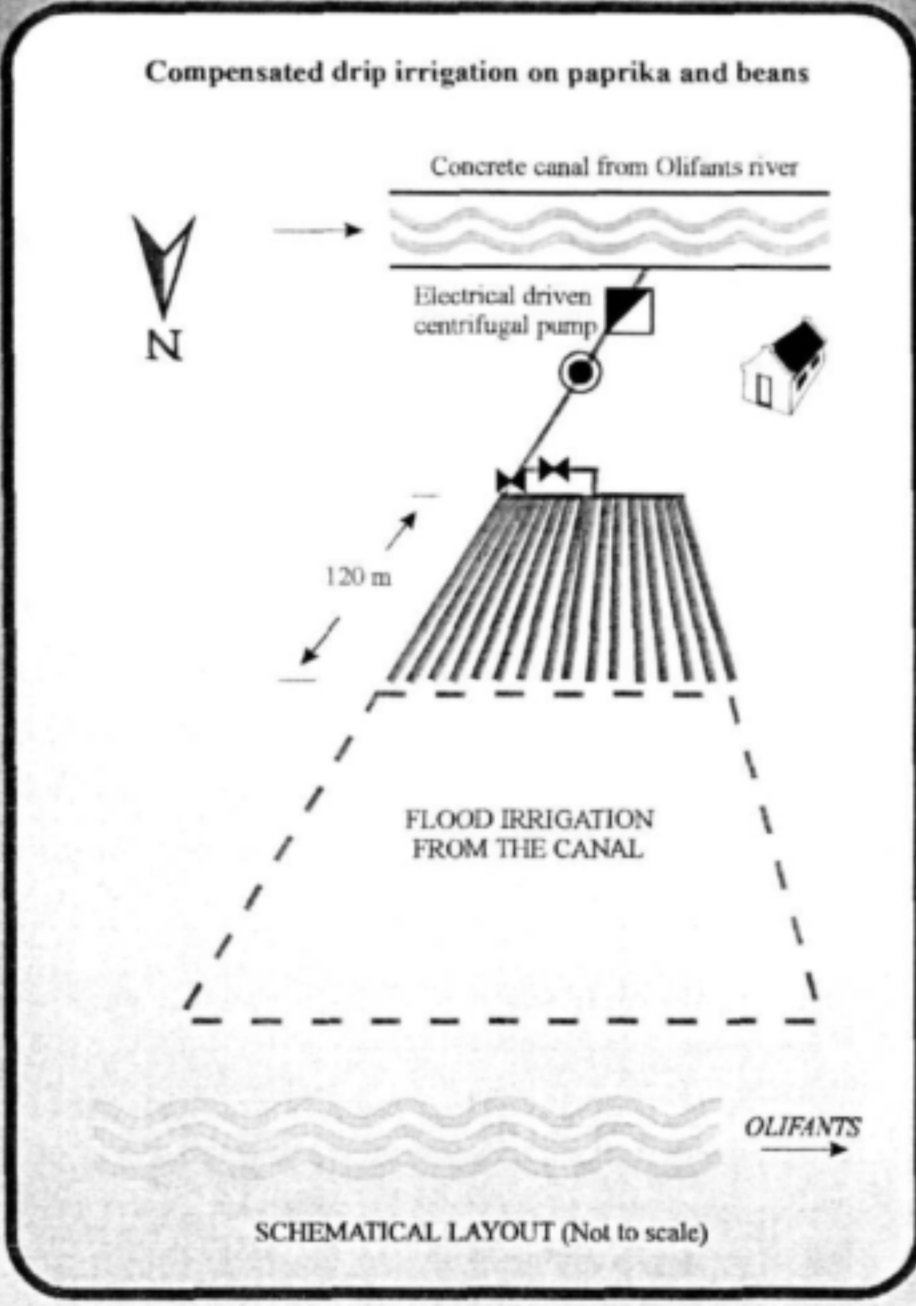
1. Province/Region	Western Cape
2. District	Vredendal
3. Closest town	Lutzville - 15 km
4. Ownership	Communal land, individual plot
5. Farm area	1,7 ha
6. Soil texture	Loam
7. Irrigation water source	Olifants River canal + pump
8. Trial plot (Experimental plot)	
8.1 Installation date	December 1996
8.2 Crop	Paprika
8.3 Size	4 000 m²
8.4 Irrigation system	Pressure-compensated drip
8.5 Lay-out	1,6 m x 0,6 m
8.6 Emitter delivery rate	2,3 l/hr
8.7 Working pressure	12 m
8.8 Scheduling practice	Dept of Agriculture and project team guidelines
8.9 Application rate	2,4 mm/hr
8.10 Filtration	3 Disc filters
8.11 Fertiliser application	Fertiliser injector
8.12 Irrigation system cost	R4 000 (~R10 000/ha)
8.13 Material suppliers	Netafim, Stewarts & Lloyds, Dept of Agriculture, M&B Pumps

On request of the extension officer, compensated drippers were installed, because this would reduce irrigation management requirements. Furthermore, in their experience fewer blockage problems are incurred with compensated drip.

The system was divided into two blocks. The laterals were spaced 1,6 m apart, and the pressure-compensated drippers were 0,6 m apart. The submains were installed on the sides of the blocks.

Figure 4.2 EBENAEZER TRIAL PLOT (4 000 m²) - Northern Cape - Rural area





The farmer and extension officer took active part in the installation of the system. The project team played less of a training role in this project, because the local extension officer, who has extensive knowledge of irrigation, supervised the installation.

This was the only trial plot where a new irrigation pump (electrical) was installed with the in-field irrigation system. The farmer soon learned how to use the system. During field visits it was evident that he was controlling his system well. Initially the farmer had reservations about the pump being too expensive to run. An electricity meter was installed to enable him to record the electricity supply to the irrigation pump, and at the end of the season the total pumping cost (electricity) amounted to approximately R80, which he considered to be not excessive, but in fact affordable.

Early in the first season of monitoring it was established that occasionally the canal water is dirty and that the one installed filter often required cleaning. Two additional filters were then added to the system (paid for by the Department of Agriculture), after which the situation was considered to be acceptable.

The original idea was to pump from a small dam filled from the canal. In this case fertiliser would be mixed in the dam before pumping it into this system. During installation, however, it was decided that the pump should be installed at the canal. The Department of Agriculture then supplied the farmer with a venturi type fertiliser injector, and during operations regularly supplied him with the necessary fertiliser mixes, which the farmer managed to apply without problems. In the beginning the farmer's son helped him to adjust the valves on the venturi system.

The project team initially provided the farmer with some guidelines on irrigation programming, but it was mainly the extension officer who advised him on when and how much to irrigate. His irrigation schedule initially was to irrigate about four hours at a time, every second day, which totals 34 mm per week. He has subsequently changed to six-hour applications every two or three days, because he found that given the shorter irrigation events, the wetted area was not adequate and he therefore had to move the line closer to the plants. Over the season he applied 400 mm, which compares well with the theoretical requirement. Due to practical difficulties experienced by the farmer the differences in irrigation application and in yields between the drip and flood system could not be monitored.

The first yield of the paprika crop under drip-irrigation was better than that of the neighbors. However, there was little visual difference between the drip and flood irrigated areas on the farmer's plot later in the season, although earlier the drip appeared better. Weed control was better under drip. The extension officers were of opinion that the net income of R10 000 earned on this farm for the year was satisfactory.

After the first harvest the irrigation system had to be removed before the soil could be prepared, and the farmer exhibited exceptional initiative and insight in the way in which he lifted and stored the drip-lines. He carefully rolled each drip-line and the submain in a roll, with the two ends closed off with pieces of rag. All these rolls were then stored neatly next to the house in the shade.

The farmer adapted to drip with little difficulty once the problems of filtration and fertigation had been resolved. He displayed a good understanding of a complex process when he modified the timing and application depth of irrigation events. Drip-irrigation was also well accepted by his neighbours.

The next season (October 1997) the farmer again planted paprika, but he was concerned about paprika as a crop, because of the intensive management demands, and he was considering beans and green peppers as future alternatives.

Severe water shortages which followed brought activities almost to a standstill, but for the farmer's sustained efforts to rescue the source of his only income.

The main reason for the water shortages is the unreliable supply from the Olifants River canal. This canal serves thousands of hectares of high-valued crops for commercial farmers. These farmers also experienced shortages from time to time due to maintenance of the canal, but they were better informed about the situation. The project trial plot is almost at the end of the canal, approximately 80 km from the inlet to the canal system, and it is to be expected that the effect here will be the greatest should the whole region try and catch up with irrigation which fell behind. It also appears as if lack of co-operation amongst the users at the end of the canal, mainly small-scale farmers, is one of the main reasons for the situation.

The paprika yield for the 1998 season was considerably less than the previous year. Although not harvested separately, it can be said with reasonable certainty that the yield of the drip-section was lower than that from the flood-irrigation section. The reason could be that the available water in the root zones of the plants in the case of flood irrigation was more than for drip-irrigation. This played an important role during the periods when water was not readily available.

After the paprika had been harvested in 1998, the farmer planted beans, and almost immediately started experiencing water shortages. Again the flood-irrigation section was able to tolerate the infrequent irrigation supply from the canal better than the drip-section. At certain stages the farmer even went to the extent of closing off the canal on both sides of his pump, some distance away. He then scooped water from the upstream side with a bucket and poured it in the section where his pump is in order to get sufficient depth for the pump to function for a while. This action was his own initiative, and probably saved the situation at the drip-section. Had he consulted the project team, a different plan would probably have been made, but this would have had financial implications for him, e.g. moving the pump, supplying pipeline and electricity to a small dam (sump) below the canal.

A further negative consequence experienced with the drip was the scorching effect of the western winds on the plants, blowing over the hot dry soil between the bean rows. This was clearly evident on plants in the western row of the tram-line (double row), planted in a north-south direction.

The farmer agreed to harvest and thresh the drip and flood sections separately. In February 1999 the dry beans were threshed, and it was determined that production under the drip-irrigation was approximately 25% less than production under the flood-irrigation. It was concluded that the reasons for the lower production under the drip irrigation were the insufficient water supply, and the scorching effects on the plants.

The farmer is still uncertain when the next planting on his farm will be done. He has not lost confidence in drip-irrigation, but is clearly disappointed, not so much in drip-irrigation, but in vegetable farming in general. As for the poor water- supply, he feels that this will have to be addressed, and that a major problem in this respect has to do with the lack of co-operation among small-scale farmers in Ebenaezer.

4.2.3 Genadendal Plot 1

The plot at Genadendal is situated on an 11 ha farm which forms part of a 110 ha area of farmland. This area is allocated to twelve farmers who cultivate their land with the assistance of LANOK, an agricultural development corporation, which provides support services and advice.

There is an understanding between LANOK and the farmers that fynbos should be grown on 2 ha of each farm. On the farm where the trial plot is situated, the 2 ha fynbos was irrigated with drip-irrigation, so that the necessary basic infrastructure was available for the trial plot. The area of the trial plot used for vegetable production was previously irrigated by mini-sprinklers.

The farmer is experienced in irrigation and obtained his initial training on a commercial farm. On average he grows two crops per season on the same land. His brother, an enthusiastic young man and one of the few young farmers encountered, managed the plot. The farmer himself spent most of his time harvesting wild fynbos on commercial farmers' land. He considered this to be essential from a cash-flow point of view.

The system was installed in November 1996, and was the first installation for this research project. The irrigation infrastructure of the farm is good, with a sand-filter being used, and fertiliser applied by means of a fertiliser injector.

Installation was done with the assistance of the farmer. Small tasks, such as tying wires round connectors were left for him to complete. However, on the day the system was to be commissioned (a week after the installations had been completed), these wires were still not in place, causing the pipes to come loose under pressure. Reasons for this reluctance probably had to do with the heavy late rain which gave irrigation a low priority.

The system was operational towards the end of November 1996, the first crop being pumpkins. Already during the early stage of the project (December 1996) the farmer expressed his satisfaction with the system, and was planning to expand it to 0,5ha for his own account.

Guidelines on scheduling were given to the farmer by the project team. His normal practice is to irrigate three to four hours every day, with little change to this schedule over the life-cycle of the plants.

Information on the irrigation system is presented in Table 4.3 and Figure 4.3.

TABLE 4.3 INFORMATION ABOUT THE TRIAL PLOT 1 AT GENADENDAL, WESTERN CAPE

1. Province/Region	Western Cape
2. District	Caledon
3. Closest town	Genadendal - 5 km
4. Ownership	Communal land, individual plot
5. Farm area	11 ha
6. Soil texture	Sandy loam
7. Irrigation water source	Sonderend River & electric driven pump
8. Trial plot (Experimental plot)	
8.1 Installation date	November 1996
8.2 Crop	Cucurbits
8.3 Size	2 500 m^2
8.4 Irrigation system	Non-compensating drip
8.5 Lay-out	1,6 x 0,6 m
8.6 Emitter delivery rate	2,1 l/hr
8.7 Working pressure	10 m
8.8 Scheduling practice	Project team guidelines
8.9 Application rate	2,19 mm/hr
8.10 Filtration	Existing sand - and disc filters
8.11 Fertiliser application	Fertiliser injector
8.12 Irrigation system cost	R2 250 (=R9 000/ha)
8.13 Material suppliers	Netafim, Plastro

The total irrigation applied on the two plantings under drip-system was approximately 45 mm per week, compared to 34 mm applied under the mini-sprinkler systems. These figures are calculated from information supplied by the farmer on hours of irrigation. For average climatic conditions, one would expect a weekly application of 38 mm to be necessary for these crops, and this information was included in guidelines given to the farmer.

Figure 4.3 GENADENDAL 1 TRIAL PLOT (2 500 m²) - Western Cape - Rural area

LEGEND:

RIVER (PERENNIAL)

PUMP

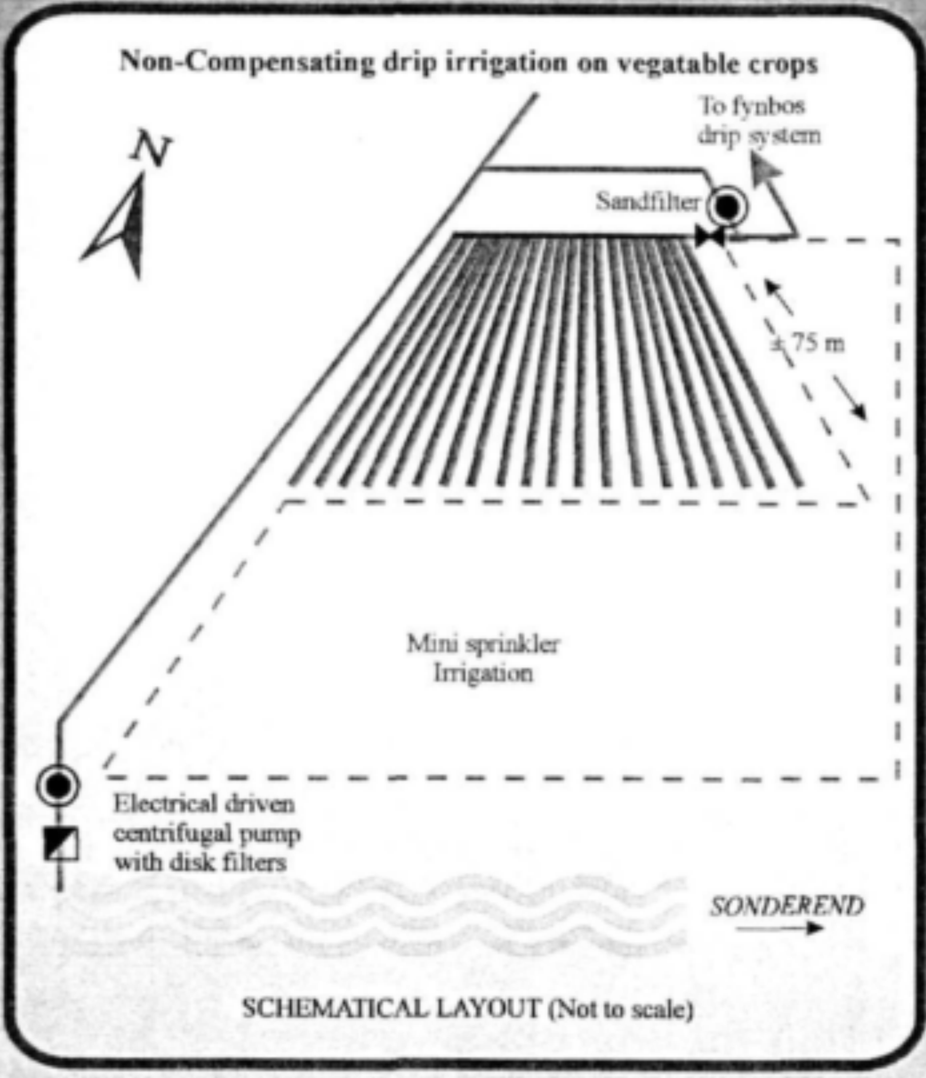
FILTER

VALVE

SUPPLY PIPE LINE

SUBMAINS

PLANT ROWS & LATERALS



An existing pump installation provides water from the Sonderend River. A disc-filter at the pump station filters the water for the micro-sprinklers, and a sand-filter in the field does additional filtering for the drip-system on the fynbos. The drip-system for the trial plot was connected downstream of the existing sand-filter.

The in-field system consisted of 20 laterals of 72 m each at 1,6m spacing, on an almost level area. The 2,1 l/hr in-line non-compensating drippers are spaced at 0,6m intervals. The system is served by a submain on the one side of the block, and equipped with a single control valve.

No clear differences were noticeable between the pumpkins under drip and those irrigated with mini-sprinklers. In both situations fertiliser was applied by means of the fertiliser injector. During initial observations it was noticed that plants which had been planted to replace dead plants had in fact grown better. It was also apparent later during this first season that there were fewer weeds in the drip-system.

After the first harvest at the end of January 1997, the farmer was planning to plant tomatoes, which would be his first attempt with this type of crop. He was also planning to expand the system to 0,5 ha.

These plans did not, however, realise, and in March 1997 he again planted squashes under drip, while other crops under the mini-sprinklers included cabbage, potatoes, pumpkins, carrots and beans.

After these first two plantings the farmer and his brother were very satisfied with the drip-system, and although not quantified, reported a production increase under the drip-system. They attributed this to the longer picking season effected by the drip-system. They experienced fewer weeds under the drip-system than under mini-sprinklers.

The next planting (spring 1997) was delayed due to waiting for the tractor of LANOK to cultivate the lands. Watermelons, squashes and potatoes were planted (October 1997) under mini-sprinklers, and the farmer intended planting melons under the drip-system. This only materialised towards the end of November 1997.

At no stage did the farmer experience problems with the operation of the drip-system, although his fertiliser pump gave problems several times. At one stage early in 1997 a pressure gauge was installed at the control valve to the drip-system for better control.

Tensiometers installed early in 1998 were well maintained, but the farmer made little use of the readings.

A deterioration of the situation on the farm was noticeable from early 1998 onwards, especially regarding the control of weeds. The farmer (older brother) decided at that stage to spend more time on the farm in order to help with the day-to-day management of the farm.

Record-keeping of irrigation activities was not maintained. After a reluctant effort, the records were lost on the farm.

Problems were also experienced at the fynbos drip-system due to the fact that laborers damaged many of the dripper lines with shovels. The plastic sheeting was then removed in order that leakages could be detected and the pipes repaired, but the fynbos growth was negatively affected.

In March 1998 the pump broke and the remaining crops were then cultivated further under dry-land conditions. Fortunately it rained frequently, but due to the weeding problems the yield was poor.

The pump remained out of operation for approximately two months, after which time broken mainline pipes were observed by the project team indicating that irrigation had still not commenced.

It was during this period that the younger brother left the farm to work as garden labourer in a nearby town, and this clearly contributed to the further deterioration of the farm.

In October 1998 the farmer indicated that due to the high risks involved in vegetable farming, he considered planting deciduous fruit. He and a few fellow farmers had suffered considerable financial losses due to an unsuccessful contract with a commercial farmer regarding the planting of cabbage. He was, however, still considering planting green peppers or tomatoes in November 1998.

Towards the end of January 1999 the situation further deteriorated and the cultivation of vegetables was discontinued. Cattle were grazing on these lands, weed problems in the fynbos area increased, and a flood which went through his field caused further damage.

Financing from LANOK ceased early in 1999, and this situation forced the farmer to discontinue farming and to concentrate full-time on collecting wild flowers for selling purposes.

4.2.4 Genadendal Plot 2

This farmer farms on open land belonging to the Genadendal community. This area comprises some 200 ha, but he concentrated on 6 ha adjacent to the town dam. It appeared that he had been given permission to farm the land and extract water from the dam, but this seemed to be a local arrangement. The land is steep and in a fairly rough condition, making irrigation management difficult. No electricity was available. He was the only active farmer in this specific area, and was producing potatoes, squashes and pumpkins under sprinkler irrigation at the beginning of the project.

The farmer is also a businessman who has a butchery, and owns taxis which he maintains himself. He is an enterprising person in his early forties and gives the impression of being someone who gets things done. He was assisted by two young men in both the taxi business and the farming. They likewise make a good impression, one of them seeming to be very knowledgeable about farming. The farmer himself does not seem to have had extensive irrigation experience, but his mechanical knowledge has stood him in good stead. He finances his farming enterprise from private sources, and his objective is to extend it to 20 ha.

The experimental plot consists of 0.25 ha of 2.3 l/hr pressure compensated drippers spaced at 0.6 m, with a spacing of 1.5 m between the dripper lines. It consists of 21 laterals, running more or less on to the contours, but with a considerable difference in height between the first and the last lateral. Compensated drip was used, due to the possible large fluctuation in pressure in the system. A disc-filter was also installed. Water is pumped directly into the system from the dam using the farmer's own diesel engine and pump.

Information on the irrigation system is presented in Table 4.4 and Figure 4.4

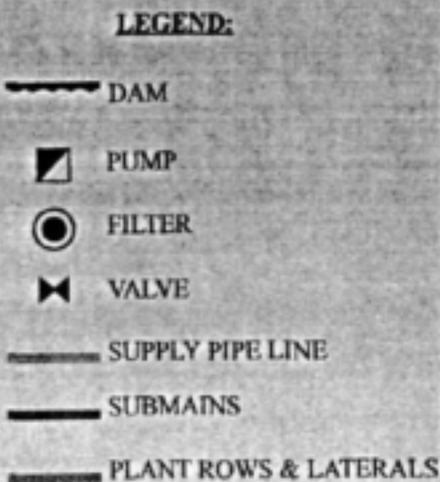
TABLE 4.4 INFORMATION ABOUT THE TRIAL PLOT 2 AT GENADENDAL, WESTERN CAPE

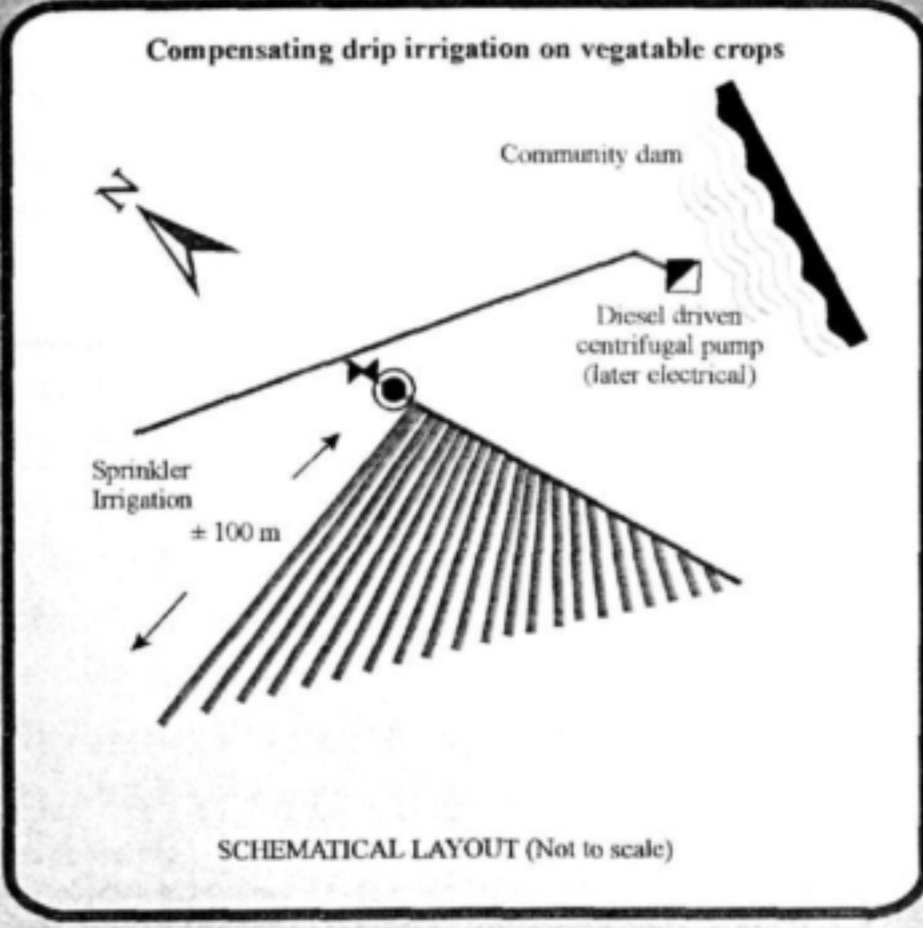
1. Province/Region	Western Cape
2. District	Caledon
3. Closest town	Genadendal - 2 km
4. Ownership	Communal land, individual plot
5. Farm area	6 ha
6. Soil texture	Rockey clay (shale)
7. Irrigation water source	Town dam for town and diesel driven pump
8. Trial plot (Experimental plot)	
8.1 Installation date	November 1996
8.2 Crop	Cucurbits
8.3 Size	2 500 m^2
8.4 Irrigation system	Compensated drip
8.5 Lay-out	1,5 x 0,6 m
8.6 Emitter delivery rate	2,3 l/hr
8.7 Working pressure	10 m
8.8 Irrigation programme	Project team guidelines:
8.9 Application	2,4 mm/hr
8.10 Filtration	Disc filter
8.11 Fertiliser application	By hand
8.12 Irrigation system cost	R2 800 (~ R11 200/ha)
8.13 Material suppliers	Netafim

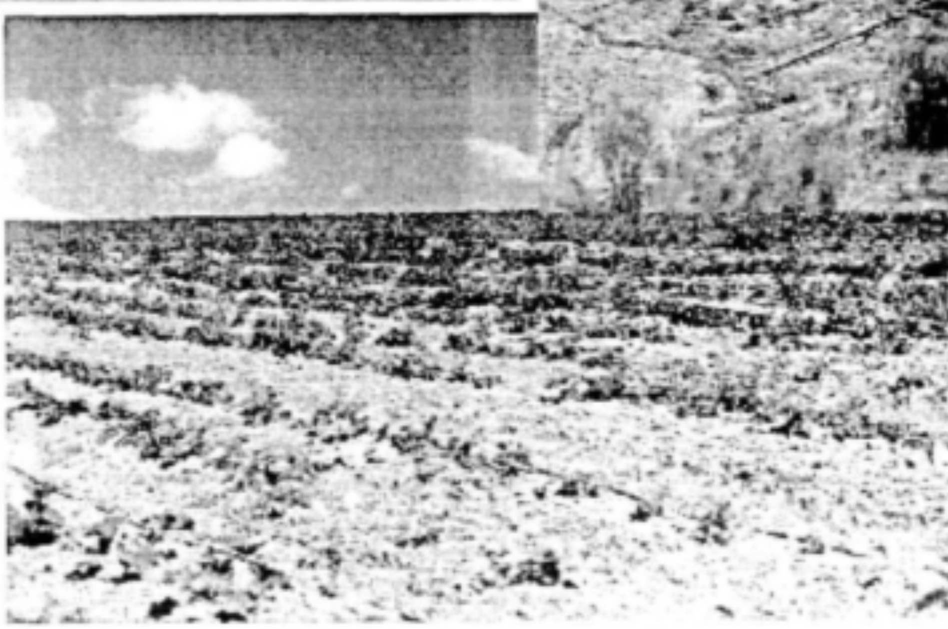
The system was installed in November 1996 with the assistance of the farmer's labourers. The farmer himself, however, was occupied with his other activities, and could not be present at the installation. As in the case of the other plot in Genadendal, the tying of wires round connectors were left for him to complete, and also in this case it was neglected, causing delays during commissioning a week later due to pipes coming loose.

The farmer has never before been exposed to drip-irrigation and after an initial relatively unenthusiastic attitude, he became much more interested when he saw the first drops of water.

Figure 4.4 GENADENDAL 2 TRIAL PLOT (2 500 m²) - Western Cape - Rural area







At time of installation the farmer was growing potatoes and squashes, the drip-system being installed on the squashes. During the second visit by the project team, approximately one month after the system had been commissioned, it was found that the farmer still had not used the system, and crops were dry (both the sprinkler and the drip-systems). The reason given was that his diesel engine had broken down and that he was urgently waiting for a new ESKOM supply-point in order to use an electricity-driven pump.

In middle January 1997 when he was again visited, the vegetables had already suffered beyond recovery. The crops under the sprinkler system suffered similarly, except for his potato yield which did not require further irrigation. Guidelines on scheduling were given to the farmer, but since virtually no irrigation occurred, it is not clear to what extent these guidelines were followed.

By the end of January 1997 a meeting was held with the farmer, and he acknowledged that the system had failed due to the breakdown of the diesel engine, which he did not intend repairing. He was, however, eager to carry on with the drip-system once he had electricity, the connection for which he had already paid a deposit.

He again started preparing the land, intending to plant onions in winter, to be irrigated by means of electricity. Removal of the dripper system was carelessly done and stored on the side of the field. In August 1997 he could no longer wait for electricity, and he had the diesel engine repaired. He changed his planting programme and planted potatoes, and was also planning to plant butternuts in October. He was very upset about the electricity supply and could not understand why ESKOM did not respond, despite his many inquires. The project team then also put pressure on ESKOM, and experienced the frustration of promises that were not honored.

In the mean time the project team also assisted the farmer with a new layout, design and pump conversion from diesel to electricity.

The electricity supply line was only constructed in the beginning of December 1997. Towards the end of January 1998 the farmer took his diesel-driven pump to a workshop in Caledon to fit a second-hand electric motor (which he had).

At this stage the small area of butternuts which he had planted earlier was in poor condition, and could be regarded as a failure.

He then built a new impressive pump-station. The installation was done on a platform above the high-water level of the dam, using an old lorry chassis as an access bridge. The hydraulic components used was correctly installed, and of a good standard.

It was only in July / August 1998 that the system came into operation. He planted broccoli and carried on with sprinkler irrigation, which performed well. He was still keen on using the drip-system and intended planting squashes in spring, and to purchase additional dripper lines. This, however, never realised, and until the end of the project the system remained on the side of the land.

4.2.5 Gugulethu

This experimental plot was installed on land which is part of an old-age home in the Gugulethu township, and is therefore an urban plot. The initial objective was to produce vegetables for the old-age home. The project team made contact with this plot-holder through the LDU at the University of the Western Cape, who is responsible for planning food plot projects in this and other urban areas.

The system was installed in April 1997 and consisted of six dripper lines, each 7,5 m long. Different types of vegetables were planted on both sides of the dripper lines. Water-supply was from the municipal system, eliminating filtration, and paid for by the old-age home.

The worker in charge of the irrigation system at the initial stage, which was during winter, expressed his satisfaction with the system, but during winter very little irrigation is obviously needed. During August 1997 he was replaced by a woman by the LDU. She developed more seedbeds, one of the objectives being to supply seedlings to other urban gardeners. Without discussing it with the project team, she removed the drip-system, because she was of opinion that it would not function well in her situation. After she had removed it, the irrigation methods were discussed with her, and she requested that a micro-spray system, better suited to seedbeds, be installed.

Micro-jets were installed on the area where the dripper lines were removed, and the plot was also extended to a new area where she was growing various types of vegetables. The total area under micro-irrigation then amounted to 140 m². This consisted of several areas (18 in total), varying from 3 m^2 to 10 m^2, each equipped with one or two micro-jets. It was controlled with two valves, fed by a supply line from the municipal mains.

She irrigated the balance of the area with a garden sprayer moved by hand. The garden sprayer tends to be inefficient due to spray drift and it is time-consuming. The light sandy soil and strong winds dried out the topsoil layers of the seedling beds to such an extent that the frequency of irrigation became of major importance.

The project team showed her how the system worked and also provided some scheduling guidelines. These guidelines were very basic, namely two hours in the morning, and if necessary, another hour in the afternoon, the reason being that wind presents a problem in the area, and these are the times of day with the least wind.

The farmer was a salaried employee and showed drive and initiative, making major progress in developing the garden. She was not only responsible for production, but handled sales as well.

This experimental plot was the closest to the Stellenbosch office of MBB, and therefore more visits were made to this plot than to any of the others. Progress was noticed on all visits and the farmer was a very dedicated user of the system. She believed that she was saving time by not being occupied with hosepipe irrigation, and also believed that the quality of the vegetables to be better under the micro-system. Information on the irrigation system at Gugulethu is presented in Table 4.5 and Figure 4.5

TABLE 4.5 INFORMATION ABOUT THE TRIAL PLOT AT GUGULETHU, WESTERN CAPE

1.	Province/Region	Western Cape
2.	District	Gugulethu
3.	Closest town	Cape Town (urban plot) - 0 km
4.	Ownership	Old Age home
5.	Farm area	2 000 m²
6.	Soil texture	Sandy
7.	Irrigation water source	Municipal Water supply
8.	Trial plot (Experimental plot)	
8.1	Installation date	September 1997
8.2	Crop	Vegetables
8.3	Size	140 m²
8.4	Irrigation system	Initially drip, now micro
8.5	Lay-out	N.A. x 2 m
8.6	Emitter delivery rate	50 l/hr
8.7	Working pressure	10 m
8.8	Scheduling practice	Project team guidelines: two hours in the morning and sometimes another hour in the evening.
8.9	Application rate	± 8 mm/hr
8.10	Filtration	No filtration
8.11	Fertiliser application	By hand
8.12	Irrigation system cost	R350.00
8.13	Material suppliers	Netafim

It took approximately six months from the date when those involved decided to accept the system, until the date that it could be installed. This was due to successive delays, mainly practical on-site aspects, such as work programming, "building" of beds and acquiring plant material.

The worker involved during the first part of this trial, who had not previously used micro-irrigation, did not experience problems with the system, and on two occasions when repairs were needed (leaking pipes), he managed to do it without having to discuss it with the project team. On one of the occasions he proved to be quite innovative by turning a lateral around which had a leak very close to the inlet of the laterals. This end then became the closed end of the lateral.

Figure 4.5 GUGULETHU TRIAL PLOT (140 m²) - Western Cape - Urban

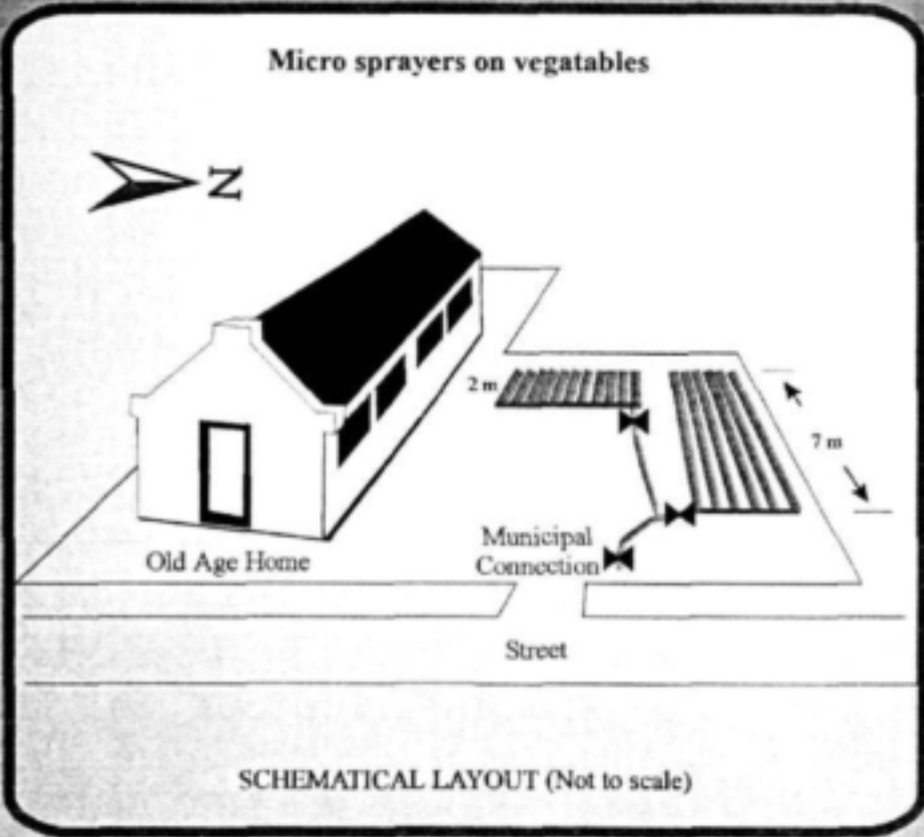
LEGEND:

VALVE

SUPPLY PIPE LINE

SUBMAINS

PLANT ROWS & LATERALS



The person who took over the garden in August 1997 also had no micro-irrigation experience and with her way of planting seeds under the drip-system, she soon made the correct observation, namely that the drip would not function well, which culminated in the better decision to install the micro-jet system.

In the beginning she contacted the project team from time to time when repairs were needed on the laterals (damage due to workers cleaning the beds), but after she had been shown how to do repairs, she did this herself, as long as she had the necessary equipment, which were provided by the project team.

She was also innovative in moving the micro-jets to new locations in the beds, which she regarded as more effective.

Certain aspects which she was asked to attend to, took very long to accomplish, e.g. burying the supply pipeline, and some tasks were never done, e.g. organising repair work to a leaking pipe. Her record-keeping of the applied irrigation was satisfactory at certain stages of the project.

Soon after she started working at the site it became evident that she was unhappy about her working agreement with her employer. This was also reflected in her attitude towards her work, and in time this was also evident in the lack of weed control and leakages in the laterals. Her problems could not be resolved, and she resigned in June 1998 to go back to the Eastern Cape where she grew up.

Water consumption at this plot was extremely high, which the farmer attributed to the fact that security personnel at the gate of the old-age home irrigated during weekends, and the system was left irrigating much longer than necessary. In addition, a leaking pipe on the upstream side of the research project water-meter had not been repaired for months, even though the project team paid for this to be done.

During May 1998 a further area of approximately 200 m² was developed by LDU on the old-age home plot. This was to be managed by an elderly man, and a drip-system was designed. However, financing was not available for this purpose, and almost all the planted vegetables were eventually (towards August 1998) destroyed by birds and lack of water. Some irrigation was done with a garden sprayer.

This particular man also continued working on the trial plot, but the situation deteriorated rapidly. By March 1999 the garden was in very poor condition, and by May 1999 the LDU decided to remove the entire micro-irrigation system.

4.2.6 Haarlem

The fruit plot at Haarlem was established in 1995 by the LDU in collaboration with Infruitec as a deciduous fruit demonstration plot. A number of different types of deciduous fruit-trees were planted on an area of 3000 m². The basic purpose of the demonstration plot was to determine which cultivars and rootstock should be used in Haarlem, and it also served as an orchard for training the community.

The general condition of the plot was not good when the project team became involved. Reasons given were frequent damage by animals from the community, insufficient labour for weed control, and lack of general maintenance. Irrigation was done by means of a few dragline sprinklers. A woman working in the town office went to the plot from time to time to apply the irrigation. This situation developed despite the involvement of Infruitec and the LDU. This situation could probably be ascribed to internal conflict in the community.

The farmer appointed to look after the plot has his own piece of land, approximately 0.2 ha a few hundred meters away from the LDU plot, with mature apple trees irrigated by movable sprinklers. He had been a carpenter and returned to Haarlem when he retired.

Information on the irrigation system at Haarlem is presented in Table 4.6 and Figure 4.6

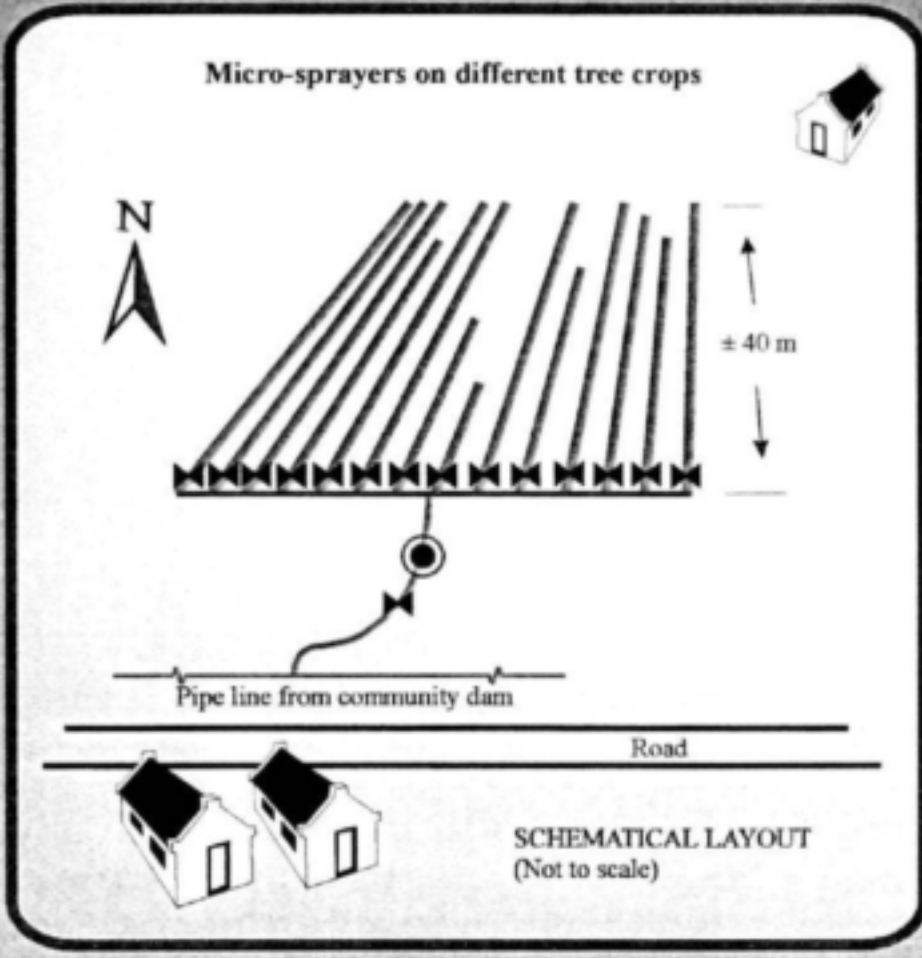
TABLE 4.6 INFORMATION ABOUT THE TRIAL PLOT AT HAARLEM, SOUTHERN CAPE

1. Province/Region	Western Cape
2. District	Haarlem
3. Closest town	Haarlem - 0 km
4. Ownership	Communal land, demonstration plot
5. Farm area	4000 m²
6. Soil texture	Clay loam
7. Irrigation water source	Community dam, under gravity
8. Trial plot (Experimental plot)	
8.1 Installation date	April 1997
8.2 Crop	Various fruit cultivars
8.3 Size	2800 m²
8.4 Irrigation system	Micro sprayers
8.5 Lay-out	4.5 m x 2.5 m (varying)
8.6 Emitter delivery rate	50 l/hr
8.7 Working pressure	15 m
8.8 Scheduling practice	Project team and Infruitec guidelines
8.9 Application rate	± 4.4 mm/hr
8.10 Filtration	Disc filter
8.11 Fertiliser application	By hand
8.12 Irrigation system cost	R2900 (~R6900/ha)
8.13 Material suppliers	Intech

Sixteen laterals, each with its own control valve, were installed at spacing of approximately 4.5 m. Spacing of the micro-sprayers varied according to the tree spacing, but was in the order of 2.5 m.

Irrigation water is withdrawn under gravity from the agricultural pipe reticulation system in Haarlem, which receives water from a dam higher up in the mountains. Due to the high pressure, a pressure reducing valve was installed at this point, followed by a disc-filter.

Figure 4.6 HAARLEM TRIAL PLOT (2 800 m²) - Western Cape - Rural/Urban area



LEGEND:

PUMP

FILTER

VALVE

SUPPLY PIPE LINE

SUBMAINS

PLANT ROWS & LATERALS

The reason for the individual lateral control was to apply irrigation according to the different irrigation requirements of the different crops on the plot. The specifications for the design came from the Department of Agriculture, also specifying that the design must be such that a maximum of any four laterals can be irrigated together. With 15 laterals it therefore implies that four "shifts" are needed to complete an irrigation cycle.

Installation of the system was done with the help of three workers organised by the representative of LDU. The appointed farmer also showed interest in the installation and appeared to be eager to start using it, the implication being that he might possibly apply it in his own apple orchard in future.

A few small outstanding tasks were left for the farmer to complete, i.e. to bury the submain and to support the filter with poles. These took a very long time (months) to be accomplished.

Initial guidelines on scheduling were provided by the project team, after which Infruitec supplied this information regularly, based on the climate data of the region.

Although the system was installed in April 1997, it was only in September of that year that the first irrigation took place. At that stage there was a keen interest among the community in the plot, and its general appearance also improved.

The farmer managed the irrigation system fairly well, although it was obvious that he was not very dedicated to the management of the plot. However, from the start he had problems with the fact that he could irrigate only four laterals at a time, the implication being that he had to spend considerable time operating the system.

The pressure reducing valve was then adjusted to allow him to irrigate five laterals at a time. This of course put more stress on the filter, and more frequent cleaning was required. From time to time the irrigation water was very dirty, and this required even more cleaning of the filter. Very often on site visits (almost every visit) it was found that the pressure in the system was too low, the reason being that the filter needed cleaning.

Towards the end of 1997 the condition of the plot started deteriorating, with excessive weed growth. Leakages due to damaged laterals were not repaired by the farmer, and although he was getting more excited about the application of a micro-irrigation system in his own orchard, it appeared that he was spending less time on the trial plot.

The project team realised that the farmer had difficulties in establishing when the filter was dirty, and for this reason two pressure gauges were installed (one upstream and one downstream of the filter). Cleaning of the filter subsequently improved slightly.

Despite regular discussions about the maximum number of laterals that can run simultaneously (which was more a filter and water-meter limitation than anything else), it happened repeatedly that on arrival the project team found more than five (six to eight) lateral valves open, with the filter dirty and the system obviously running at very low pressure.

The situation towards the end of the irrigation season of 1997/1998 (March) deteriorated further in the sense that the micro-jets could not function properly due to weeds that were almost out of control. Blockages in micro-jets were also fairly common. At this stage the farmer decided once more to use his dragline sprinkler on the rows planted with blueberries and honey tea.

He considered this necessary because the plants became fairly dense and the micro-jets did not reach all the plants. Acceptable weed control would have improved the situation so that the micro-jets could be more effective, but it was realised that dripper lines on these rows would in fact have been a better option.

The farmer was by then (April 1998) very serious about installing a micro-spray system in his own orchard. The costs involved amounted to approximately R1 840 for 0,16 ha, but whether he would have been able to afford it depended on his income for 1998.

Cattle once more caused damage on the trial plot, which was a further setback for the plot, which was already in a state of neglect.

The farmer had considerable difficulties with record-keeping, and also with taking readings from the water-meter and tensiometers. His lack of understanding of the tensiometer operation and maintenance also caused the tensiometers to malfunction continuously.

Labourers who cleaned the orchard with spades in June 1998 (not a good job done) moved the laterals very untidily, and the laterals were pulled out of the submain at a number of places. Many micro-sprayers were off their spikes.

From then onwards the system deteriorated rapidly. The farmer fell ill in June 1998 and could not manage the irrigation any more. Another man, employed full time, took over the responsibilities of the irrigation. The original farmer explained to him how to operate the system. The system remained messy and tree growth was poor.

In summer 1998/1999 potatoes were planted between the tree rows, and the area was again irrigated with the draglines. Apparently an important reason for the intercropping was to improve weed control.

When monitoring of this plot ended in July 1999, the condition of the orchard was worse, and the micro-irrigation system in a similarly poor condition. In the order of 30% of the emitters were not functioning, or were lying on the ground.

During a brief discussion with the original farmer, it appeared that he was still interested in a micro-system for himself, but due to the poor prices he received for his apples, and his high medical expenses, he is unable to afford the system.

4.2.7 Rooifontein (Kamassies)

This site was selected in consultation with the extension office of the Department of Agriculture in Springbok. The situation there is typical of this area, with the water being pumped from a well in the river into a reservoir on the hillside. Previously prickly pears and lucerne had been produced under flood irrigation, but there were no signs left of these.

The community wanted to start a vegetable garden, and change to permanent crops at a later stage.

After initial interviews with the community leaders in December 1996, it took a considerable time for the system to come into operation. There were several reasons for this, the main being late delivery of a pump and engine which was being assembled for them, and which they were organising themselves. The drip-system was installed during May 1997 and the first irrigation took place during July 1997.

Information on the irrigation system at Rooifontein is presented in Table 4.7 and Figure 4.7

TABLE 4.7 INFORMATION ABOUT THE TRIAL PLOT AT ROOIFONTEIN, NAMAKWALAND, NORTHERN CAPE

1.	Province/Region	Northern Cape
2.	District	Kamieskroon
3.	Closest town	Kamieskroon - 50 km
4.	Ownership	Communal
5.	Farm area	10 ha
6.	Soil texture	Sand loam
7.	Irrigation water source	Well in river bed + pump and diesel engine
8.	Trial plot (Experimental plot)	
8.1	Installation date	May 1997
8.2	Crop	Cabbage, onions, beans
8.3	Size	2 200 m²
8.4	Irrigation system	Non-compensating drip
8.5	Lay-out	1.6 m x 0.6 m
8.6	Emitter delivery rate	2 l/hr
8.7	Working pressure	11 m
8.8	Scheduling practice	Project team
8.9	Application rate	2,08 mm/hr
8.10	Filtration	Disc filter
8.11	Fertiliser application	By hand
8.12	Irrigation system cost	R2 000 (~R9 100/ha)
8.13	Material suppliers	Andrag

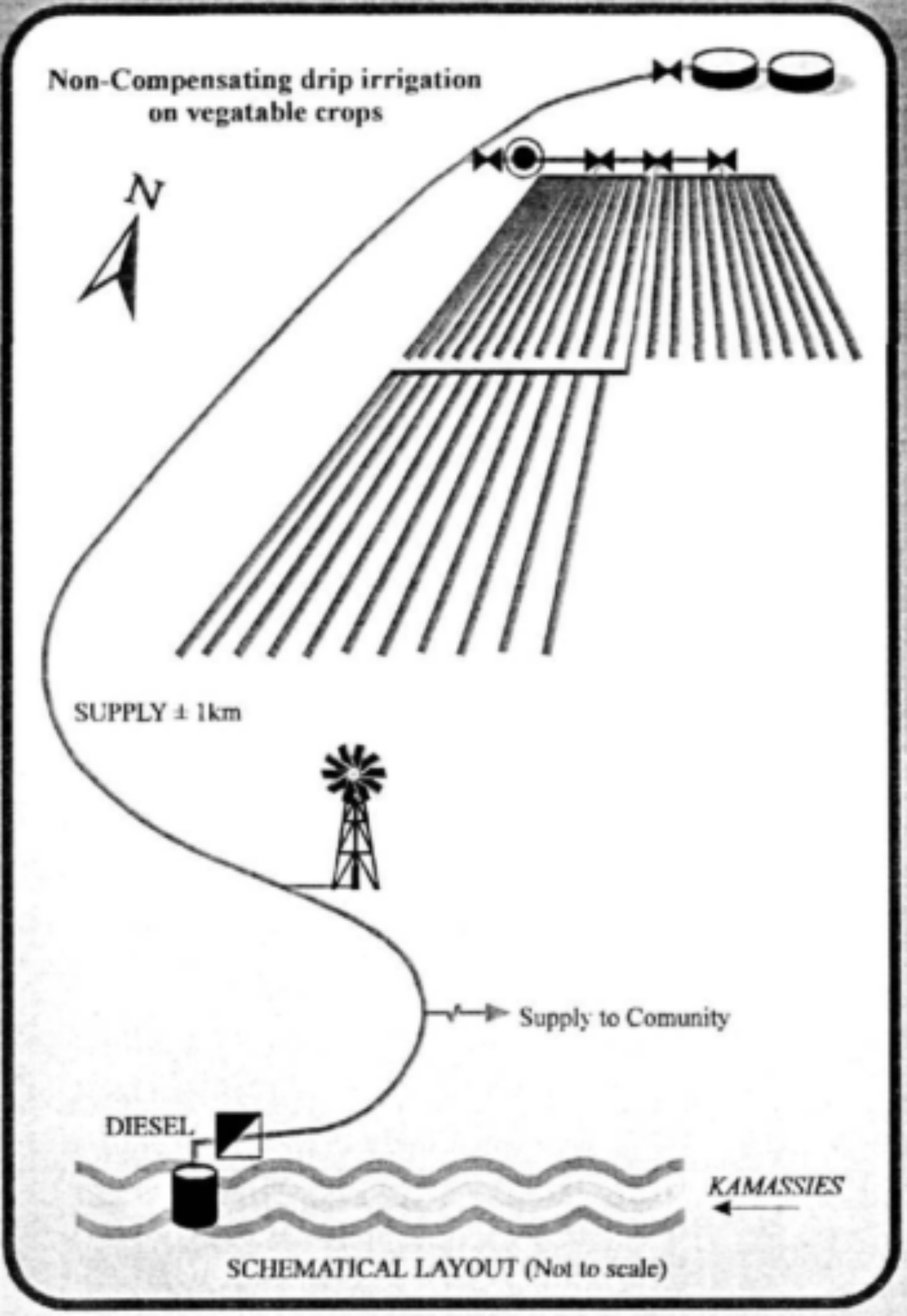
During September 1997 an additional area was developed under drip- irrigation, after which the total area amounted to 0,22 ha.

Water was pumped to two existing reservoirs about 15 m higher than the field, the working pressure at the control head being approximately 11 m. Regardless therefore whether the pump was working or the water ran under gravity from the reservoirs, the water pressure

Figure 4.7 ROOIFONTEIN TRIAL PLOT (2 200 m²) - Northern Cape - Remote area

LEGEND:

- RIVER (NON-PERENNIAL)
- RESERVOIR
- WELL
- WINDMILL
- PUMP
- FILTER
- VALVE
- SUPPLY PIPE LINE
- SUBMAINS
- PLANT ROWS & LATERALS



Extention officer assisting farmer at pump station

General drip system layout

remained at least at the specified 11 m. The system was therefore very simple to operate, and if the filter was cleaned regularly, the pressure remained fairly constant.

The system consisted of 33 laterals, each 40 m long, divided into three irrigation blocks. The laterals are 1,6 m apart and are equipped with 2 l/h non-regulated drippers, spaced 0,6 m apart.

In the beginning no one in particular was responsible for the system operation, and a number of community members attended to the irrigation.

One community leader and the extension officer from Springbok were the driving forces, although their knowledge about vegetable production was limited. The first crops planted were cabbages, onions and beans. A row of vegetables was planted on each side of the dripper line. Rain before and after planting made conditions less harsh for the young plants. The project team provided guidelines for irrigation scheduling.

The supply system, mainly the pump and diesel engine, caused farmers many problems. When the pump was running well, the irrigation system functioned satisfactorily. Mechanical knowledge to repair the machine when it broke down was lacking. The same applies for the tools necessary for repairs. The extension officer, however, played a major role in limiting delays as far as possible.

The nature of these problems varied from small matters that could be resolved on site, to replacement parts needed, which caused major delays, because it had to be obtained from Springbok, some 90 km away. Parts were also difficult to obtain, since the engine was of relatively unknown Chinese make.

Due to water-supply problems, the first vegetable planting was already wilted to such an extent by the middle of September 1997, that expectations of a harvest were rather low.

In November 1997 the engine had a major breakdown when the piston hit a hole in the engine block. The reason for this could not be established.

Good rains at regular intervals, however, sustained the vegetables, and the two elderly people (a man and woman) who were then looking after the garden wanted to continue with the plot. With the assistance of the community leader they connected two windmills, which were in fact supplying the village with water, to the system and reservoir. During the day it delivered water for domestic use, and at night it was pumping to the reservoir.

Although they managed to keep the vegetables going, the situation deteriorated, and if it was not for unusually frequent rains, the vegetables would without doubt have succumbed.

Maintenance of the system (cleaning of the filter) was poor, as well as record-keeping of irrigation activities. The water situation worsened due to the fact that a solar pump which supplied water to the village broke down, and the community was then totally dependent on the windmill.

Hare and field mice further reduced an already poor harvest. The workers were of opinion that these mice had not been there previously, and that they had in fact been attracted by the vegetables.

It was evident (and confirmed by the workers) that there was almost no interest among the villagers in what was taking place at the food plot.

They managed however to keep the irrigation system going, just managing to keep the crops alive, even during stages when the windmill also broke down and when they had to transfer water by bucket from one reservoir to the other.

The only crops which produced enough for selling purposes were tomatoes and onions, but this probably only amounted to a few kilogram (20 small bags of onions and three baskets of tomatoes).

After all the vegetables had been harvested in June 1998, the general feeling, as expressed by the community leader, was that they would not be able to continue with irrigation unless the diesel engine was repaired, or replaced. The quote of R4500 for repairs was unaffordable, and he was considering building up a pump which can be driven from the community tractor. His idea was to fill the two reservoirs every second day, or as frequently as needed, so that the tractor would be available for the rest of the time.

The extension officer became less involved with this irrigation project due to other commitments.

The winter of 1998 and the seasons following turned out to be extremely dry and irrigation was therefore out of the question. Drinking water for the village was very limited, and the community was experiencing many hardships.

In September 1999 the community leader was of opinion that irrigation would only receive attention once their water situation had been reorganised completely. Due to the severe Namaqualand heat, the project team asked the workers to remove the irrigation system and to store it for future use.

4.2.8 Thembalethu

A small irrigation scheme has been developed adjacent to Thembalethu, George, in order to provide opportunities for people who wish to farm. The extension officer in the Development Unit at the Department of Agriculture in George introduced the project team to the farmer, who turned out to be a very competent woman.

She was farming on two of the available plots in the scheme. The sizes of the plots are 400 m^2. The water-source for their irrigation system was an earth dam towards the lower end of the scheme. A pump at the dam feeds water into a distribution network which runs through each of the plots. Each plot has a take-off where the farmer can connect a hosepipe or sprinkler. The supply system is managed by a neighbouring commercial farmer, and the routine followed was that the supply system would operate on Mondays, Wednesdays and Fridays. As far as could be established, this procedure worked well for the farmers, and the supply system was very reliable.

The farmer was eager to participate, and a small drip-system covering approximately 200 m^2 was installed on one of her plots.

Information on the irrigation system at Thembalethu is presented in Table 4.8 and Figure 4.8.

The system was installed in April 1997 and consists of 200 m of dripper line with regulated drippers spaced 0.4 m apart. Water is withdrawn from a hydrant at the edge of the plot, where a small disc-filter has been installed. The system does not cover the entire plot and the balance of the area is irrigated with a movable impact sprinkler.

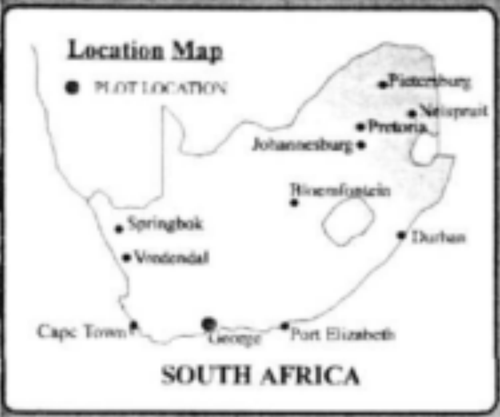
TABLE 4.8 INFORMATION ABOUT THE TRIAL PLOT AT THEMBALETHU, SOUTHERN CAPE

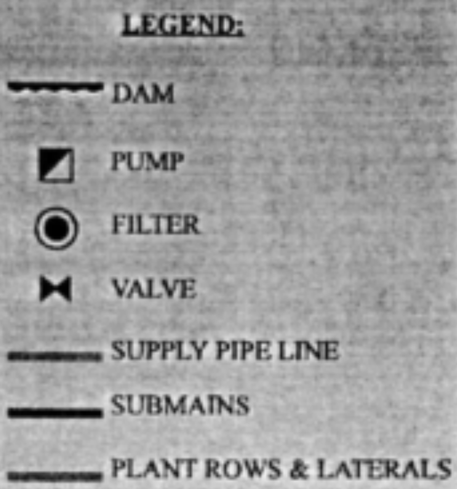
1. Province/Region	Western Cape
2. District	George
3. Closest town	George - 5 km
4. Ownership	Communal land, individual plot
5. Farm area	800 m²
6. Soil texture	Sandy loam
7. Irrigation water source	Community dam and pump
8. Trial plot (Experimental plot)	
8.1 Installation date	March 1997
8.2 Crop(s) cultivated	Vegetables
8.3 Size	200 m²
8.4 Irrigation system	Drip (compensated)
8.5 Lay-out	±1,0 x 0.4
8.6 Emitter delivery rate	2 l/hr
8.7 Working pressure	10 m
8.8 Irrigation program	Project team
8.9 Application	5,0 mm
8.10 Filtration	Disc filter
8.11 Fertilizer application	By hand
8.12 Irrigation system cost	R700.00 (~R17 500/ha)
8.13 Material suppliers	Agriplas

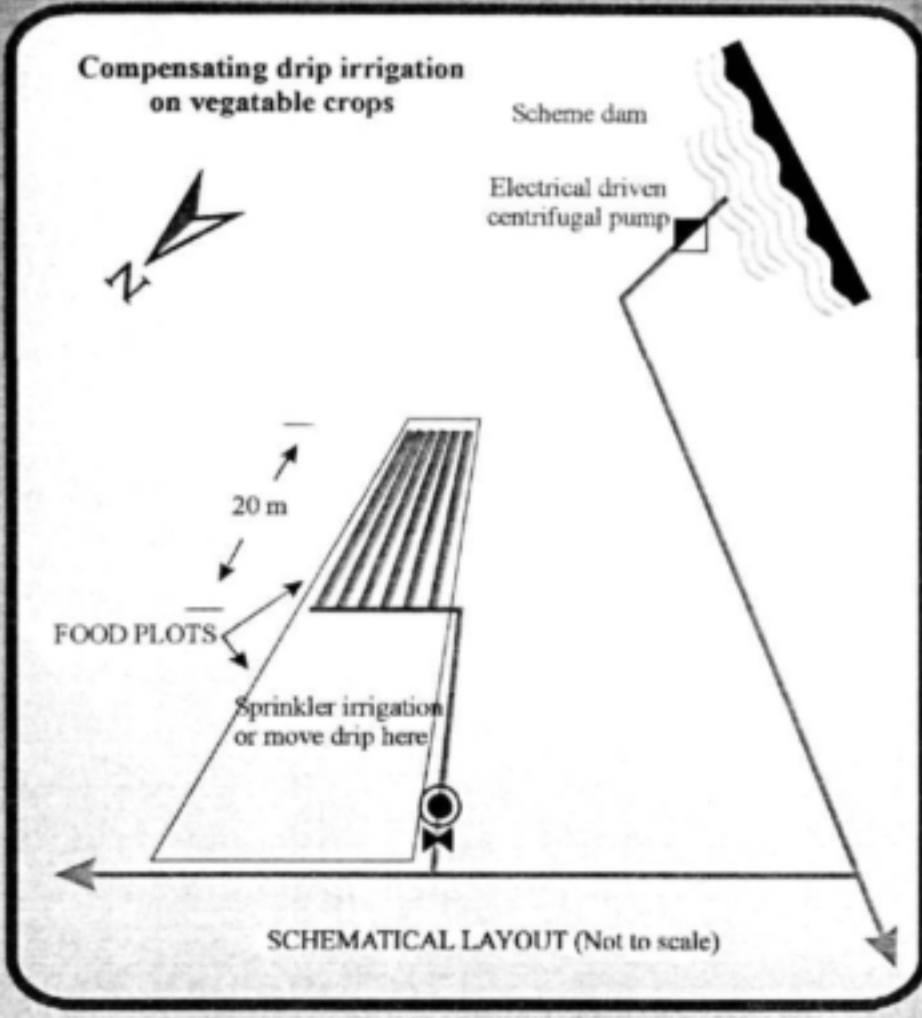
A wide variety of vegetables are produced and the laterals are spaced at distances to coincide with the vegetable rows. One row of vegetables is planted on each side of the dripper line, but at certain locations there are three rows of vegetables, in which case the farmer moves the dripper line between irrigation events.

The extension officer advised her about agronomic matters, and the project team advised her about the irrigation system and irrigation scheduling.

Figure 4.8 THEMBALETHU TRIAL PLOT (200 m²) - Western Cape - Urban area







This farmer utilised the system well, and experienced no real difficulties. On almost no occasion would the dripper lines be lying idle. The water available at the hydrant on the three days mentioned worked well for her, and on these days she irrigated for two hours. This was more or less according to the team's initial guidelines. Fertiliser is applied by hand.

One of the farmers was trained to operate the supply system, and in January 1999 he took over this responsibility. Although it did not appear as if major problems were experienced in this regard, there were, as could be expected, interruptions. Shortly after the new procedure came into operation, the project team visited the farmer, and she explained that the reason why they were not irrigating that particular week, was that the pump was out of order. A discussion with the person responsible for the pump station revealed that he was not pumping, because he suspected that there may be a major problem with the system, and he did not know what to do. The system was checked with him, and nothing was found to be wrong with the system. His concerns were caused by the lower than normal amperes reading of the electrical pumpset. After it was pointed out to him that this was due to fewer people withdrawing water from the system, the system was switched on again.

This trial plot farmer obtained a unit of 3 ha on a new scheme, and in April 1999 started on the new land. She started on a very small-scale by making seed beds. There was still no water, and she had to carry water from the dam to the seedbeds. She removed her drip-system from the old land, and was planning to install it on the new farm as soon as water became available there. She was still very uncertain as to how she would manage this big area, as well as where she would obtain the finances to develop it. The Department of Agriculture is assisting these farmers with the planning.

She makes it clear that she understands the benefits of drip-irrigation, and that she would therefore prefer to have drip-irrigation on the new farm. She is, however, not sure whether she would be able to afford it.

The new scheme met with a setback when a long piece of cable valued at a few hundred thousand rand were stolen just before the power was switched on to start pumping irrigation water, and there were no immediate funds to replace it.

A decision was then taken that farmers had to move to their individual farms before the system would be switched on, as precaution against theft.

4.2.9 Hlaneki women's club

The farmers from the Hlaneki women's club cultivate the area surrounding the Hlaneki irrigation scheme near Giyani in the Northern Province. Water is supplied from the main scheme where mangoes are grown, and an extension officers looks after the needs of the farmers. There is also a co-operative where they can obtain fertiliser, seeds, etc.

Each plot is about 20 m x 30 m in size, and a garden sprayer is used for irrigation. The garden is situated next to a stream, and some of the women have extended the size of their plots as far as the hosepipes will reach. A suitable plot was selected for the trial system with the help of the extension officer on the basis of the most suitable soil, since some of the plots are located on soil with a very high clay content.

The sprinkler used customarily by the farmers wets a circular area with a diameter of about 8 m (the sprinklers operate at the same pressure as the main scheme, and a lot of mist is formed). The farmer of the trial plot could not say how long she usually leaves the sprinkler in one position, and irrigated according to her experience.

The garden is equipped with 20mm taps located in the centre of each plot. The system that was installed by the project team covered roughly half of the farmer's plot, which is approximately level. It consisted of a submain line in the centre of the portion, with 13m long laterals on each side. Due to the high clay content of the soil, horizontal movement of water in the soil was good, and it was decided to position one lateral between every second row of crops (typical "tramline" layout). The laterals were therefore spaced at 1.2 m, with the emitter spacing 0.6m on the lateral.

Information on the Hlaneki trial plot is presented in Table 4.9 and Figure 4.9

TABLE 4.9 INFORMATION ABOUT THE HLANEKI WOMEN'S CLUB TRIAL PLOT

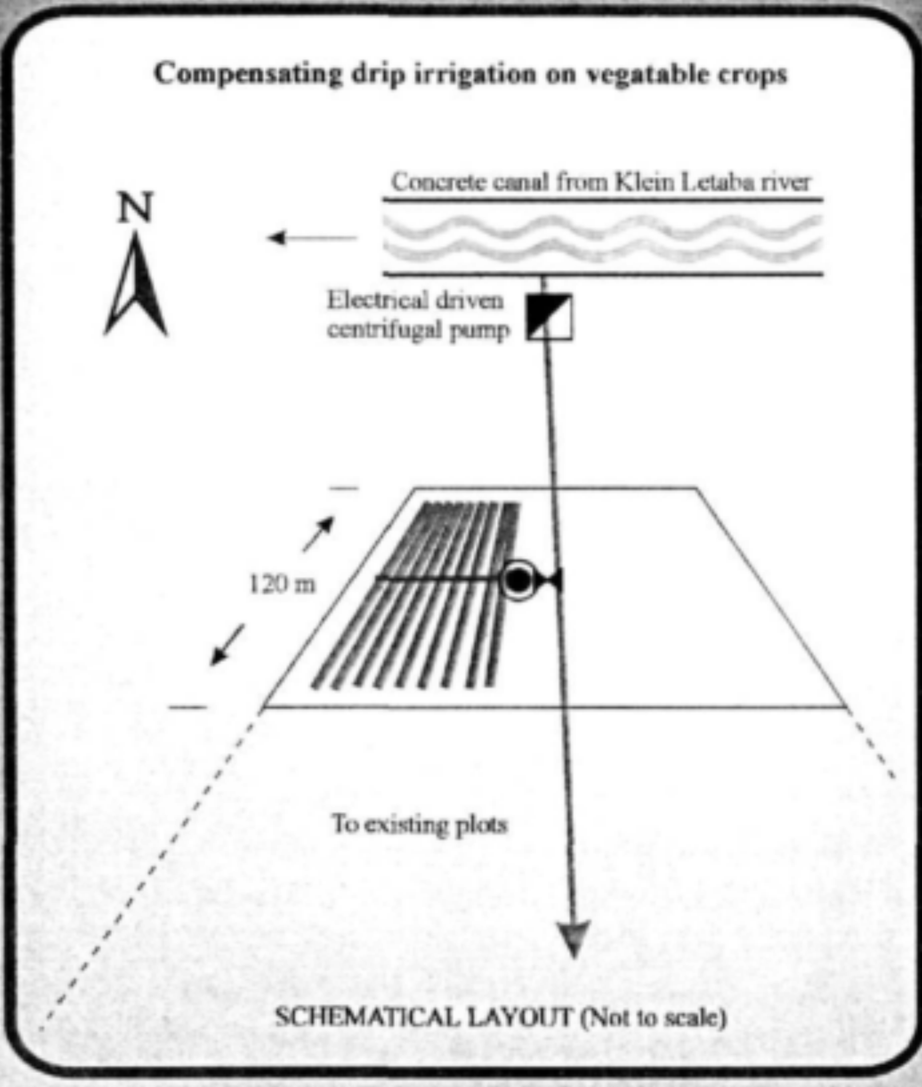
1. Province/Region	Northern Province
2. District	Giyani
3. Closest town	Giyani - 10 km
4. Ownership	Communal land (Hlaneki Irrigation Scheme)
5. Farm area	725 m² (25 m x 29 m)
6. Soil texture	Clay
7. Irrigation water source	– Pumped water supply from main scheme – 20 mm taps at plots
8. Trial plot (Experimental plot)	
8.1 Installation date	15/10/97
8.2 Crop(s) cultivated	Groundnuts, maize, beans, sweet potatoes
8.3 Size	468 m² (26 m x 18 m)
8.4 Irrigation system	Pressure-compensating in-line drippers
8.5 Lay-out	– 15 laterals, 13 m long, spaced at 1.2 m – 0.6 m dripper spacing
8.6 Emitter delivery rate	2.3 l/h
8.7 Working pressure	120 kPa
8.8 Irrigation programme	2h/day, 4 days / week
8.9 Application	25 mm / week applied over full area
8.10 Filtration	25 mm disc filter
8.11 Fertiliser application	By hand
8.12 Irrigation system cost	R1 030 (~R22 000/ha)
8.13 Material suppliers	Netafim

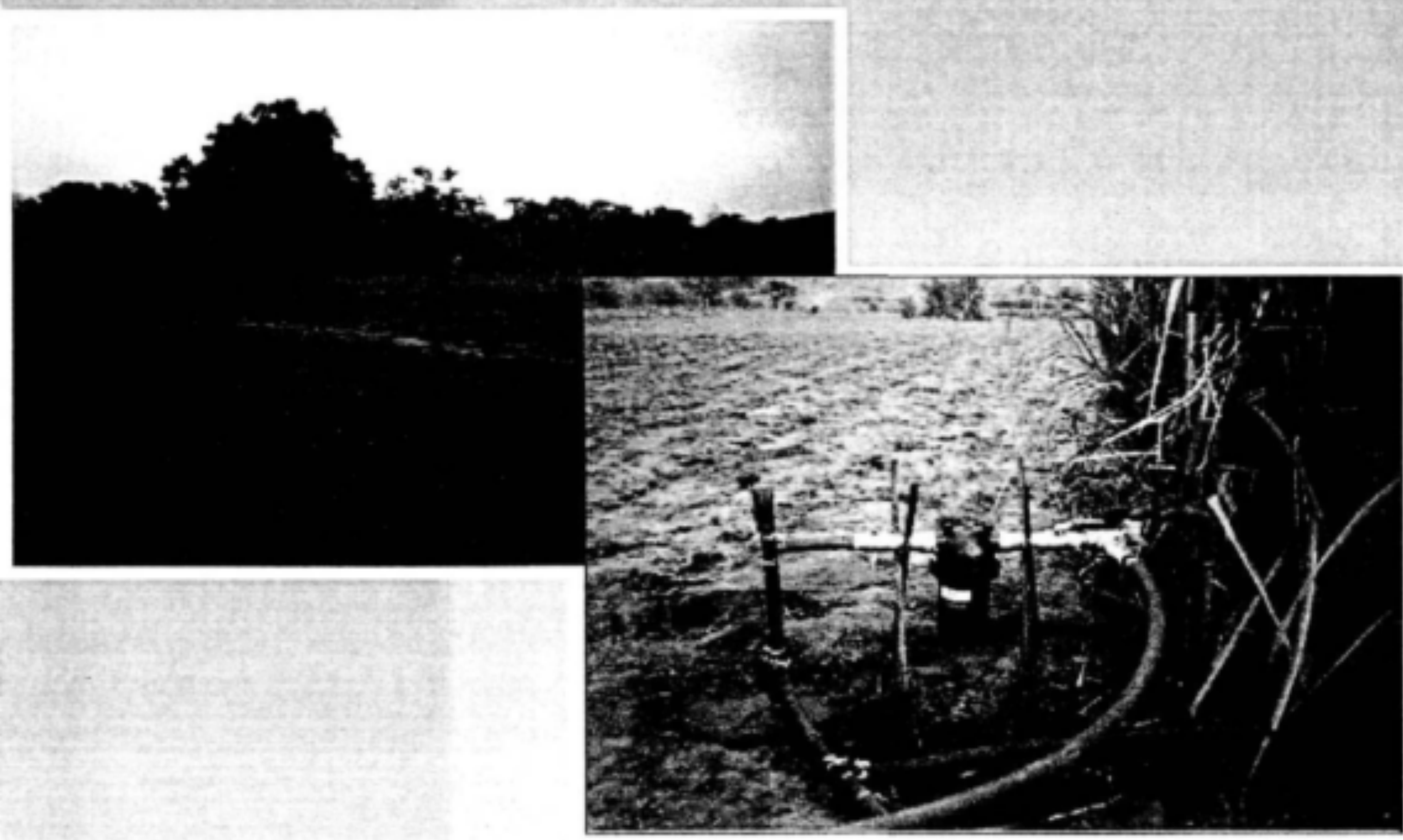
During installation the farmer wanted to know whether the water would spread laterally to the crop rows on both sides, of which she was assured by the project team. Unfortunately the soil was very wet and the wetting front could not be shown to her at that time. It was, however, demonstrated to her at a later visit by digging a hole under the drippers at various stages of an irrigation event.

Figure 4,9 HLANEKI TRIAL PLOT (468 m²) - Northern Provence - Rural area

LEGEND:

- CANAL
- PUMP
- FILTER
- VALVE
- SUPPLY PIPE LINE
- SUBMAINS
- PLANT ROWS & LATERALS





The extension officer and the farmer's son, who were initially very enthusiastic, assisted with the installation. The book for record-keeping was given to the extension officer, since the farmer is not literate, and she (the extension officer) promised to keep it updated. However, communication with the scheme is very irregular due to inferior telephone lines, and the extension officer was therefore not present during the first two monitoring visits. By the time she was contacted it became evident that she was not as dedicated as would have been presumed initially, and that the book had been "lost".

Another book was issued, and a Department of Agriculture employee, a tractor driver on the main scheme, indicated that he was willing to help with the daily monitoring. After a few visits it became clear to the project team that the tractor driver had now taken over the irrigation and was in fact making decisions on behalf of the farmer. When this matter was addressed, it transpired that the farmer did not have any faith in the system, because she could not see any water on the leaves of plants, and therefore thought that the crop was not receiving any water. Her only solution to this problem was to irrigate over the dripper lines with the original sprinkler in order to save her crop.

The project team then attempted to explain to her how plants receive water and nutrients through their roots, but despite this the farmer asked that the system be removed from her plot, since she would rather use the sprinkler. The extension officer then asked whether the system could be installed on the scheme's demonstration plot, to which the project team agreed.

4.2.10 Homu banana scheme

The Homu irrigation scheme forms part of the Mid-Letaba irrigation scheme around Giyani in the Northern Province. All the farmers grow bananas on plots of 7,5 ha which are irrigated by dragline sprinklers on a 18 m x 18 m layout. The scheme has a dedicated and knowledgeable extension officer, as well as an active farmers' committee that keeps contact with white commercial banana farmers in the area. Through this contact the scheme farmers are aware of developments and had heard of micro-irrigation before the installation of the trial plot system. Most of the farmers are interested in converting to micro-irrigation, and the idea of a trial plot at the scheme was met with great enthusiasm.

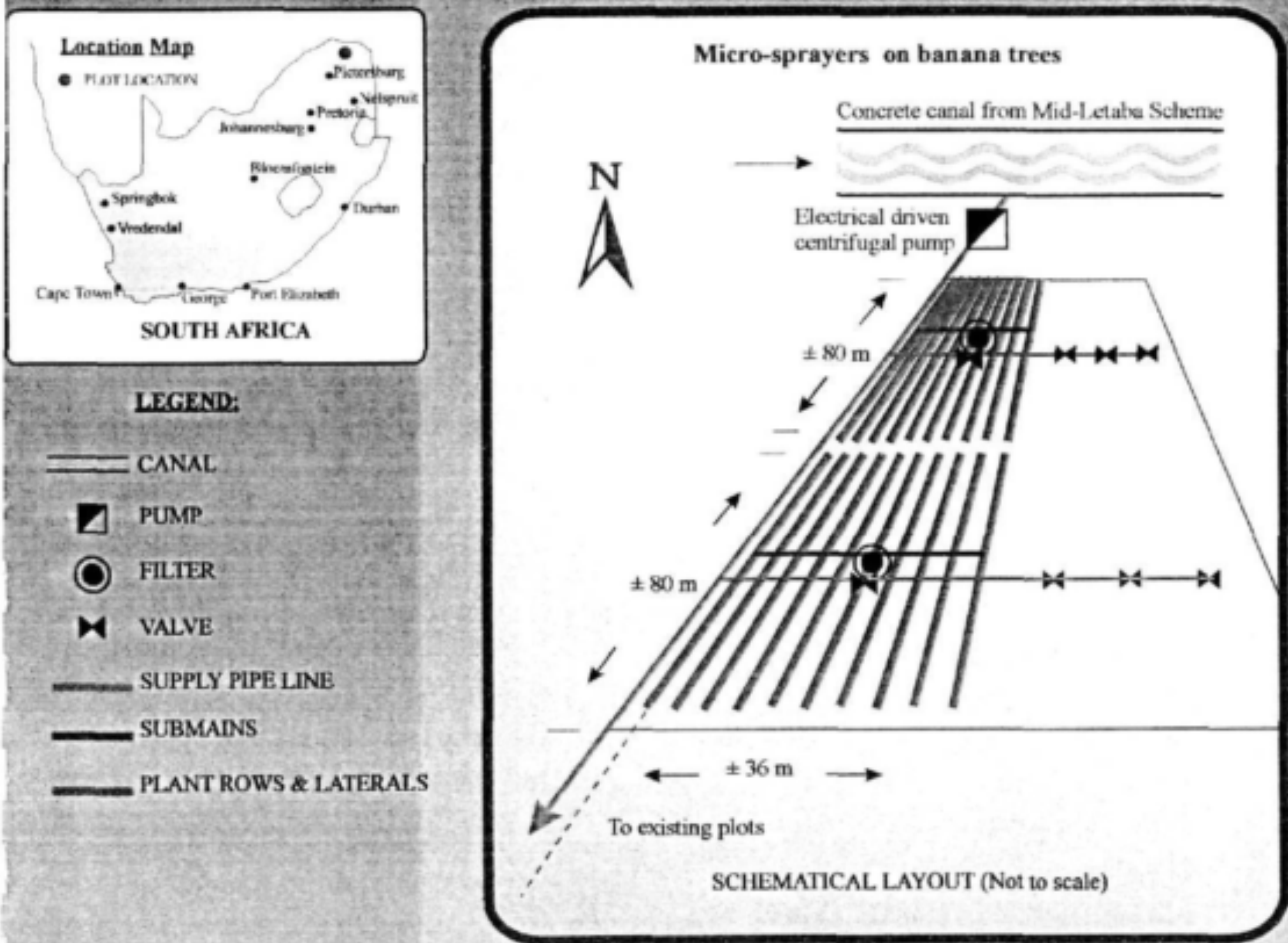
TABLE 4.10 INFORMATION ABOUT THE DETAILS OF THE HOMU TRIAL PLOT

1.	Province/Region	Northern Province
2.	District	Giyani
3.	Closest town	Giyani - 5 km
4.	Ownership	Communal land (Homu Irrigation Scheme)
5.	Farm area	7,5 ha
6.	Soil texture	Clay-loam
7.	Irrigation water source	- Pumped water supply from main scheme - Hydromatic valves at plots
-	Trial plot (Experimental plot)	
8.1	Installation date	10/09/97
8.2	Crop(s) cultivated	Bananas (ratoon)
8.3	Size	5 780 m² (170 m x 34 m)
8.4	Irrigation system	Rotating micro jets
8.5	Lay-out	2 blocks of 5 laterals, 7 m apart, with micro jets spaced at 3 m
8.6	Emitter delivery rate	40 l/h (37 l/h measured)
8.7	Scheduling practice	4h/day, 2 days/week
8.8	Application program	14 mm/week applied (over full area)
8.9	Filtration	40 mm disc filter (one per block)
8.10	Fertiliser application	By hand
8.11	Irrigation system cost(1997)	R2 537 (~R4 389/ha)
8.12	Material suppliers	Vetsak

The farmers were approached through the extension officer, who organised a meeting with the committee. The farmers nominated five candidates and names were drawn from a hat to appoint the "winner", whose plot was to be used.

At the start of the project the chosen farmer was occupied full-time on this scheme where he has two 7,5 ha plots. He is the secretary of the farmers' committee and has fifteen years' experience of irrigating bananas under dragline sprinklers. He speaks good English and Afrikaans and can

Figure 4.10 HOMU TRIAL PLOT (5780 m²) - Northern Provence - Rural area



read and write. The profit from the irrigation farming is his only source of income, and according to him a dedicated farmer could earn up to R120 000 from one plot in a year, provided irrigation and fertiliser are sufficient, weeding is done regularly and harvesting done at the right time. After all his expenses had been paid, there is usually between R60 000 and R80 000 left. One could therefore conclude that the enterprise is profitable and sustainable.

The plot was surveyed for design purposes and the equipment was installed with the help of the farmer's labourers, as well as the extension staff, an official from the local Department of Agriculture's engineering division, and other farmers.

Water for the existing dragline sprinkler system is provided by two hydrants in the identified area, as indicated on the diagram. It was decided to divide the area into two blocks, each block being served by one hydrant. The layout of the system in the two blocks are the same, with a submain line down the centre of the block, five laterals 7 m apart (between every second row of trees), with micro-jets spaced at 7 m. After the second season watermeters were installed at the hydrants to measure the amount of water used by the farmer.

It was noted during installation that there is a considerable quantity of leaves and other plant material covering the surface under the trees. In the case of the overhead sprinkler irrigation this provided good mulching material, but in the case of the micro-jets it intercepts a considerable amount of water. It was suggested to the farmer that the material be moved to the rows alternative to those where the micro-jets are positioned.

After determining the evapo-transpiration for the crop, using SAPWAT, the farmer was advised to irrigate the plot for six hours three times per week in summer, and three hours three times per week in winter. However, during site visits the first two seasons, the situation was either very wet with the farmer irrigating more than advised, or very dry due to lack of water for irrigation from the supply system. This was the reason for the over-irrigation - the farmer was concerned that the supply would fail and he would be left without water, so he tried to compensate by giving more water when it was available. Despite these dry periods, he was still giving too much water. This was evident from the amount of water flowing in drainage ditches dug next to the fields, and was also confirmed by the tensiometers installed in 1998.

From October 1998 no irrigation took place until May 1999, the reason being that the electricity accounts for the scheme as a whole were no longer being paid by the Department of Water Affairs, and that the farmers had taken over the responsibility. However, the account had not been paid for an unknown period of time, and the supply had consequently been cut off. The farmers were therefore unable to pump water from the canal serving the scheme, and could therefore not irrigate.

Farmers on the scheme then collected money amongst themselves to pay the account and the electricity supply was restored again by the end of April. Fortunately good rain fell in the area, and the farmers could harvest.

Early in 1998 an attempt was made to obtain more quantitative data from the trial plots by providing the farmer with a book for record-keeping. The type of information that had to be entered into the book included irrigation dates and periods, weeding and fertiliser application dates, labour costs, yields, etc. The book was only used for a period of about five months, and even then was not always properly completed. For the period following, a full-time labourer was employed by the farmer to attend to the banana plots, and a new book was provided, which he subsequently lost.

For the remainder of the project period some irrigation was done, but water supply was erratic, the scheme being without water for periods of up to two weeks. As for the farmer, he recently obtained a loan from the Land Bank to expand his farming activities, he acquired an additional piece of land at another venue where he is keeping cattle, and bought himself a bakkie to travel between the two sites. He intends installing micro-irrigation on the rest of his plot should financing be obtained.

The farmer's commitment to irrigation farming has decreased noticeably over the past six months of the project. The irregularity of water-supply, together with his new interests, may have caused him to spend less time on his plot.

4.2.11 Strydkraal community garden

The community garden at Strydkraal A on the Olifants River irrigation scheme near Lebowakgomo was identified as a possible site for a trial plot during a PRA exercise held there in 1996. The community garden is cultivated by women living in the nearby village, and they receive technical support and advice from the local extension officers. Each farmer cultivates a plot of about 10m x 25m, irrigating their crops by furrow irrigation.

The garden's water is supplied by a pump from the main canal about 1 km away, and is accessed in-field by hydromatic valves. Each farmer has a hosepipe which fits onto a valve close to the plot, and irrigate their crops by letting water into each furrow with the hosepipe. In order to prevent "erosion" at the top of the furrow due to the pressure of the water from the hosepipe, the end of the pipe is put into a tin (about the size of a big coffee tin) lying on its side. In this way energy is dissipated and less damage done to the furrow.

The community garden was considered to be a suitable place for a trial plot since the farmers were well established, water was already available under pressure, and the extension service seemed actively involved. The community is also fortunate in having a young and open-minded chief, kgoši Masha, who encourages development in the area.

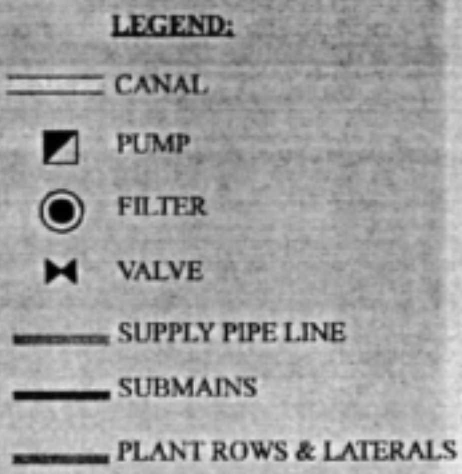
Information on the Strydkraal trial plot is presented in Table 4.11 and Figure 4.11.

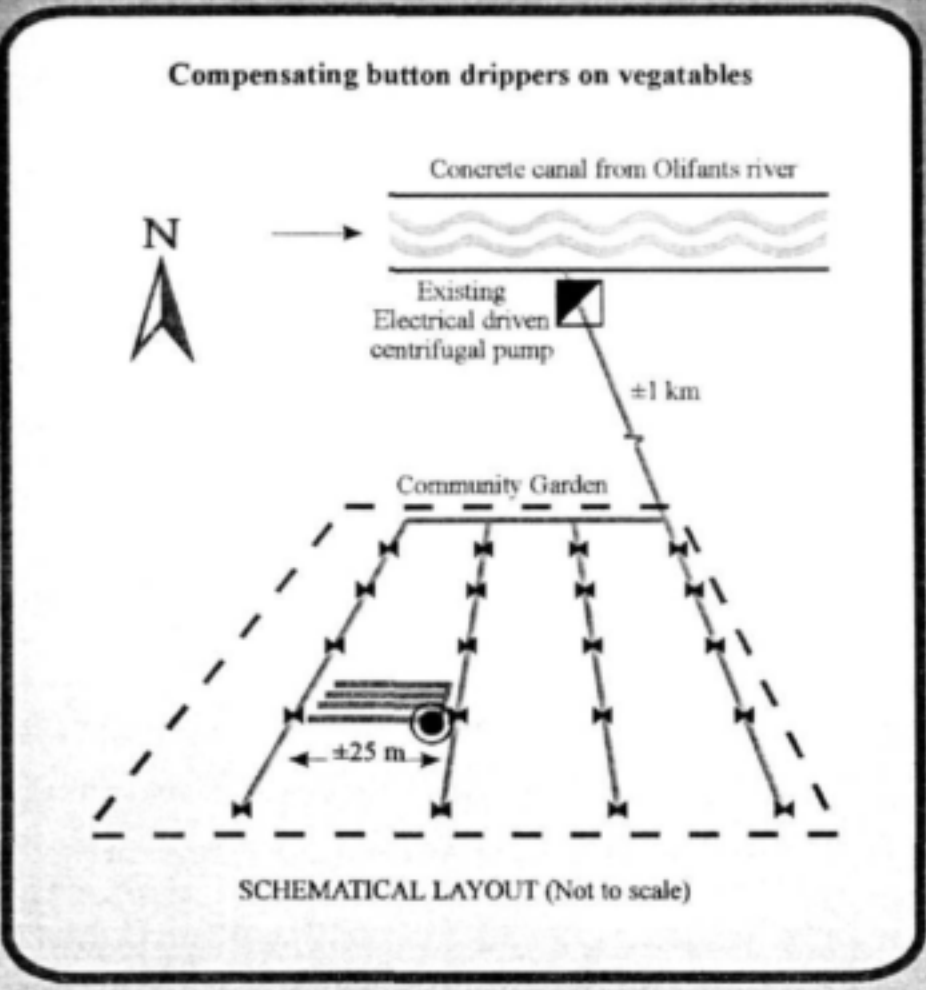
TABLE 4.11 INFORMATION ABOUT THE STRYDKRAAL COMMUNITY GARDEN

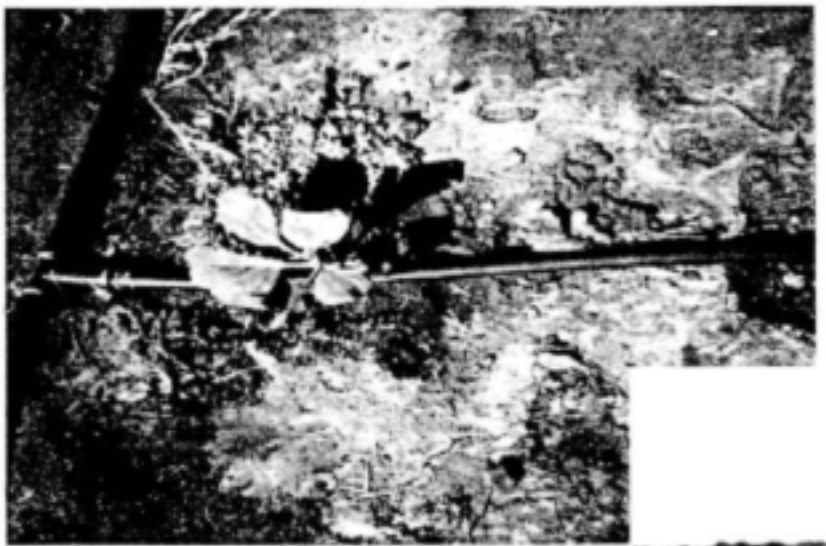
1. Province	Northern Province
2. District	Potgietersrus
3. Closest town	Lebowakgomo - 50 km
4. Ownership	Communal land (Olifants River Irrigation Scheme)
5. Farm area	500 m^2 (25 m x 20 m)
6. Soil texture	Loam
7. Irrigation water source	- Pumped water supply from main scheme canal - Hydromatic valves at plots
8. Trial plot	
8.1 Installation date	17/04/97
8.2 Crop(s) cultivated	Cabbage (145 cabbages grown , sold at ± R1 each)
8.3 Size	150 m^2 (25 m x 6 m)
8.4 Irrigation system	Pressure compensating button drippers
8.5 Lay-out	4 laterals, 25 m long, spaced at 1.2 m 0.65 m emitter spacing
8.6 Emitter delivery rate	2.4 l/h
8.7 Scheduling practice	3 h/day, 4 days/week
8.8 Application	37 mm/week applied (over full area)
8.9 Filtration	20 mm disc filter
8.10 Fertiliser application	By hand
8.11 Irrigation system cost	R419 ~ (R28000/ha)
8.12 Material suppliers	Netafim

The women were approached through the extension officer, and together they chose a suitable trial plot. Equipment was installed with the help of the extension staff, and cabbage was planted on the plot the next day. The system consisted simply of four laterals, 25 m long and spaced 1.2 m apart. The laterals were hosepipes, fitted with button drippers spaced at 0.65 m, which is the approximate spacing at which most of the crops in the garden was planted. Each row of crops was served by one lateral.

Figure 4.11 STRYDKRAAL TRIAL PLOT (150 m²) - Northern Provence - Rural area







The suggested irrigation scheduling made provision for an application of slightly more than 3 mm/day. This value was considered adequate for irrigating a crop in this area in winter. The farmer indicated that she tended to her plot four days per week on average, and it was suggested that she should regularly apply small quantities, since more vertical than lateral movement of water was noticed in the soil.

In the early stages of monitoring the extension officer was of opinion that too little water was being applied, and suggested a longer irrigation time. The farmer did not agree, however, since she already had to spend more time irrigating than the other farmers. While she had to wait three hours for her irrigation to finish, the other farmers could complete irrigating their plots with the hosepipes within an hour.

Towards the end of the growing season the farmer stopped using the system. The reason given was that she was busy preparing her maize plot on the main scheme for planting, and could not tend to her vegetable garden during the morning for the required irrigation time.

About five weeks after planting a problem was encountered with fertiliser application. Fertiliser (granules) was being applied by hand around the plants, but failed to dissolve and be absorbed by the soil. This left a white crust on the soil around the plant, and the farmer attempted to work the fertiliser into the soil with a fork. Although this was successful to some extent, it is not a satisfactory way of applying fertiliser. This must apparently have had some effect, for when compared to the cabbages grown under furrow irrigation, those under drip seemed to have suffered somewhat during the season - in general they were smaller and more of the plants had died.

At that stage the farmer suggested that the system be moved to one of the other plots where there is a full-time farmer, because she did not have the time to spend on both the maize and the vegetable plots. She felt that she was not contributing as much to the project as she would have liked to. The new plot that was selected belonged to the kgoši's wife, who is a teacher at the local secondary school, and was being cultivated by a labourer employed by her. The project team discussed the concept with her, to which she agreed.

The extension officer at the community garden requested that the system be removed until the new crop was to be planted early in 1998, because they wanted to plough the whole garden. She said that she would contact the team as soon as they received the seedlings (tomatoes) for the new planting in order to arrange for the reinstallation of the equipment. After about two months the project team visited the scheme since the extension officer did not reply to any of the calls left at the neighbouring scheme which has a telephone, and discovered that she had moved to another area.

At that stage (middle 1998) the main irrigation scheme at Strydkraal was experiencing serious water shortages in the supply canal, apparently due to other schemes higher up in the canal using most of the water. The maize crop was a total failure, due to late planting and inadequate irrigation. Irrigation at the community garden also ceased almost completely, and it was decided to discontinue monitoring at this site.

4.3 Other existing micro-irrigation projects

After the second year of monitoring, more than half of the trial plots were not functioning any more, or were functioning under great difficulties. The steering committee then suggested that the project team visit a number of existing small-scale micro-irrigation farmers.

With the assistance of committee members, a number of existing sites were identified. These were mainly located in Venda and the Free State, and a number of sites were visited recently, the findings of which are given below. This comprehensive survey also brought the project team in contact with three recent micro-irrigation installations, two in Namaqualand and one in the Western Cape. Valuable observations were made on these projects, and are therefore also included here. Photos of selected plots are included in Appendix G.

4.3.1. Diytalawa - Harrismith apple project - Free State

This project was initiated in 1997 when the first 25 ha were established with apple orchards and allocated to 25 farmers, each with 1 ha of orchards. In 1998 a second phase was developed for 50 farmers, also with 1 ha each. The farmers were selected from people who were unemployed and living in the area.

The farmers receive a monthly salary from the management company on a loan account, and will start repaying these loans in 2002.

At the time of the project's visit the farms were in a poor condition. Apparently the major problem concerns the irrigation water-supply. The farmers are responsible for the day-to-day farming activities, but the irrigation is managed and controlled by one person working for management. Micro-spray irrigation systems are used. Irrigation problems are clearly visible. The following became evident, or were mentioned during discussions with the irrigation operator and two farmers. It may, however, require some verification.

- The founder company handed the project over to a manager in the community.
- Although Phase 2 of the project is equipped with a permanent micro-irrigation system, it has as yet not been commissioned, for reasons unknown to the irrigation operator.
- With all the disruptions experienced in the water-supply system, or time lost due to pumping problems, the time available to irrigate Phase 1 is not sufficient (they only irrigate during day-time).
- The irrigation operator is under the impression that the same supply system of Phase 1 will also be used to irrigate Phase 2, but he is doubtful whether the additional time required will be available.
- No guidelines for irrigation scheduling have been provided to the operator, and he is not sure whether the schedule that he is following meets the requirements. (At the moment he is grossly under-irrigating).
- He has few spare parts available for the irrigation system, e.g. he has no additional micro-sprayers.
- He often has the need to discuss technical problems, but no one is readily available with whom to discuss these problems.
- He is desperate for training, but does not know how to approach the matter.
- He is uncertain whether the problems he experiences at the pump-stations (solids which enter the pump) are due to erroneous design, or whether they are of an operational nature.
- Farmers are applying intercropping with reasonable success in Phase 1.

At the time of the project's visit, the situation there was most discouraging. Hopefully the mistakes made at the different levels of project planning and management have been analysed and documented, so that it can serve as guidelines for other projects.

4.3.2 OTK-Bethlehem apple project - Free State

This project was started by a co-op, SOK, with partners in August 1998, when 57 ha were established with apple orchards and allocated to 57 farmers, each with 1 ha of orchard. In 1999 a second phase of 57 ha were to be developed for a further 57 farmers. As in the case of the Diytalawa project, farmers were selected from people in the area who were unemployed.

The farmers also receive a monthly salary of approximately R600 from the management company on a loan account, and will start repaying the loan in 2001.

A number of consultants, including Infruitec and commercial farmers, are involved in assisting farmers on all levels of farming.

The orchards are equipped with micro-spray irrigation systems, controlled by a computer and equipped with sophisticated fertigation equipment. Four hectares of orchards are utilised by management for experimenting, and this area is equipped with drip-irrigation. It appears as if they are considering the installation of drip- systems for Phase 2 of the project.

In this project management is taking almost all decisions regarding the farms. Two farm managers are continuously moving between individual farms and give instructions to farmers on what should be done. However, spraying, irrigation, weed control, etc. are all done for the farmers by management.

The farmers received an initial three months basic training, and weekly training sessions subsequently.

It appears as if the project is running smoothly, and farmers seem to be enthusiastic. It is, however, debatable whether this project philosophy is the right approach, but it seems as if lessons learnt at the nearby Diytalawa, started one year earlier, are implemented at this project.

4.3.3 Project at Masisi - Northern Province

This farmer cultivates an area of 10 ha near Masisi, growing a variety of crops. The entire area is equipped with a drip-system. His water-source is a river, from which water is pumped with a diesel engine to the in-field system, approximately 200 metres from the pump-station. Two sand-filters, followed by disc-filters, and equipped with hydraulic valves, are used to filter the water. Fertilisers are applied through a fertiliser pressure tank at the filter station.

Installation of the engine and equipment has been done properly, and is apparently also well-maintained. From discussions with the farmer it does not seem as if he is experiencing difficulties in operating the system, except for a limitation in the capacity of the sand-filters. He is rather concerned about things which might go wrong in future, e.g. measures to be taken to prevent his drippers from blocking. He is also eager to acquire more knowledge on various subjects relating to his farm.

At the time of the visit he was irrigating 5 ha, which consisted of maize, tomatoes and paprika. His knowledge about these crops, including production figures, appears to be sound. He is applying an irrigation schedule of a fixed number of hours per day, but will vary this according to the crop type and weather conditions. Fertiliser requirements are supplied to him by a fertiliser agent.

The farmer started farming at the end of 1997 when he took over from his father. He had been a self-employed building contractor previously, but decided to quit when building opportunities became scarce. He took up a loan and replaced the old flood systems used by his father with the drip-system.

It became clear that his record-keeping system was unsatisfactory, to which he admitted. However, he intended improving on this during the next season.

An interesting cropping pattern was applied whereby he planted paprika next to rows of mature maize. The maize is harvested long before the paprika matures, and in his opinion no damage is foreseen for either of the crops.

He emphasises the fact that he obtained his farming experience by practical training, working for other farmers, in particular a group of farmers at Nwanedzi.

4.3.4 Project at Nwanedzi - Northern Province

This farmer farms on more than 70 ha with tomatoes, and therefore falls outside the limits of smaller than 20 ha as proposed by the project steering committee in October 1999. The experience of this farmer, however, is undoubtedly of great value to this project.

The farmer has had very little formal education (Sub B), after which he started working on a farm. Later, at the age of approximately 18, he joined his father, who was a tribal captain, on a small piece of land. He farmed there until 1986 (approximately 15 years). He then decided to expand his enterprise, and started renting the land on which he is presently farming.

Until three years ago he used a quick-coupling sprinkler system to irrigate the tomatoes, and then changed to drip. He is now very outspoken against sprinklers, and regards it as "a waste of money and time." The main reasons offered is the amount of extra spraying that needs to be done due to the washing off of the sprays from the leaves of the plants.

Fertilisers are applied through the irrigation water. The water-supply is from his own electrical pump-station on a river, and filtration is done through six sand- filters, with secondary disc-filters at the irrigation blocks.

It would appear from discussions that this farmer does not have any difficulties with any aspect of his farming operations, least of all irrigation. He does not follow any prescribed guidelines for irrigation scheduling; he maintains that he can see when the plants need water, and then decides how much and when to irrigate. According to him this application varies considerably from block to block, depending on the soil type and maturity of the crop.

Weed control is done manually, and on average he employs 100 labourers. During the peak season he employs considerably more people.

He is of opinion that a farmer should start small, and learn to do things right on a small-scale, before considering further expansion. He also observed that fertilisers and sprays are provided by help providers to farmers in the region, but that this practice encourages misappropriation, the reason being that these farmers sell this material to buy food, with the result that poor yields are obtained.

4.3.5 Backyard garden projects - Free State

Approximately 1500 of these gardens have been installed in the Free State, all of which are equipped with a drip-system on approximately 30 m^2. If enough space is available in the garden, it would involve five laterals with a length of 6 m each. It can, however, be adapted according to the layout of the garden. The system is connected to the water-supply system of the house at the nearest point.

These systems were installed according to a programme with funding which was run in the Free State. A contractor was contracted to supply and install the systems at approximately R450 per garden. Included in this price was the irrigation material, installation, planting material, fertiliser, basic training, and maintenance/support for one year. After the one-year period, the Department of Agriculture would be responsible for support.

A number of these gardens were visited, but unfortunately very few were still operational, the main reason apparently being lack of support when funds from the Department of Agriculture were not available any more. Drought problems also contributed to the situation in certain cases. For example, in November 1998 when Koffiefontein was visited, a few systems were still in use, the best being operated by a woman growing a variety of vegetables. When this woman was again visited in March 1999, no vegetables were being grown due to very stringent water-restriction measures for the entire region. The woman expressed her dissatisfaction with the situation, as she had had great success with the system, and even managed to earn an income by selling vegetables from her garden.

It was apparent from discussions that lack of outside support to *the irrigation system* had little to do with system failure. The much-needed support rather involved pest, weed and disease control, as well as guidelines on what to plant and where to obtain plant material. The greatest need for support, however, was for interest and encouragement to continue with the garden.

4.3.6 Dingleydale (Northern Province, Bushbuckridge area)

This scheme was established only recently. It was initiated by a group of farmers from Tzaneen who are growing and processing peppadews, which is a cross between a tomato and a pepper.

Funds were obtained from the Danish government to establish a scheme for women farmers to grow peppadews, which are irrigated by drip-irrigation. Water is pumped from a river and filtered through sand-filters for the 30 ha piece of land that has been developed. Each woman has an area of approximately 1 ha which she has to weed and harvest. Fertiliser is applied by a fertigation system.

It is as yet too soon to speculate on the possible success of the scheme. The farmers who initiated the scheme are currently training local farmers, none of whom have previous irrigation experience, and they intend continuing their support for another few years.

4.3.7 Hlaneki B - Northern Province

This previously established site is situated on the main section of the scheme where the Hlaneki women's club trial system was installed. The farmer has two plots under cultivation, each about 6 ha in size, of which the first has mangoes and the second bananas. Both plots are irrigated with micro-sprinklers which replaced the quick coupling system installed on the original scheme. The systems were changed mainly to decrease labour requirements (and therefore costs) of the farming enterprise.

The farmer owns a chain of butcheries in the area and spends very little time on his land.

Both plots have only one full-time labourer who controls the irrigation. Other tasks such as weeding, fertilising, etc. is done by women labourers when necessary.

The micro-system utilises the original water-distribution network installed for the quick coupling system. The in-field distribution was not properly designed; only one pipe-size was used for all the submain lines (50 mm), which was not adequate for the flow required for the blocks that were laid out. The manager partially solved the problem by connecting one submain line to two hydrants and creating a kind of "closed circuit" distribution system for each block. However, this is far from ideal; pressure at the emitters was measured in various places in one block, and was not only found to differ greatly, but was also generally low (below 100 kPa). The labourer/manager on the banana plot has a diploma in horticulture and said that he had advised the farmer to buy a bigger diameter pipe for the submain lines, but the farmer considered this to be too expensive.

The laterals also consist of only one diameter (20 mm) and are about 100 m long. Each block of the system is fitted with disc-filters which are flushed regularly, and no blocked emitters were observed during the visit.

During a follow-up visit about three months later it was found that the manager had left due to personal differences with the owner, and some deterioration of the plot was noticed.

4.3.8 Buysdorp - Northern Province

Buysdorp is a coloured community about 60 km west of Louis Trichardt in the Northern Province. The farmer was born here, but spent most of his life in the Western Cape as a prison warden, and is now semi-retired.

He has been allocated 35 ha of land, of which he has debushed 5 ha for crop production. He also keeps some cattle on the remaining part. He has been growing vegetables (particularly garlic, onions, beetroot, cabbage, and carrots) for the past four years, and initially irrigated with a floodbed system.

His source of water on the 5 ha is a number of boreholes which he had drilled since starting his farming operations, which is probably his biggest concern. At the time of the visit there were five boreholes, of which three were dry, the main reason, according to him, being the close proximity of his neighbour's borehole which provides water for a center pivot. He expects his own boreholes will probably soon be dry again due to the lowering of the water- table.

The farmer has converted about 2 ha of his plot to micro-irrigation. The system was designed by a irrigation designer from Louis Trichardt and installed by the farmer himself. He obtained some financing through a development institution.

The system consists of micro-jets on a 2.5 m x 2.5 m grid spacing and the farmer seems satisfied with the system's performance. His only concern is the length of the spikes on which the emitters are mounted. He has noticed that vegetable leaves, especially the carrots, grow taller than the height of the spikes, which limits the distribution of water. He was also concerned about evaporation losses on the system due to high temperatures. A drip-system would probably have been more appropriate under the circumstances.

Although he did not have the water analysed, a chemical deposit could be clearly observed on the emitters. The farmer was not aware that this may cause problems in future, and the project team advised him to find out about routine chemical treatment to prevent deterioration of the pipes.

The farmer was considered to be rather conservative with water application, which was done according to experience. Although he mostly irrigated according to a set schedule (three hours three times a week in summer, three hours twice a week in winter), he did not know how much he was applying in terms of millimeters. He was of opinion that the system was saving water compared to the floodbed irrigation method, while still obtaining good yields, and was planning to expand the area under micro-irrigation.

4.3.9 Kheis project - Namaqualand

During July 1998 the LDU provided funding for a drip-irrigation project of approximately one third of a hectare under onions at Kheis. The system was installed by LDU in August 1998.

Apart from filtration problems (the disc-filter had to be cleaned very frequently), the operation of the system was reasonably successful, and an average yield was obtained. The system was operated by a member of the agricultural committee in Kheis, who spent considerable time on farming issues.

Despite a very dry year in Namaqualand, and a dam which was almost empty, it was decided to plant a second onion crop in December 1998. Towards the end of December 1998 the diesel engine of the pump which supplied irrigation water from the dam broke down. The project team was contacted by the LDU for assistance only about two weeks later. The pump had to be taken to Cape Town for repairs, and was returned to Kheis more than a week later, at which time very little was left of the onions. LDU paid for repairs to the engine, which amounted to approximately R3500.

Shortly afterwards it became impossible to pump water from the dam, because the water-level was too low, despite a trench dug in the dam-basin to bring the little remaining water closer to the pump.

The remaining water in the dam was taken out with 25 liter drums and transported with a four-wheel motor-cycle to a number of fruit-trees which Infruitec is experimenting with. Many of these trees have since died.

The project team is concerned about the application of drip on the already brackish soils at Kheis, and it was suggested that soil scientists be consulted before further extension of the project is considered. Due to quality of the water only drip and flood irrigation systems can be considered for irrigating vegetables and fruit-trees.

For reasons not clear to the project team, an uneasy situation developed between the LDU and the farmers at Kheis, and the drip-irrigation project was discontinued and the in-field system removed.

4.3.10 Leliefontein project - Namaqualand

Approximately 2 ha of pressure compensating button drippers were installed at Leliefontein on prickly pears. Cochineal will be introduced to the "orchard" in due course. The cochineal will be harvested for use in colour dies.

Infruitec is supporting the farmers (six men and women living in Leliefontein, calling themselves the Xhali small-farmers association) with farming and technical services, and also contributed to the financing of the project. The major part of the funding came from IDT. The cost of the irrigation system was approximately R25000.

The system has not been commissioned yet, but the supply system has already been tested. Installation was delayed due to 4 l/h drippers supplied by the irrigation company, instead of 2 l/h drippers. The appropriate material has in the meantime been sent to Leliefontein, which the farmers will install. The farmers will also complete certain outstanding work, i.e. burying submains and repairing wire-ties at connectors in the polyethylene pipes. Installation will then be checked by Infruitec, and when ready, irrigation can commence.

Irrigation water, which is very limited, comes from a shallow well some 50 m away from the land. The supply will be insufficient for adequate irrigation (this being the reason why button drippers are used, so that it can be positioned only at the trees, with the least possible waste of water). Consideration is given to incorporate a borehole approximately 800 m from the site.

A petrol engine driving a self-priming pump supplies water from the well to a 5000 liter tank against a hill approximately 100 m towards the back of the field. The supply line to the tank is also used to bring the water back to the field. The water is filtered with a disc-filter at the pump.

Operation of the irrigation system is relatively easy, considering the system can function with or without the pump, provided there is water in the tank. In addition compensating drip is used, which means that the management of the pressure in the system is less critical.

This project was planned, designed and installed towards the end of the research project, and a number of guidelines which follow from the research could be implemented. These relate mainly to the ease of operations, water- saving, backup storage (although very limited), reliable equipment and proper installation. A weak link is of course the water-supply of the system (source and pump).

Further positive aspects for this project are the support services which Infruitec is providing, as well as the product which will be produced. Prickly pear trees are well-suited to the harsh Namaqualand climate; it can survive on very little water should water periodically not be available, e.g. if a well dries up or a pump breaks, plants will survive, and the products harvested can be kept at Leliefontein until such time that transport is available to their market. The volume and weight of the product is small, and some secondary processing is done locally.

4.3.11 Blackheath backyard project - Western Cape

When the backyard gardens were visited in the Free State, contact was made with a retired farmer who was contracted by the Department of Agricultural to do the installation of most of the gardens.

This farmer wrote a letter to the Department of Agriculture in the Western Cape, introducing the concept. The department reacted favourably, and a demonstration system was installed in Blackheath on the Cape Flats. The project team has been involved in the selection of the site.

The house and plot belongs to an unemployed couple, and particularly the woman was keen to get involved with the trial. The system was installed in April 1999.

The system comprises six laterals of 5 m each. It is linked to the water-supply system of the house, and each lateral can be isolated with an inexpensive valve. The farmer was provided with various vegetable plants, seeds, some fertiliser and a small bottle of pesticides. She received some training about the system operation and scheduling. The soil is very sandy, and irrigation twice a day on hot days was recommended.

The cost of the system was R190, while the cost of seeds, plants, fertiliser and pesticides amounted to approximately R100.

It was decided to equip the system with a water-meter, in order to establish whether the water used is justified.

During the 10 months in which the system has been operational it has been proven that it is possible and justifiable to grow vegetables under these conditions. A number of important adjustments has, however, had to be made, mainly on account of the farmer.

She noticed for example that the dry sandy soil between the rows was blowing about in windy conditions, which damaged the plants. She consequently used a hosepipe on such days to "stabilise" the surface. (The water from the hosepipe also passes through the water-meter). With the next plantings she planted maize on the borders of the irrigated area, and this improved the situation.

She has been using the system very intensively, and in a short period the couple's personal situation improved visibly. They are both still looking for employment, but as a rule there is something to eat from the garden, and often also something to sell. The improved situation is illustrated by the first day of installation when she remarked at lunch-time that she had nothing to eat. Since the garden has been established, there is almost always something available from her garden.

Two additional gardens were developed during November 1999. One was at a house of a woman in her eighties, and the other at the house of someone who is employed full time. These gardens were not nearly as successful as the one mentioned above, and the first farmer contributes it to the lack of attention given. It is also true that the project team did not spend as much time with these gardens as with the first one. Another factor which might have had a deleterious influence is the very hot weather that the new plot owners were exposed to, without the benefit of getting to know the system during less harsh periods.

Inherent in the first farmer's motivation to succeed is that if the Department were to become involved on a bigger scale, she might be employed by them as part of the field personnel.

The total water used over a 10 month period in the first garden was 18 m^3. The total weight produced is unfortunately not known, but based on observations it could probably be between 50 % and 70% of what is attainable under good conditions.

For a better indication of the economy of a small project such as this, a preliminary model has been built of what could be harvested, and the volume of water required. The objective was to plan it in such a way that the household would always have something available in their garden to eat. This model appears in Appendix F, and the results indicate that despite municipal water tariffs, production of food is economical on this scale.

The question whether it is advisable to develop many of these gardens using expensively treated water is debatable, especially if groundwater is readily available, as is the case on the Cape Flats.

4.3.12 Small-scale farmer in Jenin - West Bank - Israel

During a visit to the Middle East by a team member in October 1999, a brief call was made to an Arabic farmer in Jenin, a village on the West Bank in the Yisrael Valley. An Arabic business acquaintance, who also lives in the area, introduced the team member, and acted as interpreter.

Each farmer in the area has 4 ha of mainly deep red fertile soil on which cash crops are grown. Because of the cold winters, most vegetable crops cannot be planted in the open during this period. For the purpose of an adequate cash flow, production in the green houses, which covers 1 ha of the farm, is therefore necessary.

This particular farmer is in his fifties and started farming in 1995, after he retired as teacher in Jordan. He has no other income, and is consequently very serious about his farming enterprise.

A number of relevant aspects were identified during discussions with the farmer:

- There is an irrigation dealer approximately 3 km away, where all necessary items can be bought.
- The farmer does not get any support from the government, not in terms of extension services, or subsidies.
- The companies from whom seeds and plants are bought sometimes advise him on disease and pest control.
- Water is supplied to his land under pressure (government scheme). However, he experiences major problems with the supply system. Due to the region's great demands, pressure at his delivery point is too low and he therefore does not receive the required volume of water. Because of inadequate pressure, his filtration system has to be bypassed. This causes blockages in his drippers, because the water is not always clean. The dirt in the water also prevented his water-meter from functioning properly.
- Pipe bursts in the supply system occurs regularly, which disrupts the water-supply.

- Blocked drippers are opened by bending (twisting) the dripper lines.
- Government does not allow further drilling of boreholes.
- He does not use any electricity on the farm since it is too expensive.
- He applies fertiliser through a tank, but because of the low pressure this method is not very effective.
- He controls all irrigation valves manually.
- He markets his products in local villages, which he considers to be very time consuming.
- He applies scheduling by visually checking the moisture in the soil, and the water-meter is only read occasionally.
- Water is very expensive at IS2.50 per cubic meter. This is approximately R 3.50.
- His production of tomatoes in the green house totals 400 tons per hectare, and outside 30 tons per hectare.
- As for his knowledge about other types of irrigation systems (he only uses drip), he maintains that he does not have sufficient water for micro-sprayers and that sprinkler irrigation is used in the region only occasionally (uses too much water). When asked about flood irrigation, the concept first had to be explained to him, as it was completely foreign to him.

4.4 SUMMARY

During the course of the project about 30 sites were visited or monitored where small-scale farmers utilized micro-irrigation. Of the 23 sites discussed in detail in this chapter, 11 were newly established for purposes of the project, a further 11 already existed in South Africa, and the remaining site was the one visited in Israel by a member of the project team.

A variety of situations (related to the farmers, their characteristics and circumstances, the types of irrigation systems, etc.) were covered by the surveys. The sites included individual and scheme farms of varying sizes, as well as demonstration plots and farms operated by managers on behalf of owners. The farmers encountered ranged from "new" farmers with no experience or training, to others with many years of irrigation experience and formal/informal training. The circumstances surrounding the farming enterprises varied not only geographically, but also as regards support service availability and economical situations.

Of the 11 trial plots established specifically for purposes of the project, only four remained in operation by the end of the monitoring period. The rest all failed at an earlier stage, for various reasons. During the initial stages of monitoring, the reliability of the water-supply was identified as one of the biggest contributing factors to failure of many of the trial plots.

The surveys conducted at previously established irrigation systems provided valuable additional information and insight, especially since some of these systems had already been running for a number of years and had therefore already experienced the problems that were encountered at the trial plots. It was encouraging to see the successful enterprises of established farmers in the Northern Province, proving that difficulties can be resolved.

On the other hand, there are unsuccesful projects that were not evaluated during the course of the project, and the surveying of these projects and identification of the causes of failure can make a further contribution to the information that was gathered. It may be especially important for the rehabilitation or re-organising of projects which are currently at risk.

Observations made during monitoring of the trial plots, and the survey of existing systems, together with information obtained through literature studies and discussions with other parties involved in small-scale irrigation, were used to identify six aspects which are considered to be of major importance when evaluating small-scale micro-irrigation farming. A number of descriptive properties are listed for each aspect, and is presented in Chapter 5.

5. INTERPRETATION OF TRIAL PLOT OBSERVATIONS

5.1 INTRODUCTION

The number of trial plots to be included in the project were increased from five to eleven at the end of the first year of the project. Towards the end of the second year six of these plots had failed. A number of existing farms were then visited, and useful information was obtained. Four of these farms were included for evaluation of observations. The others are described in Chapter 4, but information available for evaluation was considered to be insufficient.

In the final two years of the project contact was also made with three other small projects related to micro-irrigation and small-scale farmers. All of these are described in Chapter 4, but only two are included for evaluation purposes.

These two sites generated a considerable volume of information, and for this reason was grouped together with the original 11 for evaluation purposes. The evaluation results are therefore based on 13 sites where new micro-irrigation systems were installed, and four sites with established/existing systems. Information of the two groups are shown separately in the tables with evaluation results.

This chapter summarises the most important findings at each of the trial and existing plots / farms, and the SAPFACT program was utilized to expedite interpretation of information.

5.2 SAPFACT PROCEDURE AND ITS APPLICATION IN THIS PROJECT

A proposal was made at the October 1998 steering committee meeting that the SAPFACT questionnaire be used in interviews when other (established) schemes are visited.

The SAPFACT program and procedures are described very briefly in the following paragraphs.

SAPFACT is a computer program developed to promote the application of interview-based qualitative research techniques by practitioners with a scientific and technical background and no formal training in the social sciences.

The program identifies six aspects important in assessing the situation of irrigation farmers, each aspect consisting of eight factors, giving 48 factors in total. The six main aspects are as follows:

Irrigation management

Crop profit potential

General management

Labour management

Farmer aspects

Financial situation

The program can be edited to modify either or both the aspects and the factors to suit the specific needs of the user. The aspects listed here represent the conclusions derived by the researcher from interviews undertaken in the course of the pilot project (WRC Report no 382/1/96), and can be regarded as some of the results of that study.

After interviewing a farmer, the interviewer runs through the program and, for each factor, identifies the key word that best describes the impression he had formed during the interview. The program then converts this to a rating and, for each of the six aspects, an integrated combined rating of the factors is generated. A rating profile of the farm and farmer is presented on the screen. The whole process takes a few minutes and it is possible to identify strengths and weaknesses, bottlenecks and the likely consequences of remedial action or changing external circumstances.

The questionnaire was applied for two projects: the first on one of the original participants, and the other on a farmer in Venda. The analyses of the individual aspects, as well as the results for the two projects, appear in Appendix A.

The outcome of the SAPFACT runs on the two farmers shows that of the six aspects evaluated, Farmer 1 is better off than Farmer 2 in five aspects, and they are equally well off in the sixth. The actual field situation gives a different picture. However, the possible subjectivity of the project team's input should be kept in mind in any conclusions drawn from the results. The real situation on the farms, as well as difficulties experienced in a number of aspects when applying the pre-defined questions, supports the opinion that, in order to apply the SAPFACT procedure, changes are needed to the existing aspects to apply it successfully. These proposed changes appear in paragraph 6.3.

5.3 DETERMINING ASPECTS AND FACTORS FOR SMALL-SCALE MICRO-IRRIGATION APPROPRIATENESS

Although the SAPFACT program was ruled out to be applied for this project in its present format, it was recognised that the procedures followed by the program are appropriate, and that a new set of aspects, factors and criteria should be developed on which another version of the program could be based for micro-irrigation small-scale farming.

For each factor a few criteria (usually three) were identified according to which the evaluation of the different plots were done, and on which conclusions are based. These criteria are listed for each factor in an order regarded from least to most favourable for farming conditions. The number of plots belonging to each of the criteria are then shown in a table for each of the aspects. There are 17 plots in total, of which 13 were trial plots and the remaining four were existing micro-irrigation farmers. The number of farmers in each of these groups are shown separately in the table for each criterion, i.e. 2+1=3 means that for that particular criterion two farmers came from the trial plots and one farmer came from the existing farmers.

The outcome of the evaluations is not discussed in the same detail for all factors and all criteria. For most of these the important results, as per the view of the research team, are highlighted. For some factors it may be the negative criteria, for others the positive, and for some it might have been all the criteria.

Although the evaluation includes existing farmers, discussions concentrate more on the trial plots, though reference is often made to the existing farmers.

In very few cases can performance of the trial plots (positive or negative) be attributed to a single factor, and reference is made to other factors which have a bearing. The relationship between factors are shown in Guidelines for the Implementation of Micro-Irrigation in Small-Scale Farming - Chapter 6.

5.3.1 The farmer and his circumstances

During monitoring of the plots it was observed that characteristics of farmers, as well as circumstances under which they farmed, differed widely, which could contribute significantly to the success or failure of the particular plots. This was especially evident in the case of the established farmers during the secondary monitoring process, but also with hindsight in the case of the trial plot farmers. Consequently characteristics and circumstances were described by a number of aspects by which each site was evaluated.

5.3.1.1 Level of literacy and numeracy

Definition: General indication of farmer's education

This factor was evaluated in order to give an indication of the background of the farmers encountered. According to Bembridge et al. (1992) in Van Averbeke et al. (1998) people having attended school for a period of less than 4 years, can be regarded as functionally illiterate.

Four criteria were applied, namely:

Criteria	No of cases
Low level of literacy and numericy	2+0=2
Possesses some basic skills	5+2=7
Some formal education	3+0=3
Adequate formal education received	3+2=5

The farmers' levels of literacy and numeracy varied from very low (cannot read or write, cannot tell time from a watch, speak no second language) to very high (secondary education completed). It can however be concluded that a high level of literacy and/or numeracy is not a prerequisite for successful irrigation farming, but its absence could be an obstacle to adapting a new technology.

The farmer at Masisi cannot read or write, yet he obtained a loan from a development agency and installed his own system correctly without the use of a map. He also does not keep written records, but can recall most information from memory.

On the other hand, a possible contributing reason for the failure of the trial plot at Hlaneki could be difficulty in communicating, as well as a lack of understanding of plant production and irrigation. It could rather be attributed to the effect of a low level of literacy on access to information, than on the farmer's management capabilities.

5.3.1.2 Irrigation farming experience

Definition: Past experience of the farmer with any type of irrigation method when the research project commenced.

Micro-systems were introduced to farmers with various irrigation backgrounds. Although experience is probably one of the best substitutes for formal training, it was still found that some of the farmers had been irrigating for long periods without understanding certain basic concepts, or with some serious misconceptions.

Three criteria were applied, namely:

Criteria	No of cases
None	10+1=11
Informal training (worked for another farmer)	1+2=3
Formal training (courses, diploma, etc.)	2+1=3

Of all the farmers with none or limited previous irrigation experience who were introduced to micro-irrigation, only two (Buysplaas and Blackheath) are still operating successfully. These farmers have considerable support. Again, failure of the projects cannot be attributed to this aspect only, but possibly has to do with the fact that food production under irrigation historically played a lesser role in the lives of these farmers, and therefore a number of new factors were probably involved for them. Not to be successful was not disastrous for them, seeing they were not that dependent on irrigation.

Of the farmers with much experience, only one failed to change to micro-irrigation successfully, the reason being fear of possible risk with a new system, while nevertheless in desperate need of the income. Exposure to the system during installation, which he did not take part in, could possibly have prepared him sufficiently for successful implementation of drip-irrigation.

Micro-irrigation (and more specifically drip-irrigation) is a more sophisticated way of applying water. A high risk is involved due to the smaller volumes of water applied at a time, and this requires a good understanding of crop production and irrigation, as well as adequate infrastructure. Before a farmer can use this method of irrigation, certain basic concepts have to be understood, and this can often be learnt more easily (or at a lower risk) with a simpler method of irrigation.

According to Crosby (1994) in his survey on irrigation farming, most commercial irrigation farmers went through an evolutionary process, typically starting with a phase of flood irrigation, moving on to sprinklers and then to more modern systems (such as micro). It would seem as if this is the natural way in which development takes place, and would be the ideal way to introduce farmers to new technologies. This process does, however, take years and considerable financial investment. It would be better if a way could be found to apply the knowledge gained from this observation to successfully introduce up-coming farmers to micro-irrigation.

5.3.1.3 Irrigation farming training

Definition: Level of training in irrigation related aspects.

This training refers to the management of the in-field system. Aspects related to the supply system (pumps, reservoirs, etc) require a different level of training.

Although it can be said that knowledge of good practices forms the basis of successful irrigation, opportunities for small-scale farmers to learn these skills through formal training are limited. Not only are the locations often remote and funding not available, but a general low level of literacy makes the use of written information almost impossible.

The three criteria used are:

Criteria	No of cases
None	10+1=11
Informal training (worked for another farmer)	1+2=3
Formal training (courses, diploma, etc.)	2+1=3

Of the 10 trial plot farmers who had none or little irrigation farming training, failure of only one of these plots (seven of these farmer's plots failed) can to a small degree be attributed to the training aspect (Haarlem).

Thirty-five percent of farmers had received some training, which could be categorised as either formal or informal training. Formal training implies that the farmer had attended a course(s), or had obtained an agricultural diploma. Informal training is regarded as any form of "hands-on" training, for instance where the farmer worked for another irrigation farmer and learnt new skills in the process.

Of those three farmers from the trial plots who received informal and formal training, one plot failed (Genadendal 1), mainly because of financial difficulties.

The farmer at Nwanedzi (existing farmer) left school when he was 14 years old to work on a commercial farm. He tried to learn as much as possible, and eventually left to start his own enterprise. He has developed his present farm up to the same level as that of any of the commercial farms in the area, and is treated as an equal by his neighbours.

The importance and value of training is evident in that two-thirds of the farmers who had received some training (formal or informal) were operating their systems with a relative degree of success. Although training played an insignificant role in the plots which failed, the trained person has the skills which are necessary for success.

5.3.1.4 Farmers' views on micro-irrigation

Definition: View of the farmer when the subject of micro-irrigation was first discussed with him by the research team.

Not all farmers using micro-irrigation who were monitored or visited by the project team were familiar with this method of irrigation until they had to operate it themselves. The systems were met with a variety of attitudes, but a positive view should improve the chances of a farmer being successful. If he is naturally curious about or interested in the system and its potential, he is more likely to search for solutions to problems and be innovative in his management.

Three criteria were applied, namely:

Criteria	No of cases
Not familiar with micro-irrigation	10+0=10
Familiar with, but skeptical	1+0=1
Familiar with, and positive	2+4=6

In general, most of the farmers saw conversion to micro-irrigation as an opportunity for development and improvement. Although this attitude was sometimes based purely on the fact that they saw commercial farmers using it and considered it therefore to be good, they were willing to discard their old methods and try something new.

For those who had no previous irrigation experience, the systems were met by anything from indifference to optimism. Especially on some of the schemes there was something of a "top-down" approach when the systems were introduced.

For those farmers positive about micro, the system they would go for if they could afford it, is *micro-irrigation*.

It is important that care should be taken when introducing up-coming farmers to a new technology not to create too much anticipation as to the potential of the system - being successful at irrigation farming remains hard work and requires extensive inputs from the farmer. Even a sophisticated system does not make it any easier, or guarantees success, but rather requires more skill (effort) of the farmer.

5.3.1.5 Location of the farm

Definition: The geographical location of the farm in relation to infrastructure and services.

The importance of this factor is reflected in terms of the influence it has on other factors, such as access to markets, access to infrastructure, etc. This could have consequences for the economic viability of the operation, because it may limit the choice of crops to be grown, availability of spares, or extension officers with sufficient know-how.

Four criteria were used to categorize the location of the farm:

Criteria	No of cases
Remote and reached with difficulty	3+1=4
Remote but within reach of basic services	1+2=3
Rural but close to urban area	7+1=8
Urban	2+0=2

Of the three trial plots, all of which are remote, none is still operational. The problems experienced with pumps at Rooifontein and Kheis could more likely have been solved if repair services were more easily available. On the other hand, some of the most successful existing farmers are in remote areas (Masisi, Nwanedzi). They do not rely on external support, and have their own input supply, transport and marketing services in place. Their location is no obstacle, but rather forces them to improve on their planning, and to make full use of all available sources.

Another implication of remote areas, is the farmer being isolated from others using the same system. Farmers want to discuss their experiences with those who employ the same equipment and practices. If a farmer is isolated, and he experiences problems, this may influence the effort he puts into finding a solution. This is more relevant in the case of small-scale farmers, or those who are less confident about adopting a new technology.

Location of the farm is therefore an important aspect, but should be judged in terms of the available infrastructure, or how easy it is to access.

5.3.1.6 Suitability of climate for crop production

Three criteria were used for this factor, namely:

Criteria	No of cases
Unsuitable	2+0=2
Moderately suitable	2+2=4
Suitable	9+2=11

For 11 of the 13 trial plots the climate was moderate to favourable. Both plots with extreme climatic conditions (both in Namaqualand) failed. Although the harsh climate was not considered to be the main reason for failure, it was without doubt an important contributing factor.

When water is available for irrigation, it is possible to produce crops in areas where it has not always been feasible due to the climate, or to produce crops which are not naturally suited to the local climate. This could increase the risk associated with crop production. In order to produce optimally, the farmer should rather produce crops suited to the climate.

Although irrigation opportunities make it possible to produce crops in areas where it would not even have been considered under dry-land conditions, there is a real danger of the system failing. If the farmer cannot irrigate, crops have no chance of surviving the harsh climate. Soil preparation, planting and irrigation equipment can be very expensive, and the farmer's financial loss will be substantial if the irrigation system should fail.

Reliability of water-supply and the water-supply infrastructure are of the utmost importance in areas with extreme climates. These were the main causes of failure of the trials at Rooifontein and Kheis.

5.3.1.7 Production potential of soil

Principles of micro-irrigation make it possible for soils marginally suitable for crop production to be cultivated. Although there are formal soil classification methods, soils at the sites were simply categorised as either low, medium or high potential.

Three criteria were applied, namely:

Criteria	No of cases
Low	2+0=2
Medium	3+1=4
High	8+3=11

Both farmers on the low potential soils (urban plots on Cape Flats) succeeded in obtaining acceptable yields from good quality crops. It is important to note that adequate water of good quality was available in both cases, and fertiliser was regularly applied. They were also well supported, and had a very reliable water-supply system, with little management responsibilities. However, as in the case of climate suitability, a very sandy soil will not be able to retain an adequate water reserve for the crop for a long period if the water-supply should fail.

The project proved that when the right decisions are made about fertiliser application, irrigation system, scheduling, plant and emitter spacing, etc., low potential soil can be utilised productively.

5.3.1.8 Size of operation

Definition: This is the size of the land which the farmer regularly irrigates. Micro-irrigation might have been done only on a part of this area.

As mentioned before, small-scale irrigation is defined in this study as cultivation of an irrigated area of 20 ha or less. In the case of the trial plots, the area served by the micro-system at each site was usually dictated by a limiting factor, ranging from the amount of water available, to the original layout of the field, or the cost of equipment.

Six categories are used to divide the plots into:

Criteria	No of cases
Area < 0,1 ha	5+0=5
0,1 ha < Area < 1 ha	4+0=4
1 ha < Area < 2 ha	1+0=1
2 ha < Area < 10 ha	3+1=4
10 ha < Area < 20 ha	1+1=2
Area > 20 ha	0+1=1

In total just more than 50 % of the sites visited were smaller than 1 ha, and 30 % were between 2 ha and 10 ha. It was noticed that the systems operated most productively were either on the very small plots (< 0.1 ha) operated by a single farmer (Thembalethu, Gugulethu, Blackheath), or on the larger farms (2ha -10 ha) at Buysdorp, Masisi and Hlaneki B.

In the case of very small plots, farmers can exploit the opportunity created by the decrease in labour demand due to the change in irrigation method, to expand their crop production and cultivate a larger area. On a larger farm the decrease in labour demand (in this case, hired labour) also appeals to the farmer, because it has a direct influence on his production costs.

5.3.1.9 Land ownership

This is probably one of the most debated issues surrounding small-scale irrigation, and is seen by many farmers as a major obstacle in development and growth. Farmers who cultivate and develop land which they do not own cannot offer it as security to obtain credit, and also feel that maintenance is not their responsibility.

Four criteria were applied, namely:

Criteria	No of cases
Part of scheme	4+1=5
Demonstration/Experimental plot in community	4+0=4
Occupation right/Rented	4+2=6
Owned by farmer	1+1=2

Only 12 % of the farmers own the land on which they farm, although at least five of the farmers who do not own the land they farm on have substantial loans. Four of them (Buysdorp, Nwanedzi, Homu and Genadendal 1) have farms larger than 5 ha, and one farm (Ebenaezer) is larger than 2 ha, on which a different irrigation method had been used previously. These farmers had obtained loans from local development corporations for improvements or extensions.

Three of the four demonstration/experimental plots have failed, and for two of these it could be directly attributed to the farmer's lack of involvement, and compensation he received for his work.

A rather interesting opinion is held by the farmer at Nwanedzi, who rents 75 ha from the government. He believes that farmers should not own land, but that it should be owned by government, and always be used productively. If government should decide that a farmer does not make optimum use of this land, the land should be allocated to another farmer to produce crops. He is of opinion that all farmers have a responsibility to produce food for those who live and work in towns, because they cannot do so themselves. Therefore, if a farmer does not utilise arable land, he should be replaced by someone who would be willing to do so.

5.3.1.10 Dependence on farming income

Definition: The extent to which production on the farm serves the total needs of the farmer.

According to Moris (1987), irrigation is seen by policy-makers in (Sub-Saharan) Africa as the best technology for ensuring food sufficiency and for stabilising rural development within the continent's large semi-arid zone. It is therefore in times of increasing unemployment that many people turn to agriculture for their livelihood. It is generally unlikely for these farmers to continue practicing agriculture if they should find another way of earning money. On the other hand, there were also farmers who have other more secure sources of income, but would like to farm full time. This difference in dependency could have a decided influence on the decision-making and management approach of the irrigation farmer.

In some cases the crops were not as yet mature enough to produce, for instance fruit-trees, and the potential income from the mature crops was projected.

Three criteria were applied, namely:

Criteria	*No of cases*
(Potential) farming income is only supplementary	5+1=6
(Potential) farming income makes substantial contribution to total income	6+0=6
Farming is only source of income	2+3=5

In all cases where farming income is only supplementary, farming operations are handled by a *manager/worker/operator who is paid a salary* (Hlaneki B, *Gugulethu, Haarlem, Buysplaas*, Rooifontein and Kheis). In five of these cases it happened during the course of the monitoring that the operator had left and the systems were unattended for a period of time. It would seem therefore that if the farmer (owner) is not dependent on the income, he is willing to delegate responsibility to someone else and only play a role in major decision-making. The operator may be very capable, but will only stay dedicated as long as it is to his/her advantage. The inconvenience and financial implications caused by the operator leaving plays a significant role in the success of the project.

On the other hand farmers who were completely or to a great extent dependent on the farming income generally managed their own farming enterprises. The option of trying a new irrigation method was met by one of two possible attitudes: it was either seen as an opportunity to be more productive and economical (Homu, Nwanedzi, Masisi, Ebenaezer, Thembalethu, Genadendal 1), or as a risk that could reduce already marginal gains (Hlaneki, Genadendal 2). These farmers realised that they had to keep producing crops in order to secure an income. This caused them to either use the system optimally, or to revert to previous systems if they considered their crops to be at risk.

5.3.2 Water-supply

Definition: This term refers to the farm's water-source, in other words the source from where the particular farmer receives his water.

This could be a dam, a canal, a borehole, a water-board connection, or a municipal connection. In some instances farmers control, or partly control the water- supply to their project, but in most cases this responsibility lies somewhere else. It includes the complete system between the point where the water is "generated", to the point where the farmer withdraws the water to his fields, in other words where his irrigation responsibilities on his farm start.

The water-supply to the farm was clearly found to play an important role in the successful management and operation of a project. It is important that the required volume of good quality water be withdrawn at the required stage before damage occurs to the crop. It is therefore partly a given for the farm (the water-source itself), as well as its management. If water shortages are experienced on the farm, it is necessary to clearly distinguish between a water-supply problem, and a water-distribution problem. Over some of these the farmer has (some) control, but for others he can do nothing to improve the situation.

Water-supply is subdivided into six factors on which the evaluation is done.

5.3.2.1 Available water

Definition: The water available at the source (volume, flow-rate and pressure) in relation to the requirements which the water-supply system has to serve.

Availability of water determines whether irrigation farming can be considered, as well as to some extent the type of system to be considered. In many areas in South Africa dry-land cultivation is viable, but this project specifically addresses irrigation farming, and it is therefore important to establish how the project will be affected by the availability of the water.

In calculating available water, periodic droughts should be taken into account, and the necessary adjustments made to the area to be irrigated from the water-source.

Three criteria were identified to sub-divide the trial and other plots, namely: inadequate, barely enough, and adequate.

Criteria	No of cases
Inadequate	4+0=4
Barely enough	0+1=1
Adequate	9+3=12

Of the eight trial plots which failed, three could be mainly due to inadequate water availability, and for another it contributed to its failure. The three successful plots all had adequate water available. Of the four existing projects, three have adequate, and one barely enough water available.

In all cases of inadequate water-supply this potential danger was recognised when the project was started, but realising that an irrigation project cannot be sustainable with inadequate water, the scale of the project accommodated this. However, other additional aspects eventually caused the damage. The most important contributing aspects included: extreme climatic conditions (droughts), reliability of supply, responsibility for supply, management of supply, support services and cash flow (access to financing). Problems experienced with on-farm distribution systems also contributed to system failure, but the primary reason in these cases were cash-flow difficulties to repair the systems, as well as lack of support services to advise the farmer on what to do and the logistics around it.

It must, however, be borne in mind that scheduling of irrigation was not satisfactory on all sites, and in this sense adequate water, where available, did benefit all plots. This was the case at nine of the experimental plots, but in four of these in particular it could be regarded as a major counter "action" for other aspects which were not favourable, namely poor soil conditions (sandy soils), poor crop management (weed control) and utilisation of the system (productive use).

5.3.2.2 Reliability of water-supply system

Definition: An indication of the effectiveness of the system supplying the available water between the water-source and the irrigation system.

Reliability of the water-supply system plays an important role in making decisions about crops to be cultivated, and the type of irrigation system to be implemented. With a reliable supply system there should be no risk that available water will not reach the irrigation system when required at the volume, flow-rate and pressure as planned. Safety factors need to be built into calculations should the water-supply system not be reliable.

Four criteria were applied, namely:

Criteria	No of cases
Unreliable	2+0 = 2
Reliable source, but capacity limited	3+1 = 4
Reliable source, but with limitations (infrastructure or management	0+0 = 0
Reliable	8+3 = 11

Reliability of the water-supply adds very much to the ease of managing the irrigation project.

Unreliability of supply was directly responsible for the failure of two projects (Ebenaezer and Rooifontein). Another closely related aspect is pump operation and the on-farm water distribution system, which is discussed in paragraph 5.3.3.1.

Reliability of water-sources for the projects which failed were not considered by the farmers or community to be very unreliable when the projects started. During its running, however, sources came under pressure, due to severe droughts and additional water (domestic) requirements. This combination made heavy demands on a particular source. For one of the plots irrigation would have ceased due to a lack of water available for irrigation, all else being equal. For another the irrigation area was too big for the source to support when rains did not come as expected.

For those plots with reliable water-sources, farmers were ignorant about potential problems, and this issue was in fact not even raised. On the other hand, on those plots where a shortage of water was experienced, farmers could hardly talk about anything else.

5.3.2.3 Water quality

Definition: A rating to indicate suitability of water available for irrigation purposes.

The measurement and interpretation of water quality is usually one of the first steps when planning an irrigation system. Water quality has an effect on plant growth, the soil, as well as irrigation equipment. Water containing a large component of total dissolved solids (TDS), can cause problems when used for irrigation. The total amount of physical (eg. soil particles), organical (eg. algae) and chemical (eg nitrates) impurities was taken into account when water was classified as of either poor, acceptable or good quality, as shown in the next table.

Criteria	No of cases
Poor	2+0 = 2
Acceptable	2+1 = 3
Good	9+3 = 12

Figures indicate that for the majority of plots quality water was available for irrigation, the reason being that the project team did not attempt to develop irrigation schemes where it was not already practised, although in most cases on a different scale. It was obvious that the water quality was such that it could be used for irrigation.

Both plots with poor quality water failed, but not due to the quality of the water. This, however, does not exclude the possibility that over a longer period of using poor quality water it may cause problems in the system, in particular to the soils.

In two cases (Ebenaezer and Haarlem) the organic load in the water caused filtration problems which put additional pressure on the operation of the system.

5.3.2.4 Farmer's responsibility for irrigation water-supply

Definition: Defines the extent of the farmer's own responsibility towards management op the water-supply (water available and reliability of supply).

In most commercial farming enterprises the farmer is responsible for the major part of his irrigation water-supply (see sources of available water in paragraph 5.3.2). With small-scale farming under present conditions, the farmer has less responsibilities with regards to water supply, which appears to be a critical aspect in his project's success.

Three criteria were applied to describe responsibility for the water-supply.

Criteria	No of cases
Farmer fully responsible	2+1 = 3
Farmer has some say about the supply (committee on scheme, etc)	2+1 = 3
Farmer has no responsibility for the supply	9+2 = 11

Due to the limited number of trial plots, the available results do not illustrate the impact of this aspect very clearly. As a general remark it can be stated that if the farmer is fully responsible for his supply system, and he is not well-trained and well-backed up with support services, there is a real danger that things could go wrong with his project. In only one such case (existing project Buysdorp) the farmer is running a successful operation, despite a fairly complex system.

In the case of Ebenaezer a group of farmers are sharing a canal, and they are responsible for organising the operation of the canal among themselves. Although sufficient water was released into the canal by DWAF, the trial plot holder suffered severely due to unreliable supply. (There were also communication problems which aggravated shortages). It is evident that all the necessary support structures are not in place to resolve these problems. The situation is furthermore exacerbated by the poor financial situation of the group of farmers.

Repairs to the supply system is normally a costly matter, and could be difficult to manage financially, or if for a group of farmers, difficult to allocate responsibility to each for maintenance or repairs. This leads to delays in water-supply, which in turn causes crop losses.

Ideally, if a farmer is not fully responsible for the water-supply, he should have a major say in its management. This research project, however, showed that the fewer additional technical responsibilities the farmer has, the more time he can spend on things he is better equipped to do.

5.3.2.5 Frequency of supply

Definition: An indication of the comprehensiveness (luxury) of the supply system design.

Frequency of supply of an irrigation system is determined by the design of the system, and may vary from a very flexible system where irrigation water can be withdrawn on demand, to withdrawal restrictions based on limitations of the system.

The frequency of supply experienced in the fields (irrigation system) is normally determined by the management of the supply system. In some cases the farmer himself is responsible for this task, and in other cases an outside authority is responsible. In the aspect under discussion, the frequency of supply is evaluated at the point where the farmer's responsibility begins.

Three criteria were applied here, namely irregular, regular (at a fixed schedule and at a fixed flow-rate) and on demand.

Criteria	No of cases
Irregular	3+0 = 3
Regular	3+1 = 4
On demand / always available	7+3 = 10

The table above shows that about 60% of the trial plots could withdraw water on demand, which is obviously a very favourable situation. It is, however, interesting to note that the remaining plots with a less favourable supply, in other words either a more structured (regular) or problematic (irregular) supply, in general performed better. The reason could be that the discipline required to cope with this system "limitation" is also applicable to other aspects of the farming operation.

In the three cases where irregular supply occurred, serious setbacks were experienced during these sporadic periods. In all of these instances the irregular supply went hand in hand with poor management of the supply system.

Plots which had an irregular supply suffered seriously because of this. Irregularity of supply in these cases was closely related to management of the supply system, and if this could be dealt with effectively, problems could be avoided. A clear distinction must be made here, in the sense that if the supply was irregular due to system limitations (before the point where the responsibility begins), e.g. too small a supply system which causes cycles which are too long, farmers would have had no choice but to reduce the area which they irrigated. However, in the case of a management problem, certain issues, such as system operation, could be addressed to solve the problem.

5.3.2.6 Management of supply

Definition: An indication of the effectiveness of water-supply system (source and delivery system) management.

This aspect is closely related to factors such as water availability, reliability of supply, and frequency of supply. If any of these are negative, the management of the supply will consequently also be negative. In this sense it is therefore not necessary to consider this aspect separately, but under different conditions it may be possible that management may be poor, but, due to an over designed system, all other factors are positive. There may also be situations where an unreliable source can do well due to good management, or vice versa.

The three criteria applied here were as follows:

Criteria	No of cases
Poorly managed	3+0 = 3
Managed acceptably	1+1 = 2
Well managed	9+3 = 12

In general water-sources were managed well. Partial failure was experienced at Ebenaezer, where a reliable water-source with adequate available water was not supplied frequently (see paragraph 2.4 for description) due to poor management, which could be improved if the farmer and his fellow farmers were better organise. Much the same applies to Strydkraal. However, in this case there was little that the farmer could do, because the cause of the problem was located in a different section of the canal system, where she had little or no say.

At Homu all the aspects mentioned were also present, but the reason for poor management was that the authority who paid for pumping of the water often did not have money, and the electricity was consequently cut off. Eventually the farmers paid the electricity bill. Fortunately, due to frequent rain, not much damage was done to the crops because of the irregular water-supply.

On the other hand, a situation was experienced where an unreliable and inadequate source with poor quality water was well-managed at Kheis in order to supply water to the irrigation system. Eventually no water was left at the source, and the irrigation project had to be terminated. At Buysplaas, where water became very limited, the well-managed supply system probably saved the project from total failure

Well-managed water-supply in almost all of the plots undoubtedly contributed much to farmers' achievements.

5.3.3 Irrigation system

Definition: The irrigation system starts at the point where the supply system releases the water on the farm. It includes the distribution system, comprising the pump, filtration and fertigation equipment, and in-field system.

This aspect includes seven factors and deals with technical issues of the irrigation system and its installation. Although closely related to the management of the system, which is dealt with in paragraph 5.3.4, the emphasis here is more on "problems" experienced with the system, rather than on how well the system was utilised by the farmer.

5.3.3.1 Pump and on-farm water distribution system

Definition: A rating on how well the pump (if applicable) and main pipe distribution system perform in terms of the task for which it was designed.

In most of the trial plot cases distribution systems were installed by the research team, and it could therefore be expected that, provided it was done thoroughly, the systems would be adequate. For general application, however, provision is also made for inadequate systems, for which four criteria were applied.

Criteria	**No of cases**
Insufficient capacity	0+0=0
Unreliable and prone to breakdowns, leakages, etc.	0+0=0
Adequate, but could be improved	4+3 = 7
Good	9+1 = 10

The "adequate" rating which four of the trial plots received had to do with partly existing systems, which in all cases were reliable and adequate, but there were aspects which over time would require upgrading.

Of the 13 trial plots, five had systems equipped with pumps as part of the irrigation system. Three of these were diesel driven (all existing) and the other two electrically driven. One of the latter was a new pump installed with the system.

Although all trial plots received a rating of "adequate" and better, all projects where pumps were involved were seriously disadvantaged due to pumping problems. Problems and consequences of these problems include the following:

- Genadendal 1: The pump broke down and due to cash-flow limitations it took a considerable time (two months) to repair, with consequent loss of a crop.
- Genadendal 2: The diesel engine broke down and due to cash-flow problems took months to repair, with consequent crop loss. Delay of electric power installation also affected the situation negatively.
- Ebenaezer: Stones got into the pump. The farmer realised that he had problems with pressure, but nevertheless carried on irrigating like this for weeks, because he did not know what to repair, or how to do it. Crops were consequently damaged.
- Rooifonten: The diesel engine broke down (almost beyond repair), and due to the financial situation it could not be repaired. For some time they tried irrigating with water from a windmill, but this was discontinued when this source was needed for domestic and livestock use.

- Kheis: After about two months of irrigation the diesel engine started using oil. The Christmas season with limited access to services was on hand. After further delays to acquire finances for the repair work, the water supply eventually dried up and consequently the vegetables and most of the fruit trees did not survive.

Of the remaining eight trial plots, six had some degree of pumping in the supply system (beyond the control of the farmer). No problems were experienced with supply of water to the irrigation system in any of these cases.

In a few cases the relative success of the operation could be greatly contributed to a well-running system.

5.3.3.2 In-field system suitability

Definition: The degree to which the in-field system suits the purpose it was designed for. The in-field system starts at the control valve of the block (at the beginning of the submain).

As in the case of the on-farm distribution system, the in-field system was planned and designed for individual trial plots and is therefore assumed to be suitable for the conditions.

Three criteria were applied, namely:

Criteria	No of cases
System found unsuitable for physical reasons (wind, soil, weeds, water)	0+0 = 0
Concern about suitability of system	6+1 = 7
Suitable for crops, climate and farming practices	7+3 = 10

The advantages of micro-irrigation contributed in a number of cases to the success of the trial plots. These advantages (or qualities) are as follows:

- Water saving: It was possible to keep crops alive during periods of critical shortages. This is more applicable for drip than for micro-jets.

- Frequency of supply: Irrigation can be applied as frequently as needed. This allows very poor soils to be irrigated successfully.
- Limited wetted area: Due to a smaller wetted surface area (more applicable to drip), less weed control is needed, and in cases where weed control is poorly managed, the system is preferable to other forms of irrigation.

Although micro-irrigation was not found to be unsuitable anywhere, cases where there was concern about the system were related to the following:

- Crop management: Where weed control was poorly managed with micro-spray irrigation on trees and other permanent crops, water distribution was very poor, and water from some emitters did not reach the root zone of the crops.
- Reliability and frequency of supply: If the water-supply is unreliable and / or infrequent, the lower water-holding capacity of the soil (due to smaller wetted zone) created a worse situation (especially with drip-irrigation) than with other systems where the "reservoir" in the soil was bigger.
- Soil structure (infiltration): In the case of coarse sand, water distribution in the soil profile under drip-systems may be inadequate for proper root development.
- Soil structure (wind damage): With a sandy soil irrigated with drip, damage to foliage occurred when the wind was extreme. The wetted surface area under the drip is small, and the rest of the surface sand was easily blown about by the wind.
- Soil and/or water "chemistry": Where saline conditions were present, danger existed of concentrating harmful salts in certain locations in the soil under drip-irrigation, which may, under certain conditions, return to the root zone in higher concentrations than could be tolerated by plants.
- Climate: Under hot climatic conditions the hot dry surface area between drippers had a scorching effect on plant foliage. The presence of hot winds deteriorated the situation.

The views expressed above are those of the project team. There were, however, indications that farmers had difficulties in understanding drip-irrigation, and that this influenced their view of drip-irrigation. Some of these are given below.

- The farmer at Gugulethu removed her drip-system without discussing it with the project team. After the concept was discussed with her she insisted on micro, which she managed well. She had a problem with the fact that such a limited area is wetted for vegetables. She was right to some extent, because she also planted seedbeds.

- The problem of the farmer at Genadendal 2 was "fear". He preferred to continue with a system familiar to him, rather than taking chances with a system which was foreign to him. This despite the fact that he maintained that he preferred drip, which he intended implementing the following season.
- At Buysplaas it was found that a small hole had been made in the dripper pipe at the trees. It seems as if the operator preferred to see a jet of water. Nobody actually admitted to this, and this conclusion can therefore not be confirmed.
- The farmer at Hkaneki did not believe in drip because she could not "see" the water, and asked for the system to be removed.

5.3.3.3 Filtration

Definition: The way the farmer utilised / experienced the filtration system included in his system.

Filtration was singled out as an aspect on its own due its importance, as well as the high degree of management and maintenance it requires. Criteria applied for filtration are about understanding, as well as problems experienced.

Three criteria were applied, namely:

Criteria	No of cases
Filtration concept not understood	5+0 = 5
Filtration caused some problems in the system	3+1 = 4
No problems, and/or concept of filtration understood	5+3 = 8

Although the majority of the trial plot farmers did not understand the filtration concept well, and / or experienced some problems with it, this did not impact significantly on project outcomes, except in two cases, namely:

- *At Ebenaezer the original filter was found to block rather quickly due to the dirty canal water,* despite normal standards applied for filter selection. Fortunately the problem was identified early in the process by the extension officer, and another two filters, paid for by the

Department of Agriculture, were fitted. This solved the problem and the farmer consequently spent less time on cleaning the filter.

- At Haarlem, where the design was for four laterals to run simultaneously, the operator wanted to spend less time at this experimental plot, and therefore continuously opened more laterals. This caused higher friction losses in the filter, which also had to handle a bigger volume per time unit. This caused a rapid drop in available pressure. At some stage two pressure gauges were installed (up- and downstream of the filter) which the operator understood better, though he made little effort to adjust his procedures accordingly.

Although the farmers in general did not seem to understand filtration, most of them cleaned the filters as a matter of routine according to the guidelines provided. It is important however to evaluate their experience from time to time, for example the amount of dirt on the filters at time of cleaning, and to adjust guidelines where necessary. In general there were few complaints about this "additional" irrigation task, compared to the systems they used formerly.

The fact that compensated drip was used in a number of cases benefited these projects, in the sense that much bigger pressure tolerances (due to a filter getting blocked) could be absorbed before it could impact on the volume of water applied.

Although cost is a significant component in small-scale farming projects, it is recommended that filtration capacity be over-designed in order to accommodate management difficulties. The farmer's limited knowledge on filtration functioning, as well as limited financial acumen, will tempt him to acquire a smaller filter than necessary, which could cause problems in the long run.

The quality of the water, and how it changes over time, must be thoroughly considered when a decision is taken about filter size. In this project this problem (of quality deterioration) was experienced only at Kheis at a stage when the dam was nearly empty. An attempt was made to improve the situation by digging a deeper trench in the basin of the dam so that the suction pipe could be submerged deeper, but this did not really solve the problem and eventually the filter had to be cleaned at less than hourly intervals. Problems with water quality often occurs in practice, irrespective of the water-source, such as dams, rivers, boreholes and canals.

Disc or mesh-filters should be considered for micro-irrigation, and for drip if at all possible, and when flows are low (smaller than 10 m^3/h). This is recommended because of the higher cost of sand-filters and their high management requirements. A sand-filter was used on only one of their plots. This was an existing filter, used for existing drip-irrigation on 2 ha of fynbos on the farm.

5.3.3.4 Fertiliser application

Definition: Farmer's experience in applying fertiliser to his crops, either through the irrigation system, or manually.

There is concern about the efficiency of fertiliser application if not applied through the system by dissolving the fertiliser in the water, making use of injection methods, especially in drip-systems. Fertiliser application was therefore identified as an aspect of the irrigation system (factor) which needed to be addressed separately.

Four criteria were applied, namely:

Criteria	No of cases
Problems experienced with fertiliser application	2+0 = 2
Innovative adjustment made to improve fertiliser application	1+0 = 1
No problems experienced	10+4 = 14

Early in the project this aspect was considered as being crucial to the farmer's success. It was found however that sophisticated equipment is not essential if the scale of the farming is small.

Fertiliser was applied by means of the irrigation water on only two of the plots, namely at Genadendal 1 where an injector was used, and at Ebeneazer where a venturi was used. At Genadendal the injector (already on the farm) caused many problems, and was used on a limited scale only. The venturi at Ebenaezer was used intensively without incurring problems. The extension officer prepared the solutions, and delivered it to the farmer whenever there was a need for application.

On the rest of the plots granular fertilisers were used, mostly by just applying it on the soil surface. In some cases, however, it was worked into the soil by spade. In very remote areas the use of compost and manure (from donkeys and goats) was encouraged.

The research project has as yet no clear recommendations on appropriate procedures or on the efficiency of the different systems, and it is recommended that additional work be done in this respect, focusing clearly on the following: soils, fertilisers, crops, methods and management.

It is not exclusively a technical problem, but also a financial one. Due to the financial constraints of the small farmer, cheaper alternatives to the standard, well-proven, commercial procedures of fertiliser application techniques are applied. The efficiency of some of these alternatives may however be inferior, which would impact on the financial situation of the farmer. This implies that money is lost due to wasted fertiliser and/or poor yields.

The following fertiliser application methods are presently being used or considered for small farmers using drip-irrigation:

- Hydraulic or electric fertiliser injectors
- Venturi, using pressure from the irrigation water
- Venturi, using pressure from an external energy source
- Fertiliser pressure tank in which fertiliser is dissolved, and through which part of the irrigation water is pumped. Bagged manure inside the tank can also be used.
- Fertiliser dissolved in a large volume of water in a tank or small dam before being pumped into the irrigation system.
- Fertiliser dissolved in water, and then applied manually to each plant by bucket.
- Fertiliser granules spread in rows and worked into the soil with a spade or fork
- Fertiliser granules spread around the drippers, to be washed into the soil via the drippers.
- The exclusive use of manure and organic material

Special attention will have to be given to the role of rainfall and the type of crop irrigated. For instance in the Stellenbosch area it may be possible to use a drip-system and apply fertiliser granules on the soil surface in vineyards. During normal years rainfall is sufficient during the critical fertilising months (September / October and April / May) to carry the fertiliser to the roots. However, this will not be a suitable practice in Vredendal, or even Stellenbosch, if vegetables were to be grown in the summer months.

The different types of fertiliser will have to be assessed in the context of irrigation practices. Investigations will have to be done in conjunction with specialists at ARC institutes, universities and the fertiliser industry.

5.3.3.5 System installation

Definition: Interest exhibited by the farmer during installation of his system.

In all but one case the trial plots were the first direct contact the farmers had with micro-irrigation. It was therefore obvious that the project team had to do the installation. This aspect, with details of the farmer's involvement, is included to illustrate the role of involvement in the management and maintenance of the project.

Two criteria were applied, namely:

Criteria	**No of cases**
Farmer not involved in system installation	2+0 = 2
Farmer responsible for system installation	11+4 = 15

In both cases where the farmer was not involved in installation of his system, and therefore missed an opportunity to learn more about the system, it had important implications for future management.

- In the case of Genadendal 2 the farmer could not be present due to other commitments, and as discussed in Chapter 4, he never really had the confidence to work with the system. The careless manner in which he dealt with equipment and pipes when it had to be removed for soil cultivation purposes clearly illustrated his lack of knowledge.

- The opposite was experienced at Ebenaezer where the farmer was very involved with the installation, supported by the extension officer's involvement. Removal and storage of material were done with the utmost care to protect it against dirt and physical damage.

Installation of the system must be regarded as the first and major step in a farmer's training. Since extension services' input in future farming activities is of major importance, the extension officer involved should be present. In most of the trial plot cases extension officers in those regions also had very limited experience of micro-irrigation.

5.3.3.6 Comparison with other systems known to/used by farmer

Definition: Farmer's view on micro-irrigation after becoming familiar with the micro-irrigation system.

This aspect is influenced by a number of other factors, for which three criteria were applied for purposes of evaluation, namely farmers who prefer other systems, farmers who prefer micro, but with certain reservations, and farmers who prefer micro-systems.

Criteria	No of cases
Prefers other system	3+0=3
Prefers micro, but with certain reservations	1+0=1
Prefers micro-system	9+4=13

It is important to distinguish between sound and valid reasons for certain farmers' dislike of and reservations on micro-irrigation, and reasons founded on poor knowledge of the system. In this project the reasons for the four farmers falling in these categories varied:

- Genadendal 2: Fear (as discussed in Chapter 3.1). His problem could possibly be resolved through training.
- Hlaneki: Understanding (as discussed in Chapter 3.1). Her problem could possibly be resolved through training.
- Strydkraal: Management reasons. The farmer had other commitments during the afternoon, and could therefore not stay to close the drip-system. Her problem could possibly be resolved by a system with a higher application rate.
- Kheis: Concern about system type. There is concern, also among project team members, that drip may have negative long-term implications. It was suggested that further soil studies be carried out before drip-irrigation is applied on a bigger scale.

Micro-irrigation did not, however, evoke only negative responses. There were in fact also positive responses, albeit based on misconceptions about the system, e.g. farmers not realising that they can over-irrigate with drip and in the process damage their crops.

5.3.3.7 Innovative/different use to overcome problems

Definition: Measures taken by the farmer to improve the overall efficiency of the project. These may include farming practices.

Three criteria were applied, namely:

Criteria	***No of cases***
Innovation which could have improved efficiency but were not applied	4+0=3
No need for innovative adjustments	2+1=3
Innovative changes made to conventional system to improve efficiency	7+3=10

The criterion "no need for" is strictly speaking not correct, because in any system, no matter how well it was designed, there will always be occasions for innovative improvement. In this project, however, it was not used for situations where the system was functioning well, and the farmer managing more or less as expected.

Those farmers falling in the "could have improved" category, could have improved on the following:

- Intercropping: Although this was encouraged, and practiced to a limited extent, it was disappointing that it was not applied more aggressively. In Haarlem, where a micro-jet system was installed among young fruit-trees, this could easily have been accommodated. Apart from improving the financial position, successful intercropping would have inspired better weed control. At Buysplaas dripperlines were moved from the tree-rows to a row of onions during the first season with great success. Unfortunately this was not continued, although it must be said that limited water-supply also had an impact.
- Leaking pipes: This occurred at a number of locations. In many cases very little was done to repair it, and sometimes the system was not used until the project team made routine visits.

To some extent innovations implemented by farmers did not, generally speaking, offer useful solutions in general, but in a few cases it made a difference. Outstanding innovations are the following:

- Innovative pump station: An impressive structure was built by the Genadendal 2 farmer to get his pump to the tail water edge of the dam in such a way that it does not necessitate moving the pump when the water-level drops or rises.
- Moving of dripper lines: The Thembaletu farmer moved the irrigation system on her plot so that she had it virtually working full time. She then moved the line between different rows of vegetables at each installation. She accomplished this (effectively) with very little guidance from the project team or extension officer.
- Drainage control: The farmer at Gugulethu planted vegetable patches in the very sandy soils on top of cardboard sheets (old boxes). This delayed drainage of irrigation and rainwater, and caused loss of nutrients. She was given guidance on this by the LDU.
- Insufficient water-supply: The Ebenaezer farmer dealt with the very low flow in the canal in a rather remarkable way. At times he built an earthwall downstream of his pump in order to get sufficient suction head. When this proved inadequate, he built a wall upstream of the pump and then transferred water with a bucket from upstream of this wall into the suction dam created. He probably did not realise at which rate the pump was pumping, but went to this extreme to save his crop.
- When the engine broke down at Rooifontein, the farmer connected a windmill to the supply system in order to save his crop. Unfortunately this water was later needed for domestic use and irrigation had to be discontinued.
- At Kheis the level at the dam fell so low that the pump could not withdraw water any longer. The farmer then stopped irrigating his vegetables (onions) and carried buckets of water from what remained in the dam 600 m away with a four-wheel motorbike to keep the fruit-trees alive. Eventually there was no water left and a number of these trees succumbed.
- Insufficient flow in in-field system: When the pump at Ebenaezer did not deliver the design flow-rate (due to dirt in the impeller of the pump), the farmer realised that the pressure in the system was very low, and closed some dripper lines during irrigation.
- Repair of damaged pipes: Due to a lack of equipment, the farmer at Ebenaezer used "fluitjiesriet" to temporarily repair damaged dripper lines.
- Soil stabilisation: On windy days sand from the very sandy soils at Blackheath "sand blasted" the vegetables. The farmer started applying a little water to the surface with a hosepipe on such days. This improved the situation markedly. In her latest planting she put in maize on the edges of the beds as a windbreak.

5.3.4 General management

Definition: The term general management is used to describe how the farmer manages his project, in particular his irrigation system. Because this project is about small-scale farming, a high level of management is not be expected.

This aspect includes seven factors which is discussed in more detail in procedures followed by farmers. In discussions on the previous factor, i.e.the irrigation system, aspects pertaining to management were referred to. In the next chapter, which deals with guidelines on system planning, the findings are grouped per item.

5.3.4.1 Utilisation of system

Definition: This is an indication of the extent to which the farmer used his micro-irrigation system during the trial period.

The farmer's utilisation of the system is determined by a number of factors, some over which the farmer has control, and others where he has none. Four criteria were applied to categorise this factor, namely:

Criteria	No of cases
Never used by farmer	0+0=0
Operated on a limited scale due to external factors	6+0=6
Operated on a limited scale due to internal factors (managerial)	5+0=5
Operated productively	2+4=6

The above table shows that only two plots were operated productively. These were Themaletu and Blackheath, both small food plots. In both these cases the available water was adequate, the supply systems were reliable and the supply regular systems functioned well, food was produced that could be sold or used, and farmers received the full benefit of their production.

In six of the cases where opportunities to use the system were limited because of external factors, farmers were differently affected by these limitations. These details are covered in the description of the other factors and aspects in this chapter.

It is, however, necessary to have a closer look at those cases where operations were limited due to internal (managerial) aspects, of which there are five. In all of these cases the systems had failed, and taking all factors into account, this aspect was the major, if not the only reason for failure. These systems, as well as internal limitations, are as follows:

- Genadendal 2: Reservations on or fear of a system the farmer is not sure how to manage, while knowing what to expect from his sprinkler system. Further training could solve this problem.

- Haarlem: No direct benefit from the project, since the farmer was working for a salary. Better compensation and more commitment could solve this problem

- Gugulethu: Same as for Haarlem

- Hlaneki: Ignorance about micro-irrigation (mistrust) which could be solved by additional training.

- Strydkraal: Practical problems with available time make it impractical for the farmer to apply drip-irrigation. An alternative scheduling procedure could probably have solved the problem.

Longer term seasonal planning of cash crops were also problematic for most sites, which could be attributed to limited available markets for products. This aspect also applies to those sites which received a productive rating.

5.3.4.2 Maintenance of system

Definition: The effort put in by the farmer to maintain irrigation system elements, which he is responsible for. This mainly involves the factor "irrigation system".

Four criteria were applied, namely:

Criteria	No of cases
No maintenance	1+0=1
Limited maintenance	6+0=6
Adequate maintenance	3+2=5
Applied innovative practices	3+2=5

The criterion "no maintenance" and "limited maintenance" can in fact be categorised together for purposes of the research project, although in practice there will be differences. Farmers in this category put in very little effort to solve problems they had with their irrigation systems. Typically they would "live with their problems", and though it would be raised with the project team or extension officers, the same problems would be raised again on follow-up visits. Continuous training could improve the situation. Typical problems in this regard are:

- Flushing / cleaning of filters
- Flushing of submains and laterals
- Leakages in the system
- Completion of installation and regular checks on backfilling
- Positioning of laterals and correct positioning of micro-sprayer
- Cleaning of blocked micro-sprayers

Although the above list includes very important factors about micro-irrigation, none of the system failures can be attributed to any of these, or even to a combination of these.

The two more positive criteria in this aspect are related to the same items mentioned above, and were more effectively dealt with by farmers. The training given and information gained play a major role in maintenance of the irrigation system.

5.3.4.3 Scheduling practices

Definition: Criteria which indicate how effectively the farmer irrigated according to water requirements of crops.

During commissioning of each system the farmer was given guidelines on the volume of water to be applied per irrigation event and at what intervals. During site visits, as a rule monthly, these guidelines (scheduling) were discussed and changes made if necessary.

Four criteria were applied, namely:

Criteria	No of cases
Scheduling guidelines not followed	2+0=3
Some scheduling attempted	9+0=8
Scheduling guidelines adhered to	0+4=4
Scheduling guidelines followed and adjusted according to soil water conditions	2+0=2

From the above table it is clear that scheduling practices were poor. On the other hand, however, it does not differ much from that in commercial farming.

In general over-irrigation occurred on all sites where sufficient water was available, and under-irrigation where the water-supply was limited or irregular. On some sites both these situations occurred on different occasions, in which case over and under-irrigation followed the same pattern.

It must be emphasised that the project team did not put too much pressure on farmers not to over-irrigate, the reason being that there were so many matters which the farmer had to deal with which the team was unaware of or did not understand. For the farmer it is also a new concept of irrigation, and the most important thing at this early stage was to get the farmer to operate the system with confidence, and to help him obtain results which would convince him that a good yield is feasible with micro-irrigation.

Circumstances which impacted on scheduling capabilities of farmers, and which were not relevant as major potential problems during initial interviews with farmers, included the following:

- Cash flow to keep the system operational.

- Whether the farmer lives close to the project, and the effort to get to the project, for example during weekends.
- Infrequent water-supply for various reasons, e.g. management, breakdowns and maintenance of equipment, insufficient water at source, financial difficulties.
- Backup operator during weekends, illness and leave, for the experimental and community plots.

The two sites with the best scheduling, were Ebenaezer and Blackheath. In both cases they varied their standing time and intervals between irrigation, depending on the moisture in the soil and weather conditions. Two possible reasons are:

- Keen interest by support groups, who also provided valuable input on scheduling.
- Farmers are very poor, and therefore try to limit their expenses (cost of irrigation water)

The last season proved to be a difficult one for the Ebenaezer farmer because of the unreliable water-supply. Should this problem recur, there is a real danger that he may grossly over-irrigate when water becomes available, due to fear of the canal flow stopping

Although there is concern about the farmers' poor scheduling performance, this problem can be successfully addressed with the necessary training and support. It was evident that farmers did in fact follow the guidelines provided, but they did not have the know-how to change these according to weather conditions, or when something occurred which altered their routine.

The use of scheduling aids such as tensiometers and water-meters could be considered, but experience showed that it caused confusion in many cases. It is once more a matter of training, but the literacy level of farmers also play a major role in communication.

5.3.4.4 Crop management

Definition: An indication of the farmer's handling of crop related aspects, such as cultivation, diseases, pruning, etc.

The three criteria applied were:

Criteria	No of cases
Poor	0+0=0
Average	3+0=3
Good	10+4=14

In general farmers managed their crops well under their particular circumstances. Weed control is one of their major tasks, and if financially stronger, chemicals would offer a better option. In the case of the existing farms, chemicals are used. Disease control could also be improved, but again relates mainly to financial limitations.

In some cases farmers were dependent on labour and rented tractor facilities, or organised for them by support groups. Often this did not run according to schedule, causing delays in their programmes, but normally it is accepted with patience and accommodated fairly easily. This is a culture, and not to the farmer's benefit, and they should be encouraged to be more insistent.

Reasons for the three cases receiving only an average rating are as follows:

- At Haarlem the farmer was elderly, and not in good health.
- At Rooifontein the farmer had very little experience in growing vegetables
- At Strydkraal the farmer was more concerned about her other plot and did not want her schedule to be different from that of the other women in the garden.

5.3.4.5 Labour requirements

Definition: The extent to which incorporation of micro-irrigation affected the labour requirements of the farmer.

In commercial irrigation a decrease in labour demand is normally part of the motivation for installing or converting to micro-irrigation.

Three criteria were applied, namely:

Criteria	No of cases
Conversion to micro did not decrease labour demand	11+0=11
Some labour reduction induced	2+2=4
Reported significant labour-saving	0+2=2

The table shows that for all but two of the trial plots no decrease in labour demand was reported. The reason for this is that most of the operations are very small, with little or no labour input apart from that of the farmer himself. For bigger sites the trial area was again small compared to the rest of the farm, and saving in labour was not that noticeable. Most of the farmers with drip-systems on the other hand experienced fewer weeds, which reduced labour, as reflected in their own time management (aspect dealt with in paragraph 5.3.4.6).

The two plots where some labour reduction was reported, were Ebenaezer and Homu. In both these cases the size of the whole operation was relatively big, and the area under micro covered a significant part. At Ebenaezer saving was noticed in terms of weed control, and at Homu the dragline sprinklers did not have to be moved any more.

At the existing plots farmers reported some to significant labour saving, more specifically related to irrigation tasks, i.e. the moving of sprinkler pipes and consequent damage to the system.

5.3.4.6 Time management

Definition: The extent to which the incorporation of micro-irrigation affected the farmer's available time.

The three criteria applied for this factor were as follows:

Criteria	No of cases
Negative effect of micro-irrigation on farmer's available time	1+0=1
No effect reported	8+0=8
Positive effect of micro-irrigation on farmer's available time	4+4=8

None of the trial plot systems were equipped with automated control systems, and in most cases consisted of only one control valve.

Although the above data could indicate indifference of farmers towards time saved because of conversion to micro-irrigation, a closer look at the information reveals this not to be so. Firstly, all the established farmers reported time saving. The four trial plot farmers who also experienced time saving are those who were very involved with their farming and irrigation, i.e. Thembalethu, Gugulethu, Ebenaezer and Homu.

Of those who reported no effect, three had not previously done all of the irrigation themselves, two did not really use the system, and three of them did not have any alternatives to compare it with.

The one farmer who reported a negative effect (Strydkraal) had problems remaining at her plot until irrigation had been completed. When she previously used a hosepipe with flood irrigation, she could finish irrigating more quickly. This problem could possibly have been overcome if she had had a better understanding of scheduling.

Although this was the outcome of this aspect, some reduction in time demand does occur, regardless of the size of the plot/farm and provided related matters are taken into account and scheduling is done reasonably well.

5.3.4.7 Record-keeping

Definition: The level of the farmer`s record-keeping of all his farming activities.

This evaluation is based on discussions with the farmers over the project period. Due to communication difficulties, the rating given to each farmer may not be very accurate, but four categories were identified:

Criteria	No of cases
None	4+0=4
No formal record-keeping, but good grasp of figures	4+3=7
Some records kept	3+1=4
Proper record-keeping system	2+0=2

In commercial farming the importance of record-keeping is strongly emphasised and indications are that much improvement is possible among the farmers in general. This is also true for small-scale farmers. Although the level of literacy plays an important role, it seems as if there is no direct relationship; it has more to do with discipline exercised by the farmer, as well as his attitude towards farming.

In keeping with the project team's doubts about farmers' general record-keeping, farmers were asked to keep record of a number of predefined aspects. A booklet with all the necessary forms were left with them, and on each visit their entries were discussed with them. Cooperation in this regard was poor, and general problems experienced included:

- Books were lost
- No entries were made in the books
- Entered information was totally wrong
- Information was incomplete

Despite the problems experienced with record-keeping, the project team still maintains that this aspect is very important for successful farming. With proper training this problem could be resolved, albeit not in conventional ways. The minimum number of important aspects could be identified and forms prepared, and of these the farmer should keep written records, or get someone to do it for him.

5.3.5 Infrastructural, institutional, extension and social factors

The project indicated that support services and/or groups are important for small-scale farmers, and three factors were identified in this regard.

5.3.5.1 Available physical infrastructure

Definition: The availability of roads, telecommunication, markets (input and output)

This aspect is closely related to location, discussed under the factor "The farmer and his circumstances" (paragraph 5.3.1), and although a wide range of facilities are covered under this heading, only those having a marked impact on the appropriateness of micro-irrigation will be discussed here. That includes access to input markets (to obtain spares for system maintenance as well as agricultural inputs), and availability of utilities (which includes power supply, communication facilities, etc.).

Van Averbeke et al (1998) give a comprehensive overview of the services that need to be in place for successful small-scale irrigation farming in general, and although all those factors are not discussed here, they are not considered less important.

Three criteria were applied, namely:

Criteria	No of cases
Poorly developed infrastructure	2+0=2
Basic *infrastructure in place*	3+3=6
Well-developed infrastructure	8+1=9

The remote location of some of the sites definitely contributed to the lack of infrastructural development. Often the market available for a private supplier in a rural area is too small to make it economically viable. This could have a costly effect on the availability of spare parts needed for the maintenance of irrigation systems. During installation of the system at Strydkraal, two simple nylon fittings were needed to complete installation. Obtaining the parts involved a 50 km journey to the "nearest" supplier where it was then purchased for almost four times the price in Pretoria.

Another similar example, but for a plot well-supported by infrastructure, is that of Gugulethu, an urban township surrounded by the eastern suburbs of Cape Town. A supplier of connectors for a damaged lateral could not be found in the vicinity, and eventually it had to be bought at an irrigation dealer about 10 km away.

Monitoring of trial plots was in some cases made difficult by the inadequacy of communication services. Although most farmers could be reached by telephone, it usually involved leaving a message for the farmer to call back, or working through the extension service. The telephone service was, however, often not functional for long periods of time.

Electricity is not readily available in rural areas, and alternative ways of powering pumps and other machinery can be costly and unreliable. Although the availability of electricity is not a prerequisite for micro-irrigation, it can reduce running costs considerably and increase ease of operation. The greater reliability of electricity, compared to alternative power supplies, can be critical when irrigating by for example drip, where a smaller soil-water reservoir is used.

Considering the results of the observations, it can be seen that all the sites with poor infrastructural development had failed, or had great difficulties keeping their systems operational (Rooifontein, Strydkraal, Kheis, Ebenaezer), while eight of the nine sites with well-developed infrastructure could continue operating, in spite of facing many of the same constraints as the farmers mentioned previously.

In a few cases the project team experienced a "don't care" attitude among parties involved in maintenance of, or creation of infrastructure, or providing services. This normally caused delays, additional costs, or lost opportunities. Reasons for this state of affairs could be any of the following: farmers' financial constraints, commercial farmers applying more pressure for these services, communication, patience of the farmer, lack of negotiating skills, farmers' acceptance of the situation due to being conditioned most of his life by indifferent attitudes. It was recognised that farmers needed someone with know-how and trustworthy who could advise them on procedures to follow, who would support them, and in some cases act on their behalf. Also related to this problem is payment for these services.

In as far as government or voluntary services are concerned, it would seem as if there is not enough involvement, or that they are simply not available when needed. There is little understanding among service providers for the problems which developing farmers have to face in order to achieve a certain goal. Even arranging a meeting with the necessary parties presents serious obstacles, not only because of communication problems, but also to understand who should be involved and where the process should begin.

The country is experiencing rapid development, and those who lead in identifying opportunities are duly rewarded (although risks are usually involved). Developing farmers should be assisted to compete for these opportunities, and for that they need support (experts), also to define goals, and assistance in achieving this. It often starts with exercising of their water "rights", or obtaining additional water.

5.3.5.2 Extension services

Definition: Advisory support to farmer on all matters related to farming.

General inadequacies and limitations of extension services (public and private) in South Africa will not be discussed. However, it can be said that major changes will probably take place in due course as a result of new policy.

What is important here, is that when a farmer converts to a new technology, he will probably encounter difficulties and will therefore need a knowledgeable person to assist him. Micro-irrigation is still a relatively recent technology, and virtually unknown in many rural areas. This not only implies being confronted by foreign technical properties, but may induce the farmer to alter some existing practices, for example method of applying fertiliser, plant spacing, irrigation stand times, etc. A capable extension officer should be able to educate the farmer in all these aspects in order for him to use his system optimally. The question, however, is the availability of officers with the necessary know-how to ensure successful conversion to a new technology.

Four criteria were applied, namely:

Criteria	No of cases
Poorly developed service available	2+0=2
Some services available, not necessarily knowledgeable about micro-irrigation	3+3=6
Adequate services available	2+1=3
Knowledgeable and efficient service available	6+0=6

It is reassuring that there was not a complete absence of extension services on any of the sites. In some cases the services of private "advisors" were used extensively. These include irrigation designers, employees of the local co-op, as well as seed and fertiliser manufacturing representatives.

Farmers need guidance in operating their irrigation systems and maintaining them efficiently. This service is often provided by the dealer/manufacturer when equipment is bought, but farmers in remote areas or without communication services may not have access to these services. If an extension officer were available, he would be able to advise the farmer.

Probably the best way for the extension officer to learn, is practical experience with a knowledgeable person. This could be achieved by exchanging extension officers between difference areas, or through public or private partnerships.

Affordability of services is an important aspect. In general, if farmers were to pay for this, little use will be made of such services. In this respect the procedure followed in India, as described in Chapter 2, could be of value as a further guideline.

5.3.5.3 Institutional and social involvement

Definition: This aspect refers to the effect/influence of (among others) local government, policy, management strategies, land tenure, the community and fellow farmers on the farmer successfully adopting micro-irrigation.

According to Pretty (1991), for resource conserving technologies to be transferred successfully, it should be developed and used by local institutions and groups, supported by facilitating external research, extension and development institutions. Farming households face considerable adjustment costs in changing to a new system. In the short term they may not see sufficient benefits from these practices, but with adequate local and external support the chances of success may increase.

Examples in India and Israel have shown that the impact of new technology can be enhanced if supported by policy and/or local government. However, care should be taken that the process by which farmers are encouraged to change does not make them dependent on incentives (for example, subsidies). History has proven this to be fatal.

Three criteria were applied, namely:

Criteria	No of cases
Poor	3+0=3
Average	5+1=6
Good	5+3=8

Although this aspect could in no case be regarded as the direct reason for failure of a system, stronger institutional and social support could have increased the chances of success.

Community involvement can stimulate proper use of the system and growth of the farmer. Farmers want to discuss and share their experiences and observations with others in similar situations. If problems were encountered, support from others could help in solving them. In the case of Homu, most of the farmers on the scheme were interested in changing to micro, and the trial plot gave them the opportunity to gain first-hand experience.

Institutional structures are necessary to provide farmers with opportunities to obtain more land, improve management structures, obtain necessary services, have access to financing, etc. If these constraints are not addressed, farmer development can be seriously impeded.

5.3.6 Economic and financial factors

The transformation of water-resource inputs to crop outputs is the basic relationship in research on irrigation economics (Van Averbeke et al, 1998). These factors therefore consider those aspects related to the costs of the necessary inputs of the farming operation, and whether it is justified in terms of the output achieved.

Developing farmers often lack knowledge of economic principles, or have little or no access to credit, and this could be an obstacle towards successful development.

5.3.6.1 System costs

Definition: System costs (including capital, installation and running costs necessary for operation), indicate whether the trial plot is economically viable/justifiable - in other words, do the benefits outweigh the costs.

Micro-irrigation equipment and the infrastructure development around it is relatively expensive when compared to other types of irrigation, and should therefore be used optimally. However, because of a number of intrinsic advantages, its implementation is usually justifiable.

The criteria applied and categorisation of the plots are very subjective and serve only as an indication whether, at the end of the research term, the installation of the system proved to be justifiable, and whether the project (plot) should continue (from an economical point of view). If the attempt to get more quantifiable data had been achieved, this aspect would have been dealt with differently.

Three criteria were applied, namely:

Criteria	No of cases
Not justifiable	0+0=0
Could be justifiable	10+0=10
Justifiable	3+4=7

In all of the trial plot cases the systems were deemed justifiable, or could be justifiable. This is conditional to other problem areas being resolved.

The conclusions would have been different had the question been whether it is justifiable to convert from flood or sprinkler irrigation to micro. In this case it would probably not have been justified for any of the plots to convert. The trial plots were too small, and the benefit too little to justify the expense. The existing micro-irrigation farmers justified their conversion by recognising benefits such as labour saving, time management, disease and weed control, more effective irrigation and fertiliser application, product quality, and production volume.

Another factor which makes it difficult to justify the cost of small-scale micro-irrigation, is that the supply system, filters and fertiliser equipment (where applicable) involves much unused time. In bigger systems the objective is to have the lowest flow-rate flowing through as big a part of the supply and distribution system for the maximum available time. In this process the number of blocks and block sizes are determined, and an optimum scheduling system selected, taking into account soil conditions and crop water requirements. This planning is then used to optimise the supply system, minimising total system costs.

With small-scale micro-irrigation, trial plots are in most cases so small that the whole area could be irrigated in a single block. One could design it in different blocks, but in most cases the additional valves and pipelines would cost more than the slightly larger filter and pipelines.

The cost per unit area for these small irrigation schemes are considerably more expensive due to the inclusion of necessary supply and filtration components. If the system were to be extended, the cost per unit area would drop.

5.3.6.2 Cost of water-supply

A number of situations was identified regarding payment of water-supply expenses. In some cases farmers have free access to water, while others were responsible for infrastructural costs (capital, e.g. borehole, pump, etc.) as well as running and maintenance costs.

What is important, however, is that the culture of "free water" should be changed by explaining the importance of payment for water to small-scale irrigation farmers. This could also contribute towards preventing over-irrigation where water is considered "free".

Three criteria were applied, namely:

Criteria	No of cases
No expenses	3+0=3
Some expenses	4+1=5
Full responsibility	6+3=9

Although non-payment of water was experienced in only three cases, it was observed that in general farmers were prone to over-irrigate if water was available. This was even more obvious in cases where frequency of supply was irregular, or the supply unreliable.

On schemes farmers often pay a set amount for water, regardless of how much they use. This management method often causes farmers to feel that they may have as much water as they wish "because they pay for it", the concept of water saving water being foreign to them. If the water used by each farmer could be measured individually and payment adjusted accordingly, it would act as an incentive to save water by means of scheduling.

Six of the farmers with full responsibility were part of the original trial plots, of which four failed, mainly for financial reasons. In all of these four cases it was the breakdown of the on-farm water distribution system (pump) which the farmer could not afford to repair, that led (directly or indirectly) to complete failure.

The farmer at Blackheath planted on a very small-scale, and she could afford the cost of water, even though it was municipal water.

The farmers at Masisi, Nwanedzi and Buysdorp are also fully responsible for their water costs, but have sufficiently healthy cash flows to cover unexpected expenses.

5.3.6.3 Economic scale of farming

Definition: An indication of the scale on which food production on the farm serves the farmer's needs.

Although this aspect is included here (because of its importance, even to the extent that "scale" appears in the name of the project), the objective of the project and methodology followed did not allow the project team to come up with a clear opinion on it. What may be an economic scale for one situation may not be economic under other conditions.

A further limitation to forming an opinion on this aspect, is that in most cases the micro-irrigation scheme constituted only a small part of the total farming activities.

Three criteria were applied for evaluation.

Criteria	***No of cases***
Subsistence	1+0=1
Own use and sell some	8+0=8
Commercial	4+4=8

In cases of very small-scale operations the economic utilisation of the planted crops follows a different pattern compared to bigger plots, e.g. the farmer would cut leaves off the growing vegetable crop for his own consumption.

Pursuance of farming on a bigger scale was evident on all levels. Existing farmers are already in this process, and in all cases farmers are planning to expand their irrigated areas.

Expansion of irrigation land was observed on only one of the trial plots (Thembalethu). This farmer moved from her 400 m^2 plot to a small farm of 3 ha. During all the years of monitoring, her devotion to the plot was clearly evident, and she was strongly motivated, because it could give her an opportunity to obtain more land.

Another example of the role of motivation was observed at Blackheath where the farmer was determined to be successful in view of a possible future work opportunity if back-yard gardens were developed on a bigger scale in her township by the Department of Agriculture.

5.3.6.4 Utilisation of financing/credit

Definition: Small farmers with little or no resources often require credit and loans to purchase inputs, prepare land, hire labour, etc., but because of their relatively poor resource background, lack of security and physical locations, they often experience difficulties.

According to Bembridge (1985) in Van Averbeke et al. (1998), lack of credit and available financing at a given time may constitute a constraint to development. With system costs ranging from R10 000 - R15 000 / ha, converting even a small area to micro is almost impossible for most developing farmers.

The aspect of financing is also strongly related to the land tenure situation. Increased tenure security of land titles/long-term leases may facilitate farmers' access to credit, which could be used to purchase inputs or to invest in the development of crops.

Four criteria were applied, namely:

Criteria	No of cases
No external financing used	3+0=3
Donations from external organisations	5+0=5
Limited financing used	4+1=5
Full financing used	1+3=4

All four farmers using full financing are highly productive, cultivate a large area (>5 ha) and have healthy cash flows. They would not have been as successful without obtaining financing. It can, however, not be ignored that they are all motivated individuals with some education. They went to the trouble of having proper irrigation designs done and business plans drawn up. What it does prove, is that financing can be obtained if the farmer is willing to make some effort, and it can be repaid if the farm is an economic unit.

The farmer at Thembalethu did not make use of any financial assistance, yet she was very successful. She has now also obtained credit to buy her own (bigger) farm, on her history of good production.

It was observed that funding agencies/development corporations are becoming more willing to provide financing to farmers who have proved themselves, and who want to extend their operations.

5.3.6.5 Cash flow from farming activities

Definition: Balance between income and expenses of the farmer pertaining to farming activities.

This a fairly private and sensitive matter, difficult to get information on, and reporting is based more on impressions than on facts.

Three criteria were applied, namely:

Criteria	No of cases
Poor	6+0=6
Borderline	6+0=6
Healthy	1+4=5

All but one of the trial plots are poor to borderline, and most farmers would probably not be in farming if they could find an alternative to generate money / food. Even though some of them produce very little, it is nevertheless a godsend. The value of their crops may not be much, but for someone with no income even one rand is of great value.

Even on very small plots (backyards) certain of the crops planted produce more than what can be consumed by the family. Selling of surplus products constitutes a bonus, but a better option would have been preservation, or a barter system to acquire other needed foods.

5.3.6.6 Marketing

Definition: Opportunities available to farmers to sell their produce. evaluated here.

Although marketing is an important aspect of rural agricultural enterprise, it is often impeded by a lack of storage, handling, transportation and processing facilities. A lack of comprehension of market details, formation of co-ops, setting of competitive prices, credit selling/buying and profit margins are some of the difficulties encountered.

Three criteria were applied, namely:

Criteria	No of cases
Little/no access to markets	3+0=3
Limited market available	8+1=9
Good marketing opportunities	2+3=5

Unfortunately many of the trial plots never reached the production stage, for reasons described in the previous chapter. However, some observations were made on the marketing strategies of farmers, which will be discussed here.

It was found that most of the bigger farmers use established marketing channels for their produce, because of the large amount they have to sell on a regular basis. The farmer at Nwanedzi delivers to a tomato canning factory with whom he has a contract, while the farmer at Homu markets bananas through a nearby commercial farmer who has transport facilities.

Genadendal farmers often produce their vegetables under contract. Smaller plot owners sell to their neighbours or people in the communities, normally private, probably at market related prices. Quality is usually not important to them.

The successful smaller farmers made use of the available local markets to sell their produce.

5.4 SUMMARY OF RESULTS

5.4.1 THE FARMER AND HIS CIRCUMSTANCES

Based on observation, one could conclude that the individual characteristics of a farmer could be a determining factor in his success or failure. The levels of literacy and numeracy of farmers were found to be significant in the sense of providing them with access to written information, and for purposes of record-keeping. Farmers with previous irrigation experience and/or formal or informal irrigation training were more likely to succeed with a new system. Another important factor was the farmer's initial attitude towards the new technology, with all the initially skeptical farmers failing to make appropriate use of the systems.

The circumstances under which trial plot farmers operated differed significantly, the consequences being evident on especially previously established farms. Plot owners situated in remote areas experienced problems with access to support services, while those facing harsh climatic conditions, or farming on marginal or unsuitable soils, were at risk if the irrigation supply proved unreliable.

Farms monitored varied from smaller than 0,1 ha, to larger than 20 ha in size, with ownership ranging from schemes and community gardens, to individually owned or rented land. Demonstration plots were generally found to have a high risk of failure due to a lack of commitment of the person responsible for the irrigation and maintenance. On the other hand, plots where the farmer was dependent on the income from crop production, seemed more likely to succeed.

5.4.2 WATER-SUPPLY

Water-supply to the farm was clearly found to play a major role in the successful management and operation of a project. If water shortages are experienced on a farm, it is necessary to clearly distinguish between a water-supply problem, and a water distribution problem.

A more than adequate water-supply benefits farmers and serves as compensation in cases where they schedule irrigation poorly and make mistakes when they start with micro-irrigation, as witnessed in most cases. Reliability of the water-supply adds considerably to the ease of managing the irrigation project. If the farmer is personally responsible for his supply system, and he is not adequately trained and well backed up with support services, there is a real risk of his project failing. Irregularity of water-supply, together with poor management of the supply system on certain plots, caused serious setbacks for these plots. On the other hand, water-supply systems which were well-managed contributed much to achievements attained by farmers. None of the trial plots failed due to poor water quality. However, over the longer term, poor quality water may cause problems.

5.4.3 THE IRRIGATION SYSTEM

The irrigation system includes the pump, filtration and fertigation equipment, and the in-field system. Research showed that all the projects where pumps, operated by the farmer himself, were involved, were seriously disadvantaged due to pumping problems.

Farmers had some difficulty in understanding filtration, but most of them cleaned the filters as a matter of routine. The in-field systems itself proved mostly to be suitable, although there were some concern in a few cases. Clear recommendations on appropriate fertigation procedures, and the efficiencies of the different systems, cannot be made, and it is therefore recommended that additional work be done in this regard.

Installation of the system is the first and major step in training a farmer. The extension officer should preferably be present. Training was also identified as being inadequate for those farmers who preferred other irrigation systems to micro-irrigation.

5.4.4 GENERAL MANAGEMENT

Irrigation systems were under-utilised on most of the trial plots, mainly due to managerial problems. Maintenance of the systems was limited in most cases, although none of the system failures can be contributed to this factor only.

Not much pressure was applied by the project team on farmers to schedule accurately, and in general over-irrigation occurred on all sites where sufficient water was available, and under-irrigation where the water-supply was limited or irregular.

Due to the size of the operation, little or no labour and time saving were reported by the majority of the farmers. Despite poor record-keeping, for various reasons, some farmers were nevertheless successful, although the project team is of opinion that good record-keeping is fundamental to sound farming.

5.4.5 INFRASTRUCTURAL, INSTITUTIONAL, EXTENSION AND SOCIAL FACTORS

A wide range of facilities are covered under this heading, but only the two considered to have the biggest impact on the appropriateness of micro-irrigation, i.e. input markets and the availability of utilities, are discussed here. A comprehensive overview is given by Van Averbeke et al (1998).

These factors are often linked to the location of the plots, with access to services and communication being more difficult in remote areas.

It was found that the local extension officer (if available) should have a good understanding of the system in order to provide support, and this is probably the group that should be targeted for training.

International experience (India and the Middle East) emphasises the importance of other support mechanisms, such as farmer groups, local government and policy. Failure due to their absence confirms their importance.

5.4.6 ECONOMIC AND FINANCIAL FACTORS

The transformation of water-resource inputs to crop production outputs is the basic relationship in the research on irrigation economics (Van Averbeke et al, 1998). The capital cost of micro-irrigation is known to be relatively high compared to other irrigation systems, and this can be an obstructive factor to many small-scale (marginal) farmers. Also, the smaller the system, the higher the cost per hectare seems to be, making development less economically justifiable. Yet it has intrinsic advantages (such as labour demand reductions) which makes it viable in other ways.

Few of the farmers encountered were concerned about the cost of water, with some receiving it without payment and others paying a "flat rate", which they accepted as giving them unlimited access. The concept of saving water was foreign to many of them, and this factor should be addressed through training. Although most of the farmers wanted to expand their areas under irrigation, opportunities were limited, mainly due to lack of money, and the increased risk associated with it. Some farmers did, however, obtain credit to expand, most of them without being landowners, but in general small-scale farmers' cash flows were found to be poor. An improvement of marketing skills and opportunities could improve the situation.

5.4.7 CONCLUSION

The analysis provides a large amount of information on small-scale irrigation, and it can be seen that most of the issues at stake and the problems encountered are generic problems of small-scale irrigation, with very few directly related to micro-irrigation. The information is presented in a more functional/user-friendly format in Chapter 6, as a set of guidelines for the use of micro-irrigation by small-scale farmers.

6. GUIDELINES FOR THE IMPLEMENTATION OF MICRO-IRRIGATION FOR SMALL-SCALE FARMING

6.1 INTRODUCTION

From the previous chapter a number of guidelines were compiled for purposes of planning, design and management of small-scale micro-irrigation projects. These guidelines are categorised in five groups. Some of the guidelines are applicable in more than one group, and should therefore be approached as such.

The issues addressed here are not conventional design requirements or criteria, and usually not dealt with in design manuals, but are considered to be important technical guidelines in small-scale development projects.

During the course of the project it became clear that many of the problems facing farmers interviewed during the surveys were not related to micro-irrigation specifically, but were common for all types of small-scale irrigation farming. In fact, in many cases it was the inability to overcome these generic problems which prevented farmers from succeeding with micro-irrigation systems, rather than problems related to systems.

It was decided to present guidelines on both generic small-scale irrigation and small-scale micro-irrigation situations, since the former has a big impact on the chances of success of any system.

These guidelines culminated in a separate document aimed specifically at irrigation planners, designers and extensionists, which will subsequently be published by the Water Research Commission. ("Guidelines for the implementation of micro-irrigation for small-scale farmers").

6.2 GUIDELINES FOR SMALL-SCALE MICRO-IRRIGATION FARMING

6.2.1 System planning

6.2.1.1 General

- Include a checklist for the designer of all the aspects which are relevant when planning, designing and training. Refer Appendix B for example checklist.

- Obtain existing reports on this and other completed projects in the area, and ascertain which other organisations are already involved in the area. Farmers could become confused if confronted with conflicting information from different sources.

- Contact the extension officer working closest with the project before the start of proceedings, and keep him involved in all stages, especially during planning, installation and commissioning.

- Plan and programme continuity of services so that the farmer can become familiar with and rely on the procedures.

- Determine which support services are available.

- Initial, or even periodic training sessions are definitely not adequate; there should be a continual presence of knowledgable people in the background. Those involved at grass-root level are to be considered as only the "eyes and ears" of the advisory component of the group. Advisors should be able to advise on the irrigation system and irrigation requirements, crops and soils, financial and marketing aspects.

- A top-down approach in the introduction and implementation of micro-irrigation will to some extent be unavoidable, but the farmer's input should be encouraged, especially his personal views, experience, and very importantly, his personal circumstances, e.g. available time, financial resources, literacy, family support, preferences and dislikes about farming practices and crops cultivated, previous successes and failures.

- The farmer should be given a realistic picture when introducing him to micro-irrigation. An idealistic picture could create unrealistic expectations.

- Accurate scheduling in the first season must not be unduly emphasised. It is more important for the farmer to become familiar with the system. This period will in most cases give an indication of how farmers are coping with the new situation. After the first season the support group and individual farmers must review both successes and problems experienced. Success during the first season is a reasonable indication of a particular farmer's future success with micro-irrigation. Success in this sense refers to a bigger yield or better quality crop, without damage to the soil. Only then should the focus move to financial aspects, including farming and irrigation practices.

6.2.1.2 The farmers

- A high level of literacy is not a prerequisite for successful irrigation farming. It could, however, be an obstacle when converting to a new technology. With a low literacy level, access to and transfer of information will undoubtedly pose a problem, and appropriate measures, which may include translation, will have to be taken.

- Previous farming experience, in particular on a commercial farm in the same region, serves as good background for success.

- A farmer who has some technical and mechanical skills will be less dependent on support services for maintenance and repairs.

- Compensation received from the farming exercise is a determining factor for success. In the case of experimental and demonstration farms, as well as part-time farmers, a specific person should be responsible for the operation of the system (usually not the farmer/owner). He should receive adequate compensation, otherwise he would be tempted to leave if better job opportunities become available. An alternative solution is that his compensation be linked to performance of the farm, which can be an incentive for commitment. There must also be a back-up plan should this person leave or become ill. Continuity in this regard is significant for the success of the project.

- *The designer must take cognisance of the farmer's financial dependency, as well as his fear* of failure because of the risk of converting to an unfamiliar system. It is suggested therefore that in cases of conversion operations should be on a small-scale.

- The fewer technical responsibilities the farmer has, the more time he has to make decisions related to crop production, a task with which he is probably more familiar.

- Most successful micro-irrigation farmers (as regards system management) had previous experience with other types of irrigation systems. If time and money were secondary, this evolutionary development (first exposing him to surface and sprinkler irrigation) would be the most attractive option to introduce farmers to micro-irrigation. With the experience obtained from this and other research projects, however, it is clear that this "evolutionary" alternative could entail many failures, with ongoing poverty and shortage of food. Means should be found to successfully introduce upcoming farmers to micro-irrigation in a much shorter period of time. The key to this is probably sound financial and extension services back-up.

6.2.1.3 Water-supply

- Unreliable water-supply probably has the biggest influence on the failure of small-scale irrigation farming.

- Reliable supply on the other hand contributes considerably towards the success of projects. Reliability of a water-source should be checked (for the different growth stages of the crop) against the total volume of water required, flow-rate and pressure available. These three aspects determine the choice of system and size of the project, applying safety factors according to the reliability.

- Availability of water should be carefully analysed, taking into account periodic drought conditions, in order to establish the potential irrigation development (area).

- Normally the supply system will also be utilised for primary purposes (human and animal consumption), and these needs must not be under-estimated. When the source is subject to pressure, e.g. during droughts, an arrangement must be in place for irrigation from this source to be restricted. Someone from the support groups needs to advise farmers and water users on the extent of these restrictions, and when to implement.

- With a risky supply system, work out a contingency plan of action should the supply fail, whether due to available water, the supply system or the farmer's system failure.

- Take all aspects related to the water situation into account before a new crop is planted in order to ensure a well-planned crop on the appropriate scale. The extension officer and/or irrigation designer should be consulted to calculate this water balance.

- Crops which are less dependent on intensive irrigation are preferable, rather than introducing something new with very sensitive irrigation demands. Once the farmer is familiar with the system and crops, he can consider new options.

- Calculate the financial risk should the system fail, and establish whether the crop will survive without water. *If not, what are the chances of this happening, and will the farmer be able to* survive such failure.

- The condition of the water infrastructure is more important in harsher climates and remote areas.

- Because the farmers will go through a learning phase, which may be longer than two or three seasons, mistakes, which will waste water, will probably be made. For this reason the size of the system should be smaller than the area for which water is available, and in general a *reduction of approximately 30% is suggested.*

- It must be emphasised that even a single interruption in the water-supply at a critical stage can cause the project to fail. This is unlike farming on a bigger scale. It must be borne in mind that the small-scale farmer is often isolated, with inadequate transport and no communication services to help him solve problems. Finance-related problems are even more difficult to solve.

- In situations where reliability of the water-source is in question, some sort of a reserve buffer *storage facility should be built into the supply system if at all possible and affordable.*

- Should the irrigation designer conclude during the system planning stage that the water-supply is unreliable, he must establish whether it is a managerial or technical problem. Only then can a decision be made about the irrigation system.

- The farmer should have a say in the management of his water-supply system. Management should either be done with the assistance of support groups, or by an appointed experienced manager.

- Avoid drip if the supply system is not reliable or if availability of irrigation water poses a risk. This is especially true for lighter textured soils, because of the reduced water-storage capacity of the soil.

- If the supply system is pressurised (sufficient pressure for micro), but the pressure and / or flow-rate is unreliable, micro-irrigation should be considered with circumspection. The irrigation blocks should then rather be subdivided, so that smaller units can be irrigated during times of insufficient flow and / or pressure. If the system is small it could even be considered to equip each lateral with an inexpensive plastic valve. This may have the further advantage of different laterals being treated differently, should age and/or crops vary.

- If a water-source is definitely unreliable, drip-irrigation is not advisable. Crops sensitive to periodic moisture stress should be avoided.

6.2.1.4 Crops

- If the farmer is not strongly supported by extension services, he should rather keep to crops with which he is familiar.

- With permanent crops, where there is no yield until a certain level of maturity, intercropping should be seriously considered as a temporary source of income until the permanent crop becomes productive. This will influence the system design, but not necessarily make it more expensive.

- *Good quality crops are possible with micro-irrigation in conditions not otherwise conducive to* successful irrigation farming, e.g. poor soils, inadequate water, etc. However, the risk involved in successful management of a project with poor quality water and/or poor quality soil is high, and it is therefore not recommended that micro-irrigation, and especially drip-irrigation, be installed under these conditions, unless reliable extension and other support services are in place, with adequate water-supply.

- Many crops can be grown under either micro or drip with equal success, but in some cases the type of crop may dictate the system to be used.

- Guidelines should be given on crop spacing, since the farmer often has his own ideas about this, based on practices not closely related to micro-irrigation. The wrong spacing may have a substantial negative impact on the potential yield.

- Spacing of plants (mainly with drip-irrigation) should be calculated according to the emitter spacing.

6.2.1.5 Irrigation system

- If a farmer has limited irrigation experience, rather phase him in on a small-scale (smaller than 100 m²).

- Care should be taken when the size of the farming operation is of an intermediate nature. In this project this size appeared to be between 0.1 ha and 1 ha. The benefit of the system seems to be less evident in this case.

- Quality of water and soil should be dealt with as for standard design procedures. It should be remembered, however, that the high cost of sophisticated water and soil quality manipulation methods and related effects can have serious implications for affordability of the project.

- The system should be buried as far as possible, without compromising on flexibility of moving the system between positions on the plot (applicable mainly on small food-plot systems).

- Plan the layout so that certain system components which may be in danger of being stolen can be locked away.

- Where possible, materials used must not have an attractive resale value.

- Moving of the in-field system between alternative positions on the plot (applicable mainly on small food-plot systems) should be taken into account in system planning.

- Avoid pumping with fuel-powered energy systems. Not only are the running costs about three times higher than pumping with electricity, maintenance is even more expensive, and it is difficult to apply timeously.

- When pumping with fuel the responsible operator must receive mechanical training in order to perform simple repairs and routine maintenance.

- With drip-systems the volume of water available in the soil is limited, and recommendations to apply drip should therefore be made with great circumspection.

- Do not use micro-jets if the farmer applies poor weed control methods. Better weed control is possible under drip-irrigation, which is a big advantage of the system.

6.2.2 System design

6.2.2.1 General

- The balance between material and running costs is important. Due to cash flow and available financing, the approach differs from that of commercial farming. A modular system which can be implemented in phases of the project is desirable. Although the eventual costs may be higher, it will be easier affordable for the farmer.

- If the development costs of a project is financed from grants, design for lower running costs, in other words higher capital cost.

- Standard procedures should be followed to determine water requirements and system capacity, *e.g.* SAPWAT.

- The farmer's available time must be taken into account when scheduling of the irrigation operation is planned. Since micro-irrigation is expensive, optimum use should be the objective, with minimum idle time.

- Due to cash-flow considerations (when system is initiated), the movement of laterals between crop rows (two to three rows per lateral) should be considered. Laterals and emitters account for the biggest part of the in-field system costs, therefore big savings are possible if the farmer has the time and is prepared to move laterals. The submain design must, however, accommodate one lateral per row.

- Although not to be encouraged, try and design within the allowable tolerances for one or two additional laterals on the submain, should the farmer at a later stage wish to extend his system slightly. To follow this approach along the length of the lateral will lead to considerable extra costs if the designer has to opt for bigger pipe sizes in the laterals to accommodate possibly longer laterals.

- Apply normal design tolerance standards, unless the field layout is such that considerable savings can be achieved if EU values are dropped within limits (minimum EU 85%). Such a situation may allow one to get by with one submain instead of two. More research is needed in this regard.

6.2.2.2 In-field system

- In the case of pressure compensated emitters, if laterals are not very long, e.g. shorter than 100 m, use design procedures as if emitters are not compensated. This will allow for large pressure variations at the control head (valve) of the block, while the application uniformity in the block will still be good.

- The use of pressure compensated emitters is recommended, if economically attainable. There are many advantages attached to the management of the system, e.g. less blockages, and incoming pressure that can vary widely, still leaving a system with a good application uniformity.

- The use of rotating micro-sprayers (versus static micro-sprayers) should only be considered if crops really require this. Not only is it a more expensive emitter, it also requires better weed control (grass stop swivel from rotating), and moving parts are lost or damaged.

- For drip-systems the emitters should rather be spaced closer than necessary, than further apart. Even though this is somewhat more expensive, it is easier to manage, because there is less risk of seedlings being too far from an emitter if the laterals are moved.

6.2.2.3 Filtration and control components

- Filters are required on all farming micro-irrigation systems, unless the water is purified before the off-take, e.g. municipal water.

- Select a filter with a capacity larger than needed. This reduces cleaning requirements, and allows for expansion of the system.

- If at all possible, use disc-filters. With mesh-filters damage to the mesh is normally not noticeable when the damage is still slight, but irreversible damage can be done to the in-field system, especially drip. The mechanisms of sand-filters and their cleaning are difficult to fully understand, and if things go wrong, serious damage can be done to the system. Sand-filters are also expensive.

- The farmer (even though not the operator of the system) must understand the importance of filtration and the operation of the filter. Due to the disciplined, normally unpleasant (wet), and time-consuming procedure which has to be followed to ensure proper functioning of the system, the operator of the system will occasionally be tempted to neglect this aspect. The farmer must be in a position to check on these, especially if the filter is tampered with in such a way that dirt enters the in-field system, e.g. removing some of the filter rings (leaving bigger gaps between the rings), or not adjusting the screw on the filter element tight enough. Both of these actions will necessitate less flushing of the filter, because most of the dirt passes through it. The operator, however, believes that these actions will not really have an impact on the system, while his workload is reduced.

- Install a pressure gauge (or two gauges) at the filter in such a way that the farmer can check the upstream and downstream pressure to ascertain whether the filter is dirty. He must be given sound guidelines to read them. Instructions on flushing cycles also work well in situations where the water quality remains constant, but as a rule this is not the situation.

- Include a schrader valve for checking pressures downstream of the control valve of the block.

- If the supply pressure can vary considerably, include a secondary valve for pressure control. The primary valve can be a ball valve (inexpensive) and the secondary valve a gate valve.

- On small-scale it must be considered to equip each lateral with a valve, seeing that crop types and maturity often vary within the same block.

6.2.3 System installation and training

6.2.3.1 Installation

- The installation of the system should be regarded as part of the training of the farmer. For this reason the farmer must be closely involved with the installation, and someone who can transfer the information about the different components' management and maintenance must supervise it.

- Make sure that all aspects of the installation, from the source to the last emitter, is done properly. Don't rely too much on the farmer's judgement that he is satisfied after installation, because he will not be familiar with acceptable procedures. Often minor issues such as connections in plastic pipes coming loose, suction problems with pumps, leaking fittings, etc., cause problems with which the farmer cannot cope, eventually culminating in system failure. Unlike the goal for bigger projects, that improper procedures during system installation are unacceptable, it should be specified in the case of small-scale farming that workmanship in system installation be close to perfect. This guideline does not imply a more expensive installation, but rather good quality control.

- As many installation aspects as practically possibly should be delegated to the farmer, provided these are checked afterwards.

- The reason for being so adamant about installation standards, is that problems will arise in the system after installation, during operation, e.g. damage to pipes through cultivation practices, vandalism or theft, breakage of faulty equipment and materials, etc. This will demand the farmer's time, effort, skills and money. Additional problems emanating from poor installation may cause the farmer to lose faith in the system, or even total failure of the system.

6.2.3.2 Commissioning

- Commissioning of the system is the next stage in the training process, and the farmer must then be provided with the necessary information to proceed on his own with system operations.

- The farmer must be briefed thoroughly to operate the system as designed, and that extensions or alterations not designed for, not be done.

6.2.3.3 Training

- The farmer must be given exact instructions of the company and contact person to contact per item in his irrigation system, should something go wrong. The service supplier should have a file of the farmer in which all items in his irrigation system are specified and listed. This includes suppliers of irrigation systems, repair services, weed control, diseases, fertiliser aspects, water authority, extension services, and marketing channels. Although the farm may not be isolated, the farmer may not be aware of available services, a typical list of which is provided in Appendix C.

- Provide the farmer with a file which includes sketches of items most used in his scheme, together with an indication of the cost of these items. A farmer with no previous experience of micro-irrigation is not able to install his system on his own, in spite of complete documentation. In most cases the relevant extension officer's knowledge in this respect will also be limited. It is therefore of major importance that both the farmer and extension officer be present when the irrigation designer, or knowledgeable person tasked with this, installs the system. Relevant documentation should be available during this stage, and must be regarded as a major step in the training of the farmer and extension officer.

- The system, or part of it (laterals) will be moved from time to time, and the farmer must be trained to prevent dirt from entering the pipes when this is done.

- Farmers find the drip concept difficult to understand, the reason being that they don't "see" the water. Practical aspects such as putting a container under a dripper to illustrate the discharge, and trenches across the dripper line to show spread in soil, should be done fairly early in the project. If this aspect is not dealt with successfully, eventual damage (of holes in the pipes) is very likely.

6.2.4 System operation and maintenance

6.2.4.1 General

- All standard practices related to system maintenance, such as flushing of mains, submains and laterals, positioning of laterals and micro-jets, etc., have to be applied, and are not repeated in these guidelines.

- Though record-keeping is not essential for successful farming, it is nevertheless important, and simple methods to effectuate this should be strongly encouraged. Analyses of the records, which will have to be done by a support service, will provide the farmer with useful information which will encourage him to keep records.

- When converting to micro-irrigation the farmer may probably not save time initially, but once he understands the system, he will be able to save both time and labour (and therefore costs), and he should be encouraged to make the most of this advantage.

6.2.4.2 Supply system

- If the farmer himself is responsible for pumping the water from the water-source and electricity is not available, micro-irrigation is not a viable option, unless the farmer is mechanically skilled. If electricity is available and the farmer can afford to pump the water, an electric motor should be used to drive the pump, and the farmer should be thoroughly briefed about the maintenance of the equipment.

- If possible and affordable, someone skilled should be responsible for the water-supply system. This applies mainly to scheme farmers. The chances of a project being successful increases dramatically when the farmer`s responsibility for water-supply decreases.

6.2.4.3 In-field system

- Micro-jet systems are easier to manage than drip-systems, mainly because the functioning of drip is not as visible to the farmer as micro-jets.

- Drippers gradually become blocked, and this will often only be detected when they stop dripping completely. It is therefore advisable that drippers be monitored for possible blockages, and that a number of the drippers (three per lateral, beginning, middle and end) be marked for periodic checks by both the farmer and irrigation support services, or extension officer.

- Emphasise the lesser effect of rainfall with drip-irrigation due to the root zone occupying a smaller volume of soil.

- The farmer must be given clear guidelines for cleaning the emitters. The size of the pin with which the nozzle of the micro-jet is cleaned is important, and for drippers the "knocking" of drippers, or applying external pressure on the dripper are issues to be considered.

- Flushing of main pipes, submains and laterals are important measures for successful long-term operation of the system, and the farmer must likewise be given clear guidelines on these.

- The use of chemical weed control and spraying for diseases must be encouraged.

6.2.4.4 Fertiliser application

- For drip-irrigation on a small-scale (less than 2000 m^2), granular fertiliser should be applied by hand. If possible it must be worked into the soil with a fork or spade. Despite concerns about surface application of fertiliser in drip-systems, this method appears to offer reasonably acceptable results.

- For micro-jet irrigation, granular fertiliser should be applied by hand. Clear guidelines on this procedure should likewise be provided (type, dosage, time of application).

- For larger areas the following (conventional) methods can be considered; a decision about the appropriate system will depend on the circumstances: Venturi apparatus, fertiliser tank, hydraulic injector, electric injector, mixing of fertiliser in a storage tank at the water-source.

- More research is essential in order to establish how effective fertiliser is applied with the different methods. Other methods can also be checked, e.g. injection of concentrated liquid fertiliser into individual laterals by means of e.g. syringes (by the operator).

6.2.4.5 Scheduling and monitoring

- As a rule farmers are not aware of the potential hazards of over-irrigating with drip. They must be shown how to check the moisture in the soil by digging holes.

- The use of monitoring aids can be of value, but it is not recommended at the start of the project. In this respect tensiometers could be considered, but the high cost and maintenance involved, as well as interpretation demands, are negative aspects which should be considered. Should these aids be considered, it should preferably be tried on a trial basis and the results then evaluated.

- The farmer should be provided with guidelines on irrigation scheduling based on climatic conditions, crop and growth stage, as well as cultivation practices. An elementary program for the full season for different crops could be considered. Periodic updates during the season is, however, much more advisable,

6.2.4.6 Support services and trouble-shooting

- Bring the farmer in contact with other users of micro-irrigation, so that he can discuss problems and / or interesting experiences of the system. This should be in addition to support services.

- Communication is often a major problem. Obtain a contact number, or preferably two, early in the project where the farmer can be reached.

- The farmer should be able to contact the appropriate person/support service for assistance with any problem, and provided with procedures in cases of emergency.

- Technical aftercare service is imperative to ensure sustainability. These costs, which may be considerably more than the cost of the system, could be carried by either the farmer, the irrigation company, or government. A period of two years is proposed for this.

- During routine visits to the farmer, effort must be made to determine the state of affairs of both the farmer and his irrigation system, and for this purpose a checklist can be used. The farmer needs to be reminded about importance matters which occurred since the previous visit. Discussions on the checklist should not be overly structured, because the real state of affairs may not be revealed, and important information overlooked. It should only serve as reminder of subjects to be discussed during the visit. A suggested checklist appears in Appendix D. A checklist could be left with the farmer, but cooperation would probably not be very satisfactory.

- The farmer should be provided with a "what - if" list, which should include the most general things that could go wrong with the system, with temporary solutions for irrigation to proceed, if possible, until such time that it can be fixed properly, as well as a solution to fix it correctly. Aspects which should be included appears in Appendix E. If the farmer is not responsible for the system operation, he must make sure that a back-up operator with some system training is available.

6.2.5 Financial issues

6.2.5.1 Capital costs

- Ownership of the land is not necessary for the farmer to be successful, but he must have some assurance that he will have access to the land for a set period of time.

- The farmer will need access to financing, usually for capital or production loans, even if the land he farms on is not his property and he consequently cannot offer it as security. This has fortunately been provided for by the Land Bank's new loan schemes, but more avenues for credit will have to be found in future.

- There will always be a need for farmers to expand, and success at the start of the small-scale project could provide the farmer with the necessary confidence to do this.

- This success should also be evident to the support services involved, and could act as motivation to continue their commitment to the project.

- Few farmers are in a financial position to convert from flood and sprinkler irrigation to micro-irrigation without financial aid. New farmers are not sufficiently informed to start with micro. A concerted effort must be made within the framework of official policy to address both the financial and technology transfer issues.

- Micro-irrigation systems are expensive. Good quality equipment and materials should nevertheless always be specified in the design. New, unfamiliar manufacturer's products should be discouraged, since it could cause problems in future which the farmer may not be able to accommodate.

- *The idle time of the on-farm supply system and in-field systems must be analysed and* evaluated in detail with the farmer. If it is used effectively, the cost of the system per unit area can be reduced three to four times.

6.2.5.2 Crops

- Due to unstable cash-crop prices, when competing on a commercial scale and given the size of the operation is bigger than two or three hectare, permanent crops should be seriously considered, provided suitable crops (climate, resources, markets) can be planted. For purposes of cash-flow considerations, however, income from another source will be needed initially, for example a salary (work done elsewhere), cash crops elsewhere on the farm, or cash crops between the permanent crop rows (intercropping).

- The farmer must be properly briefed on intercropping and assisted to manage it correctly, using the same irrigation system, even if it involves moving the dripper line side-ways two or three times without moving the lateral to an alternative connecting point on the submain.

- *If farming operations are such that production exceeds immediate requirements,* crops should be selected with great circumspection. If the necessary support services are in place, perishable products could be considered. If not, the farmer should keep to products which do not spoil easily, or preferably a crop to which value can be added and which could be kept for a while, e.g. drying of paprika, etc.

- A seasonal plan needs to be worked out with the farmer (in the case of cash crops), with indications of crops to be planted, and procedures to follow before planting. It is not necessary to keep to this program. It should rather serve as an agenda to be discussed periodically.

6.2.5.3 Water

- Water used by farmers in schemes should me measured individually. This encourages the effective and accountable use of water.

- Grey water used with micro-irrigation has a definite place in backyard gardens. More research in this regard is necessary.

- Municipal water used for micro-irrigation can be affordable, but the scale of such farming activities may not fit in with the overall water-plan of local authorities. If the scale of this type of irrigation is sufficient, the exploration of ground water may be a better option.

6.2.6 Summary

Guidelines presented here were concluded from experience gained during the course of the project and are believed to present a realistic picture of the situation. Observations at the pre-feasibility and planning stages of a proposed project were deemed important in order to increase the chances of success.

It is crucial that micro-irrigation should not be regarded as answer to all small-scale irrigation farmers' problems, and that its implementation may in fact leave some farmers worse off than before. However, it is the responsibility of the engineer or designer to identify potentially hazardous situations before a resource-poor farmer invests in a future with unlikely returns.

6.3 PROPOSED ADAPTATION OF THE SAPFACT PROCEDURE FOR SMALL-SCALE MICRO-IRRIGATION FARMING

The project team concluded that the SAPFACT procedure is appropriate for evaluation purposes, but that aspects, factors and criteria presently included in the program to evaluate a farmer (project) need changes when applied to micro-irrigation in small-scale farming. The procedure offers a sound method of obtaining order and meaning when a number of independent and interdependent variables have to be analised.

In the process of identifying aspects and factors for this project, it was attempted to maintain the same number provided by SAPFACT, namely six aspects, each including eight factors and four criteria. If considered a useful procedure to apply, it would have the added advantage that changes to the software would be relatively simple.

This framework was soon found to be too limiting, and it was decided to move away from it, but retaining the principles of aspects, factors and criteria. This culminated in the development of six aspects, each having between three and ten factors, which are discussed in Chapter 5. The weight accorded each aspect will vary, since some are considered more important than others. Although the attempt to determine these weights were not considered part of this project, it is believed that enough information has been generated to develop a first-order set of values.

Development of a SAPFACT version for micro-irrigation in small-scale farming can be a useful addition to the guidelines included in this chapter.

6.4 TRAINING REQUIREMENTS AND APPROACHES

Based on the project team's experience during monitoring and visits on more than one occasion, training (or lack of it) was identified as probably one of the biggest contributing factors to the success or failure of small-scale farmers.

The project (and other development situations) has shown that the best approach to training small-scale irrigators is "on the job" training, as opposed to top-down education for purposes of a qualification. Because of the diversity of individuals, situations and objectives involved, generalised training procedures are not feasible, and a preliminary needs analysis should be conducted to establish the required focus and approach to be taken.

Participation in the development and start-up of an irrigation scheme is a very intensive period of learning for most of those involved. Farmers in particular are rapidly and continuously exposed to a wide range of new concepts, and in the first year of production many new skills and more basic knowledge have to be acquired.

It is therefore important that the person responsible for training should be informed as to the requirements of the aspects on which he is presenting training. In small-scale farming in particular, appropriate farming approaches often require a unique combination of modern and traditional methods and technology. An approach of "learning together", much rather than a traditional one-way teacher/pupil approach should be taken. For this reason the trainer must take cognisance of both local situations and the new technology.

For more comprehensive information, the WRC project 774: "Development of guidelines for appropriate training levels and content in support of sustainable small-scale irrigation development" can be consulted.

7. CONCLUSION

7.1 REACHING THE PROJECT OBJECTIVES

At the start of the project the objective was to assess the implementation of micro-irrigation under small-scale farming conditions in order to identify aspects related to micro-irrigation which determine the success or failure of these systems. As the project progressed, however, it became apparent that external factors, generic to any small-scale farming system and seemingly unrelated to micro-irrigation, had a significant influence, and that it would therefore be almost impossible to evaluate the former without taking the latter into account.

As a result the project not only provided an opportunity to identify aspects directly related to micro-irrigation, but also an opportunity to demonstrate the impact of external factors on emerging farmers. During the course of the project about 30 sites were monitored or visited where small-scale farmers use micro-irrigation. Of the 23 sites discussed in detail in this report, 11 were newly established for purposes of the project, a further 11 were already established in South Africa, and the remaining site in Israel was visited by a member of the project team.

Observations made during monitoring of the trial plots, and a survey of existing systems, together with information obtained through literature studies and discussions with other parties involved with small-scale irrigation, were used to identify six aspects considered to be of major importance when evaluating small-scale micro-irrigation farming. These are as follows:

(a) The farmer and his circumstances
(b) Water-supply
(c) The irrigation system
(d) General management
(e) Infrastructural, institutional, extension and social factors
(f) Economic and financial factors

A number of factors describing each aspect were then listed.

The analysis provided extensive information on small-scale irrigation, most of the relevant issues and problems encountered being generic problems of small-scale irrigation, of which few are directly related to micro-irrigation. This information formed the basis of a set of guidelines aimed at project planners and managers for small-scale farmers' use of micro-irrigation.

7.2 IMPLEMENTING MICRO-IRRIGATION SUCCESSFULLY IN SMALL-SCALE FARMING

It is important to realise that micro-irrigation is not the answer to all small-scale irrigation farmers' problems and that there are situations where its implementation may cause farmers to be worse off than before. However, it is the responsibility of the engineer or designer to identify a potentially hazardous situation before a resource-poor farmer invests in a future with unlikely returns.

Micro-irrigation can be implemented successfully in small-scale farming, provided that a number of support services are in place. Small-scale farmers experience very few problems with the operation of the system as long as the design and materials are of a good quality, and he follows operational guidelines reasonably well. However, when something fails in the system, especially if it is related to the water-supply, a project can come to sudden standstill with serious consequences for the farmer.

Guidelines for the implementation of micro-irrigation in small -scale farming, which are based on all the surveys, are practical, and can serve as a checklist for planners, designers and extension officers. These guidelines have been further refined, and culminated in a separate document aimed specifically at irrigation planners, designers and extensionists, which will subsequently be published by the Water Research Commission. ("Guidelines for the implementation of micro-irrigation for small-scale farmers"). Its aim is to help prevent problems and mistakes of the past. Hopefully it will contribute to policy-making on small-scale farming, which will lead to more successful projects in future.

7.3 THE WAY FORWARD

To date a number of research projects have been carried out on different small-scale farming issues. Definite parallelisms are observable in the findings of these projects, and it is recommended that an abstract be made of all the findings or reports, including guidelines on a broad range of aspects. This abstract can be included as an additional chapter in the Irrigation Manual published by the ARC Institute for Agricultural Engineering and the Department of Agriculture.

A number of aspects were identified which require further investigation:

- Design norms for small-scale micro-irrigation. At present the norms are the same as for commercial schemes, although the project team would like to see some adaptations in future.
- Application of fertiliser. Many questions remain about the methods to apply, types of fertiliser and efficiency of application.
- The use of grey water with micro-irrigation systems by small-scale farmers.
- Rapid (revolutionary) conversion to micro-irrigation system versus step-by-step traditional (evolutionary) conversion. In this regard processes in other developing countries, especially India and Israel, should be studied in greater depth.
- The development of a complete SAPFACT model specifically aimed at small-scale micro-irrigation farming.

REFERENCES

BACKEBERG, GR, TJ BEMBRIDGE, ATP BENNIE, JA GROENEWALD, PS HAMMES, RA PULLEN & H THOMPSON. 1996. *Policy proposal for irrigated agriculture in South Africa: Discussion paper.* WRC report no KV96/96. Water Research Commission of South Africa, Pretoria.119pp.

BURGER, JH, PJ HEYNS, EPJ KLEYNHANS, FH KOEGELENBERG, MT LATEGAN, DJ MULDER, HS SMAL, CM STIMIE, FPJ VAN DER MERWE & PJ VILJOEN. 1996. *Irrigation Design Manual.* ARC-Institute for Agricultural Engineering. Pretoria.

CROSBY, CT. 1996. *SAPFACT 1.0 A computer program for qualitative evaluation of irrigation farming.* WRC Report no 382/1/96. Water Research Commission of South Africa, Pretoria. 122pp.

CROSBY, CT. 1996. *SAPWAT 1.0 A computer program for estimating irrigation requirements in Southern Africa.* WRC Report no 379/1/96. Water Research Commission of South Africa, Pretoria. 80pp.

DE LANGE M (1994) *Small scale irrigation in South Africa.* MBB Consulting Engineers/Water Research Commission of South Africa, Pretoria. 29pp.

Development of guidelines for appropriate training levels and content in support of sustainable small-scale irrigation development. WRC project no 774. MBB Consulting Engineers Inc.

Drip irrigation in India. 1994. Indian National Committee on Irrigation and Drainage: New Delhi, India. 176pp.

Evaluation of irrigation techniques used by subsistence and emergent farmers. WRC project no 578. MBB Consulting Engineers Inc.

MORIS, JR. 1987. *African Irrigation Review: WMS Report 37.* Untah State University: Logan, Utah, USA.

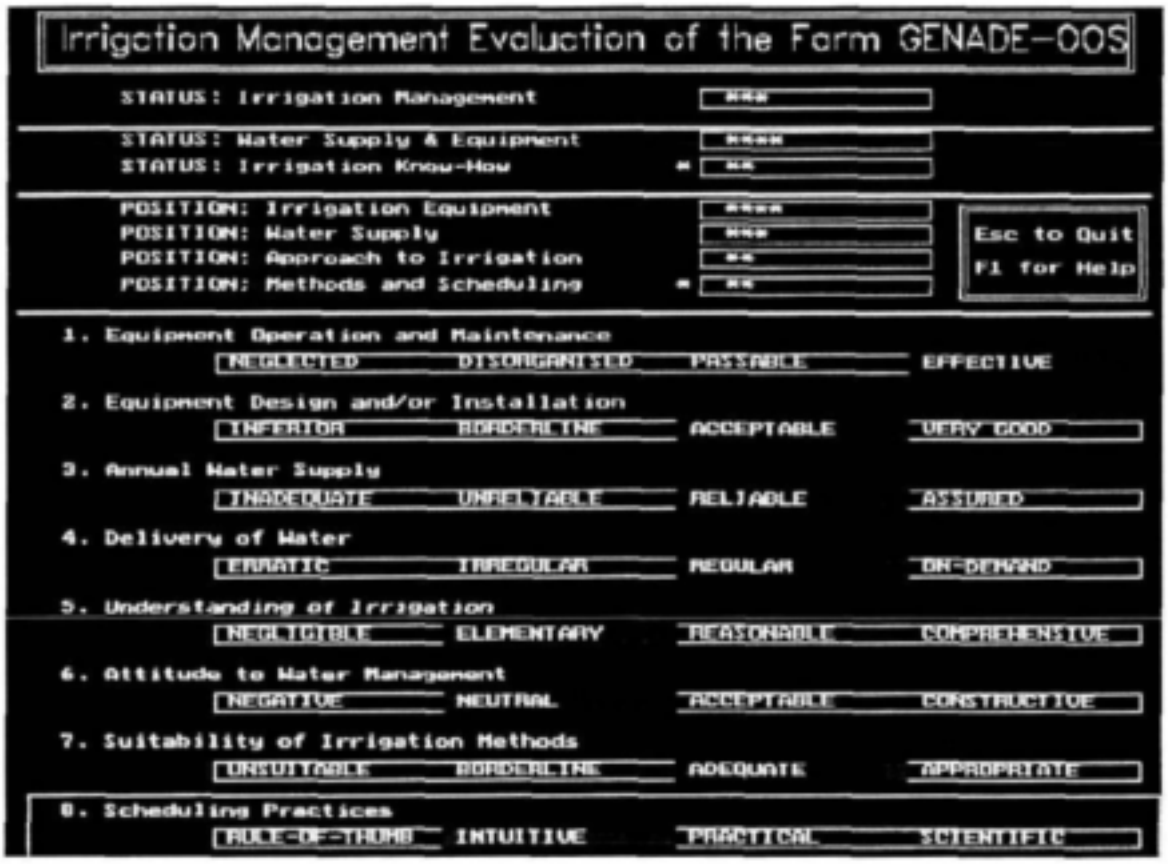
Personal computer based procedure for the estimation of irrigation requirements of crops in Southern Africa. WRC project no 624. MBB Consulting Engineers Inc.

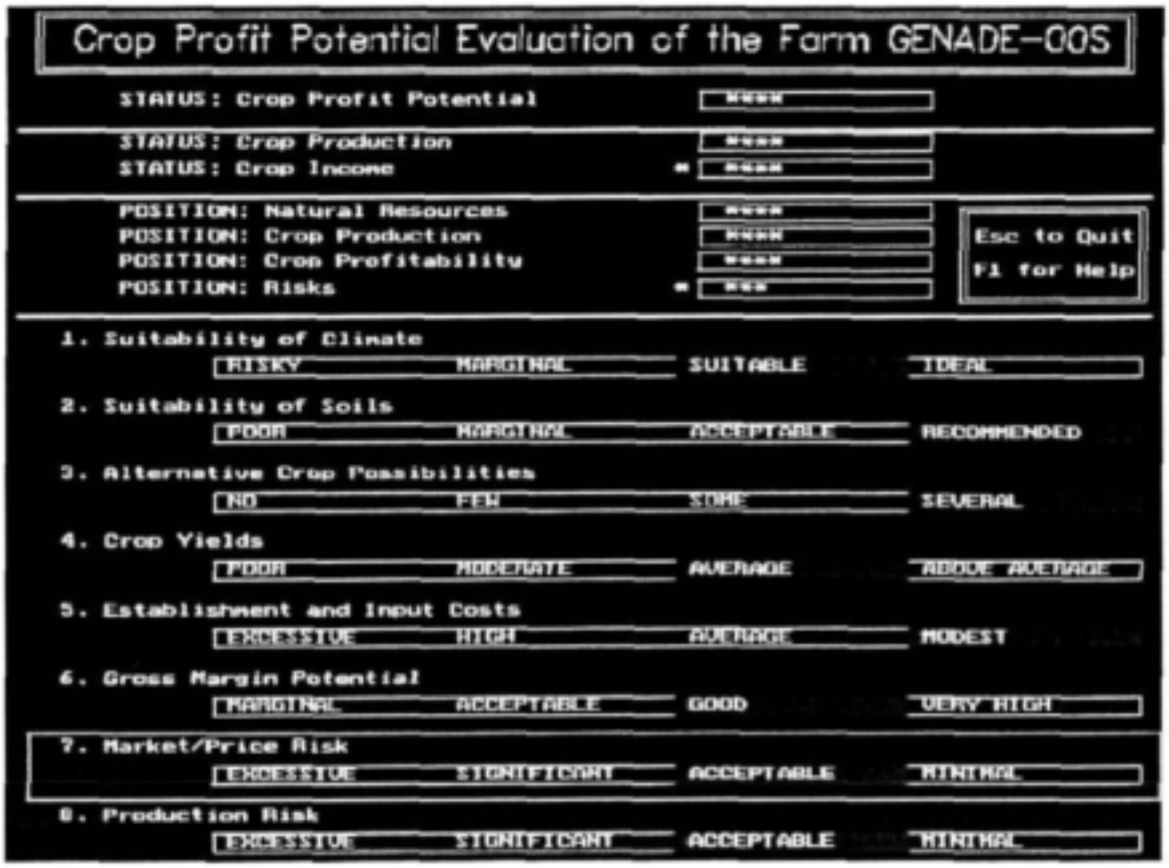
PRETTY, JN. 1991. *Regenerating agriculture: Policies and practices for sustainability and self-reliance.* Earthscan Publications Ltd. London.

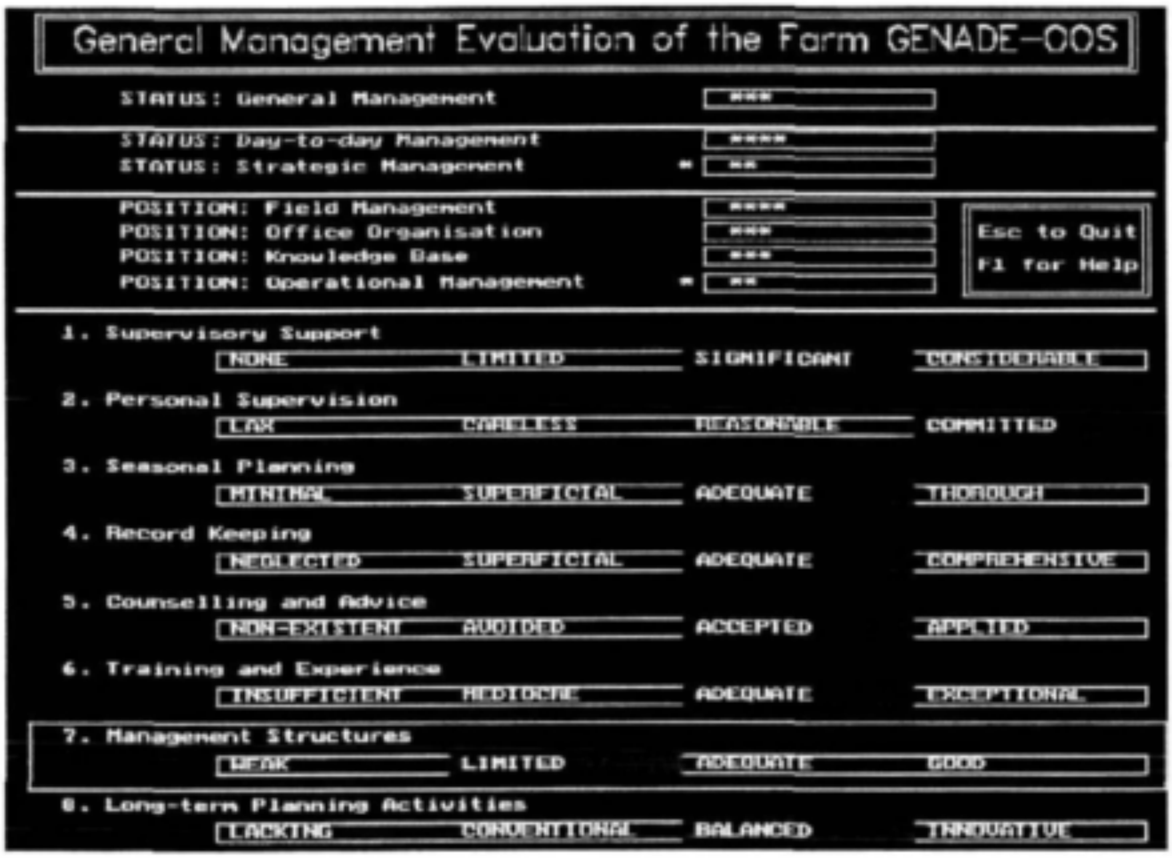
VAN AVERBEKE W, M'MARETE CK, IGODAN CO and BELETE A (1998) *An investigation into food plot production at irrigation schemes in the central Eastern Cape. WRC Report No 719/1/98.* Water Research Commission of South Africa, Pretoria.

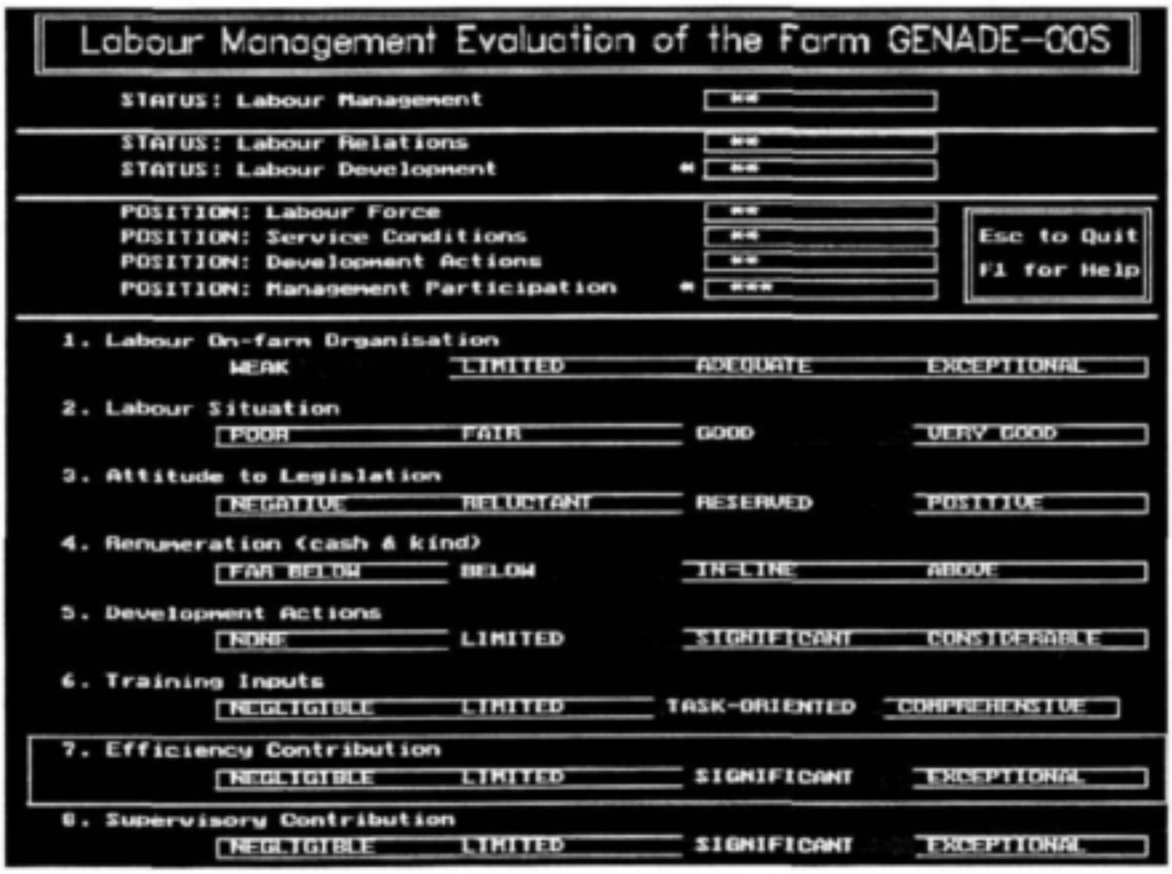
APPENDIX A

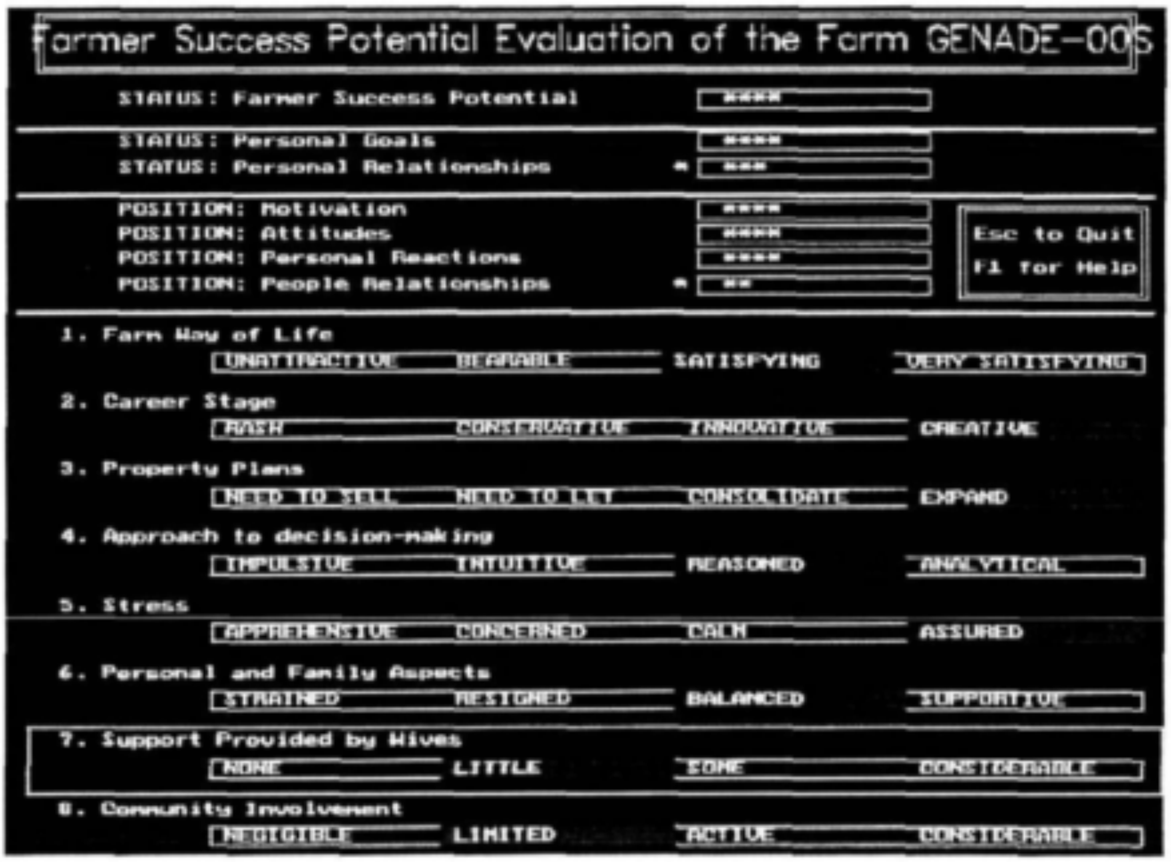
RESULTS OF SAPFACT ANALYSIS OF TWO EXISTING FARMERS

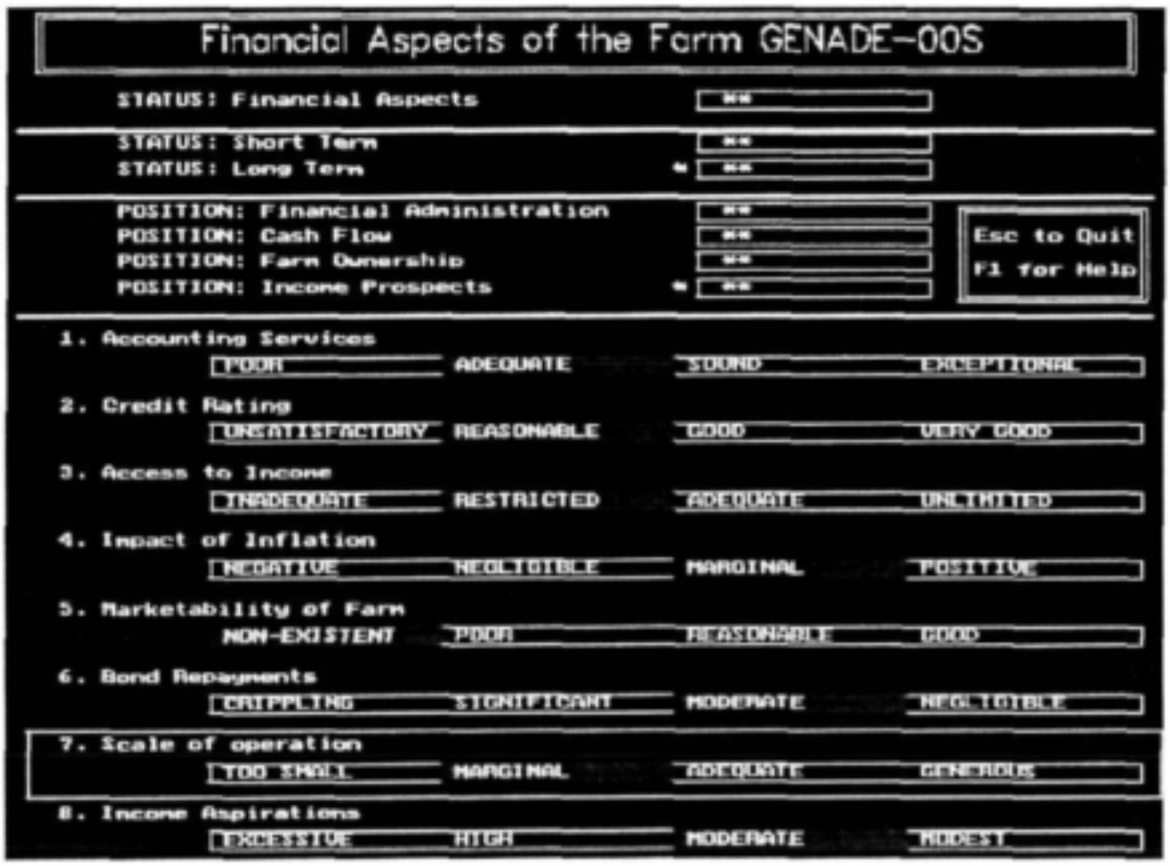

Irrigation Management Evaluation of the Farm GENADE-OOS
STATUS: Irrigation Management ***
STATUS: Water Supply & Equipment ****
STATUS: Irrigation Know-How * **
POSITION: Irrigation Equipment ****
POSITION: Water Supply ***
POSITION: Approach to Irrigation **
POSITION: Methods and Scheduling * **
Esc to Quit
F1 for Help
1. Equipment Operation and Maintenance
NEGLECTED DISORGANISED PASSABLE EFFECTIVE
2. Equipment Design and/or Installation
INFERIOR BORDERLINE ACCEPTABLE VERY GOOD
3. Annual Water Supply
INADEQUATE UNRELIABLE RELIABLE ASSURED
4. Delivery of Water
ERRATIC IRREGULAR REGULAR ON-DEMAND
5. Understanding of Irrigation
NEGLIGIBLE ELEMENTARY REASONABLE COMPREHENSIVE
6. Attitude to Water Management
NEGATIVE NEUTRAL ACCEPTABLE CONSTRUCTIVE
7. Suitability of Irrigation Methods
UNSUITABLE BORDERLINE ADEQUATE APPROPRIATE
8. Scheduling Practices
RULE-OF-THUMB INTUITIVE PRACTICAL SCIENTIFIC


Crop Profit Potential Evaluation of the Farm GENADE-OOS
STATUS: Crop Profit Potential ****
STATUS: Crop Production ****
STATUS: Crop Income * ****
POSITION: Natural Resources ****
POSITION: Crop Production ****
POSITION: Crop Profitability ****
POSITION: Risks * ***
Esc to Quit
F1 for Help
1. Suitability of Climate
RISKY MARGINAL SUITABLE IDEAL
2. Suitability of Soils
POOR MARGINAL ACCEPTABLE RECOMMENDED
3. Alternative Crop Possibilities
NO FEW SOME SEVERAL
4. Crop Yields
POOR MODERATE AVERAGE ABOVE AVERAGE
5. Establishment and Input Costs
EXCESSIVE HIGH AVERAGE MODEST
6. Gross Margin Potential
MARGINAL ACCEPTABLE GOOD VERY HIGH
7. Market/Price Risk
EXCESSIVE SIGNIFICANT ACCEPTABLE MINIMAL
8. Production Risk
EXCESSIVE SIGNIFICANT ACCEPTABLE MINIMAL


General Management Evaluation of the Farm GENADE-OOS
STATUS: General Management ***
STATUS: Day-to-day Management ****
STATUS: Strategic Management * **
POSITION: Field Management ****
POSITION: Office Organisation ***
POSITION: Knowledge Base ***
POSITION: Operational Management * **
Esc to Quit
F1 for Help
1. Supervisory Support
NONE LIMITED SIGNIFICANT CONSIDERABLE
2. Personal Supervision
LAX CARELESS REASONABLE COMMITTED
3. Seasonal Planning
MINIMAL SUPERFICIAL ADEQUATE THOROUGH
4. Record Keeping
NEGLECTED SUPERFICIAL ADEQUATE COMPREHENSIVE
5. Counselling and Advice
NON-EXISTENT AVOIDED ACCEPTED APPLIED
6. Training and Experience
INSUFFICIENT MEDIOCRE ADEQUATE EXCEPTIONAL
7. Management Structures
WEAK LIMITED ADEQUATE GOOD
8. Long-term Planning Activities
LACKING CONVENTIONAL BALANCED INNOVATIVE


Labour Management Evaluation of the Farm GENADE-OOS
STATUS: Labour Management **
STATUS: Labour Relations **
STATUS: Labour Development * **
POSITION: Labour Force **
POSITION: Service Conditions **
POSITION: Development Actions **
POSITION: Management Participation * ***
Esc to Quit
F1 for Help
1. Labour On-farm Organisation
WEAK LIMITED ADEQUATE EXCEPTIONAL
2. Labour Situation
POOR FAIR GOOD VERY GOOD
3. Attitude to Legislation
NEGATIVE RELUCTANT RESERVED POSITIVE
4. Remuneration (cash & kind)
FAR BELOW BELOW IN-LINE ABOVE
5. Development Actions
NONE LIMITED SIGNIFICANT CONSIDERABLE
6. Training Inputs
NEGLIGIBLE LIMITED TASK-ORIENTED COMPREHENSIVE
7. Efficiency Contribution
NEGLIGIBLE LIMITED SIGNIFICANT EXCEPTIONAL
8. Supervisory Contribution
NEGLIGIBLE LIMITED SIGNIFICANT EXCEPTIONAL


Farmer Success Potential Evaluation of the Farm GENADE-00S
STATUS: Farmer Success Potential ****
STATUS: Personal Goals ****
STATUS: Personal Relationships * ***
POSITION: Motivation ****
POSITION: Attitudes ****
POSITION: Personal Reactions ****
POSITION: People Relationships * **
Esc to Quit
F1 for Help
1. Farm Way of Life
UNATTRACTIVE BEARABLE SATISFYING VERY SATISFYING
2. Career Stage
RASH CONSERVATIVE INNOVATIVE CREATIVE
3. Property Plans
NEED TO SELL NEED TO LET CONSOLIDATE EXPAND
4. Approach to decision-making
IMPULSIVE INTUITIVE REASONED ANALYTICAL
5. Stress
APPREHENSIVE CONCERNED CALM ASSURED
6. Personal and Family Aspects
STRAINED RESIGNED BALANCED SUPPORTIVE
7. Support Provided by Wives
NONE LITTLE SOME CONSIDERABLE
8. Community Involvement
NEGIGIBLE LIMITED ACTIVE CONSIDERABLE


Financial Aspects of the Farm GENADE-00S
STATUS: Financial Aspects **
STATUS: Short Term **
STATUS: Long Term * **
POSITION: Financial Administration **
POSITION: Cash Flow **
POSITION: Farm Ownership **
POSITION: Income Prospects * **
Esc to Quit
F1 for Help
1. Accounting Services
POOR ADEQUATE SOUND EXCEPTIONAL
2. Credit Rating
UNSATISFACTORY REASONABLE GOOD VERY GOOD
3. Access to Income
INADEQUATE RESTRICTED ADEQUATE UNLIMITED
4. Impact of Inflation
NEGATIVE NEGLIGIBLE MARGINAL POSITIVE
5. Marketability of Farm
NON-EXISTENT POOR REASONABLE GOOD
6. Bond Repayments
CRIPPLING SIGNIFICANT MODERATE NEGLIGIBLE
7. Scale of operation
TOO SMALL MARGINAL ADEQUATE GENEROUS
8. Income Aspirations
EXCESSIVE HIGH MODERATE MODEST

APPENDIX B

PROVISIONAL CHECKLIST OF GENERAL ASPECTS TO BE ADDRESSED SPECIFICALLY DURING IRRIGATION SYSTEM PLANNING, DESIGN AND TRAINING

APPENDIX B

PROVISIONAL CHECKLIST OF GENERAL ASPECTS TO BE ADDRESSED SPECIFICALLY DURING IRRIGATION SYSTEM PLANNING, DESIGN AND TRAINING

The following list of items are additional to the normal aspects that needs to be taken into account for commercial irrigation projects.

- **The farmer**
  - The literacy level of the farmer and his family (languages, reading and writing, etc)
  - Technical and mechanical skill of the farmer
  - The available time of the farmer
  - Financial situation of farmer (afford ability of system and the operation thereof)

- **The farm location / history of development**
  - Type of development
  - Existing data/information/reports about the projects and its background
  - The possible danger of theft of system components

- **Support services**
  - Existence of relevant support services
  - Extension officer to work together with

- **Technical information**
  - Reliability of the water source and supply system
  - Additional requirements from the same water source
  - The potential (and need) for the incorporation of a buffer storage facility
  - Contingency plans when water shortages are experienced
  - Fertilizer application options

- Consideration to use regulated emitters
- The potential of intercropping
- The potential and acceptability of the movement of laterals between rows
- Possible extension of the project
- Inclusion of aids (system components) to make system operation "easier"
- Guidelines with regards to crop spacing
- Possible phasing of the project

- **Training**

  - Training material (documentation), operational – and maintenance guidelines

APPENDIX C

PROVISIONAL CHECKLIST OF TYPICAL SERVICES NEEDED BY THE FARMER WITH REGARDS TO HIS IRRIGATION SYSTEM (SERVICE SUPPLIERS)

APPENDIX C

PROVISIONAL CHECKLIST OF TYPICAL SERVICES NEEDED BY THE FARMER WITH REGARDS TO HIS IRRIGATION SYSTEM (SERVICE SUPPLIERS)

The following list of items are additional to the normal aspects that needs to be taken into account for commercial irrigation projects.

- **Water supply**
  - Water authority
  - Provincial Department of Water Affairs and Forestry
- **Soil preparation and maintenance of lands**
  - Extension officer
  - Contractor with tractor and implements
  - Builder
- **Electricity supply**
  - Escom
  - Electrician
- ***Farming needs and markets***
  - Provincial department of Agriculture
  - Extension officer
  - Fertilizer supplier
  - Weed control supplier
  - Seed supplier
  - Research units (ARC)
  - NGO's

- **Irrigation system**

  - Closest supplier of: Pumps spares
    AC-PVC-, and PE pipes
    Fittings (including all system components)
    Irrigation designer / company

- **Irrigation practices**

  - Provincial department of Agriculture
  - Extension officer
  - Research units
  - Irrigation designer / company

APPENDIX D

PROVISIONAL INFORMATION SHEET (CHECK LIST) TO BE USED DURING FIELD VISITS

APPENDIX D

PROVISIONAL INFORMATION SHEET (CHECK LIST) TO BE USED DURING FIELD VISITS

- **Water supply**
  - Extent of any shortage experienced and reasons thereof
  - How does the situation for the rest of the season look
- **Plant growth**
  - Is plant growth satisfactorily
  - The need for remedial actions
- **Weed control**
  - Are the applied techniques successful
  - The need for remedial actions
- ***Fertilizer application***
  - Was application until now according to schedule
  - Is the remaining fertilizer (or credit) sufficient to see the crop through
  - Problems experienced with the method of application
- **Irrigation system**
  - Standard maintenance applied during system operation
  - Problems experienced with pump and on-farm distribution system
  - Problems experienced with water quality and filtration
  - *Infield system problems*
  - The need for servicing of equipment, and spare parts to be held in stock

- **Irrigation scheduling**

  - How effective does the farmer and his system cope with the irrigation demand
  - The need for changes to schedule followed
  - Possible improved soil moisture monitoring procedures to be applied by the farmer

- **Marketing**

  - Is the marketing of products done according to planning
  - Are prices according to expectation
  - The need for changing the marketing strategy, and how to approach it

- **The need for training, as well as for additional support services**

  - For each of the above mentioned subjects it must be established if additional training, which is practically achievable, can improve the situation of the farmer. This also applies to the introduction of additional support services.

APPENDIX E

PROVISIONAL "WHAT-IF" CHECKLIST TO BE USED BY THE FARMER DURING SYSTEM OPERATION

APPENDIX E

PROVISIONAL "WHAT-IF" CHECKLIST TO BE USED BY THE FARMER DURING SYSTEM OPERATION

Each of the items in the following checklist will have to be sub-divided into more items (depending on the particular circumstances) in order to direct the farmer more clearly to the problem which he experiences.

- **Water supply**
  - External supply interruption
  - Insufficient flow and / or pressure received from external supply
  - Shortage of water at the source
- **Electricity supply**
  - No supply
  - No supply at pump
  - Electric cables damaged
- **Irrigation system**
  - Motor/Engine does not start
  - Motor/Engine starts, but pump does not deliver sufficient flow/pressure
  - Mechanical maintenance of pumping equipment is evident
  - Water quality (physical and/or chemical) is of concern, or creates problems
  - Problem which may be experienced (due to damage, malfunctioning, or lack of proper maintenance) with the different components of the irrigation system , i.e. the on-farm distribution system, filtration- and fertigation equipment, valves, sub-mains, laterals and emitters
  - Difficulties are experienced with the scheduling of the system
  - In-field system needs to be moved to a new area
  - In-field system needs to be extended

- **Crop production**

  - Weed control is not effective
  - Diseases in crops
  - Growth/production/quality of crop is not satisfactorily
  - Marketing problems

APPENDIX F

MODEL FOR BACKYARD FOODPLOT PRODUCTION

APPENDIX F

MODEL FOR BACKYARD FOODPLOT PRODUCTION

Water Research Commission

Private Bag X03, Gezina, 0031, South Africa

Tel: +27 12 330 0340, Fax: +27 12 331 2565

Web: http://www.wrc.org.za