ENGREF
Ecole Nationale du Génie Rural, des Eaux et des Forêts
Department of Water Management

CIRAD
Centre de Coopération Internationale en Recherche Agronomique pour le Développement

Combining Approaches to assess Economic Viability and Insitutional Arrangements in Smallholder Irrigation Schemes

November 2004

FINAL

A Case Study in the Mauluma Irrigation Scheme
Limpopo Province - South Africa

CIRAD - TERA, num. 02/05

In cooperation with:

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Internship MSc Research Report
Integrated Water Management

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South Africa

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This document assembles research results and the knowledge I gained during a most valuable and meaningful research internship concerning water management and smallholder irrigation schemes in South Africa. In particular, it reflects my close collaboration with various actors and individuals, whom I wish to thank for contributing to my work and investigations and for making this internship a precious and memorable experience.

Working for CIRAD at the University of Pretoria gave me the unique opportunity to get a glimpse and shortly be part of the South African academic world. The close cooperation with the RESIS program and representatives of the Limpopo Department of Agriculture and the Department of Water Affairs and Forestry allowed me to obtain a hands-on experience with current policies and programs concerning revitalization, institutional strengthening and management transfer of smallholder irrigation schemes, which are ongoing in South Africa. It was a great privilege to be able to be part of this exciting and challenging process, which is of major importance to the future development of rural livelihoods all over South Africa.

My gratitude goes out to everybody, for being involved in my work and for supporting me throughout my stay. Although, everybody deserves a personal word of thanks, I would like to mention a few people in particular.

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With great pleasure I did this research internship and I hope that the results will provide useful contributions to future research and ongoing projects on smallholder irrigation schemes in South Africa, such as the RESIS program and in particular may help to understand smallholder farming systems in South Africa and to appreciate the value of their development for the well being of rural communities all over the country.

Rodibuwa – Thank you!

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Pretoria
November, 2004

EXECUTIVE SUMMARY

Since 1994 the South African Government has undertaken massive reforms addressing rural poverty and inequalities inherited from the past apartheid regime. Regarding water and irrigation South Africa, like many other countries has initiated Irrigation Management Transfer (IMT), representing among others state withdrawal, promotion of the participation of water users, development of local management institutions (WUAs) and transfer of ownership and management. In the Limpopo Province, it is acknowledged with great concern that most smallholder irrigation systems are declining and have been inactive for many years, creating a major challenge for transfer policies and rehabilitation and revitalization programs, such as the Water Care Program and RESIS program in South Africa.

Research objective

This research is a follow-up of ongoing CIRAD and UP research on economic viability of smallholder irrigation schemes in the Limpopo Province. The main objective of this research is the *development of a* ***combined methodological approach****, which includes economic viability studies and institutional analysis*. In order to fulfill this main objective and former ongoing ones, this research was done on a case study basis. Therefore, the Mauluma irrigation scheme in the Limpopo Province, incorporated in the RESIS program was selected.

Methodological framework

The methodological framework used for analysis consists of two approaches: the SMILE approach and the IADF approach. The Ostrom "8 design principles" for efficient and sustainable irrigation schemes (*1. clearly defined boundaries, 2. proportional equivalence between benefit and costs, 3. collective-choice arrangements, 4. monitoring, 5. graduated sanctions, 6. conflict resolution mechanisms, 7. minimal recognition of rights to organize and 8. nested enterprises*) are added to the IADF approach. SMILE stands for *Sustainable Management of Irrigated Lands and Environment* and is a simulation platform and data capturing and calculation tool, which helps to assess the financial/economic viability and the operation and management features of smallholder irrigation schemes. The *Institutional Analysis and Development (IAD) Framework* is used for institutional analysis of the Mauluma scheme and addresses questions surrounding institutional design and performance of the scheme's institutional arrangements and inter-organizational networks. Together these approaches form a *combined methodology* for analysis.

SMILE approach

For the SMILE approach the *scheme, crops, farming systems and water balance modules* of the database have been used for calculation and analysis, generating results concerning economics and water at crop, farmer and scheme level as well as results on crop irrigation requirements (SAPWAT). As input for the *farming systems module* a typology of farmers was established for Mauluma, resulting in three farmer types: 1. Specialized summer farmers (54 %), 2. Diversified winter farmers (27 %) and 3. Specialized winter farmers (8 %). Each type has been split up into two sub-types: *pensioners* and *non-pensioners* and for each sub-type a representative *monograph farmer type* was identified.

The SMILE results show that in the scheme, the three major crops are maize, tomato and beans. Furthermore, the specialized winter farmers seem to be the most advanced and most

skilled as they have the highest gross margin. At scheme level, it seems that Mauluma is doing well compared to other smallholder irrigation schemes where similar analysis has been performed, as the scheme gross margin is relatively high as well as the water productivity. Furthermore, the water availability in the scheme seems to be constant and sufficient to fulfill crop water requirements throughout the year.

In conclusion, from the SMILE approach it is found that record keeping needs to be addressed in the scheme to ensure accurate data. Furthermore, the SMILE approach can be enriched by a detailed household and livelihood analysis to investigate famers' incomes in order to be able to assess farmers' willingness to pay for water charges and operation and maintenance costs in the future. Finally, with the current SMILE results on Mauluma, the SMILE database is ready to be used for its final phase: scenario building and testing.

IADF approach

For the IADF approach the *action arena*, its *actors* and specific *action situations*, the *patterns of interaction* among actors and their *behavior* and the different *rules-in-use* in the Mauluma irrigation scheme are analyzed. The actor arena is composed of four sub-arenas: the public sector (government), actors involved in intervention (indirectly linked to the public sector), scheme members (users) and actors who are not really part of the scheme (private sector), but surely linked to it. When analyzing the *action situation component*, three particular action situations are chosen for this research: 1. General water management and agriculture (WM&A), concerning all actor groups, 2. Individual irrigation (II) at plot or farmer level and 3. Collective maintenance (CM) at plot and scheme level.

In short, the results on farmers' practices regarding II show that the registered land farmers irrigate once a week on a scheduled day and that rejected land farmers only irrigate in weekends. Farmers making use of springs and connected to the 7^{th} canal can irrigate any day and all farmers are allowed to use "leftover" water any day, as long as other farmers are consulted. In times of drought, farmers plant less and irrigate only half days. Any violation of rules results in sanctions enforced by the scheme's Management Committee (MC). Regarding CM, it is shown that all farmers attend CM activities for the main canal and the fence. Furthermore, all farmers maintain their own stretch of the secondary canal. Also here, in case of absence or lack of participation, the MC enforces a penalty system. The respect and abiding of rules in Mauluma, which is quite exceptional compared to most smallholder irrigation schemes can be explained by the "abundance" of water available to the scheme, meaning that there is no competition over water. Furthermore, most probably as a result of programs such as the Water Care Program and RESIS and due to the good social relationships among scheme members, the farmers seem to have developed a strong sense of ownership and responsibility over the scheme.

Regarding the "8 design" principles, the Mauluma scheme scores positive on all points, except for principle two, as no water charging system has been implemented yet, which makes it difficult to predict future equivalence between benefit and costs and principle seven, as no formal recognition by government is present yet, although the establishment of a WUA is still being discussed.

In conclusion, through the IADF approach it is found that although the MC is functioning well, farmers remain a bit unsure and therefore institutional strengthening in Mauluma needs to be developed further. Also, a new water management plan could be of interest to the scheme to enhance more efficient water use. Furthermore, initiating discussions on the implementation of a water charging system is important, as the scheme needs to assess their capability to account for cost recovery in the near future. To enhance principle eight, farmers could start collective organizations for buying seeds, fertilizers and pesticides as a scheme, allowing them to buy in bulk and thus at lower prices. Finally, to draw conclusions on the institutional development of the scheme, it would be most interesting to perform the IADF approach again, once the RESIS program has been completed and the scheme has been functioning independently for a certain amount of time.

SMILE and RESIS

Since 2004, the RESIS program has shown great interest in using the SMILE approach for economic viability studies on smallholder irrigation schemes. Therefore, in addition to this research, a simplified SMILE approach has been designed and tested on the Morgan irrigation scheme in collaboration with the RESIS team. The results of this pilot study were satisfying to RESIS, but discussions are still ongoing concerning the official implementation and use of the approach in RESIS studies and DWAF decision-making processes regarding the establishment of WUAs.

A combined methodological approach

Although both approaches can be applied independently, the combination of the SMILE and IADF approaches generates complete, all-inclusive and more comprehensive results, which can help farmers' to further develop their potential, address their shortcomings and help them to move forward to a promising future and secure well being, which integrate agriculture and irrigation to "full" extent or at least in the most optimal way.

In conclusion, the *combined methodological approach* has resulted in a practical and functional methodology for studies on economic viability and institutional arrangements, which is generic enough for future use in research projects on smallholder irrigation schemes in other parts of South Africa and even other parts of the world.

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APPENDICES

1 INTRODUCTION

This chapter introduces the research study documented in this report on the economic viability, technical features and institutional arrangements and settings of a smallholder irrigation scheme *Mauluma* in South Africa. Through analysis of these aspects, the overall sustainability of the scheme is investigated. Therefore, to set the context of this research, a short introduction on South Africa and its history regarding smallholder irrigation schemes and Irrigation Management Transfer (IMT) is given in paragraph 1.1. Thereafter, the background and history of the rehabilitation and revitalization programs that took place (Water Care Program) and which are still ongoing (RESIS) in the Limpopo Province will be presented in paragraph 1.2. Paragraph 1.3 discusses the research objectives and paragraph 1.4 gives the outline of this report.

1.1 South Africa, IMT and smallholder irrigation schemes

As described by Perret, 2004 quoting Vermillion, 1997, many countries have increasingly initiated processes of management transfer of irrigation schemes from government agencies to local users (i.e. through establishing Water Users Associations; WUAs) or other private sector entities. This process is renowned as the Irrigation Management Transfer (IMT) process, which represents among others state withdrawal, promotion of the participation of water users, development of local management institutions and transfer of ownership and management (Perret, 2004).

National Water Act

As explained by Perret, 2002, since 1994 the South African Government has undertaken massive reforms addressing rural poverty and inequalities inherited from the past apartheid regime. Regarding water, South Africa has adopted an ambitious new water legislation, which culminated in the conception of a new National Water Act (NWA) in 1998, promoting sustainability, equity and efficiency in the protection, use, development, conservation, management and control of water resources (DWAF (a), 2004?). Furthermore, its key objectives are social development, economic growth, ecological integrity and equal access to water. Perret and Touchain, 2002 explain that the act distinguishes between national, regional and local water management areas. New management entities will be established at regional (Catchment Management Agencies; CMAs) and local (WUAs) level, emphasizing a largely decentralized and participatory approach to water resource management.

IMT and WUAs

In this context, South Africa has just initiated the IMT process in smallholder irrigation schemes located in its former homeland areas[1], resulting in state withdrawal from most former commitments, controls and financial support, decentralization and the transfer of power to local management and decision-making structures (CMAs and WUAs), water users'

[1] The former "homelands" or "Bantustans" were created according to ethnic, geographical and economic criteria under the apartheid period, forming "reserves" to which Black people were allocated (DNA, 1913), also see paragraph 3.2.

registrations and licensing (Perret and Touchain, 2004). At local level, WUAs are cooperative associations of individual water users who wish to undertake water related activities for their mutual benefit and to enable the community to effectively assemble financial and human resources, expertise and address local needs and priorities (DWAF (b), 2004?). A WUA would be responsible for most irrigation management functions, i.e. water distribution rules, organizing maintenance, collection of water supply charges, etc. These tasks are responses to institutional and political requirements as well as to operational needs, implying the emergence and sustainability of WUAs as local institutions and the ability to carry out technical and financial management functions (Perret and Touchain, 2002).

Smallholder irrigation schemes

As explained by Perret, 2004 at present South Africa has an estimated 1.3 million ha of land under irrigation for both commercial and subsistence agriculture. Perret and Touchain, 2002 illustrate that due to history and past policies, different types of irrigation schemes have developed in South Africa (private, irrigation board, white settlement, Bantustan and food plots and community garden schemes). These schemes consume about half the currently available water and resources of the country and contribute to almost 30 % of the total agricultural production (Perret and Touchain, 2002 quoting Backeberg and Groenewald, 1995). Most smallholder irrigation schemes were developed during the early apartheid era and cover approximately 47,000 ha and account for about 4 % of irrigated areas in South Africa (Perret and Touchain, 2002 quoting Bembridge, 2000). It is estimated that about 250,000 rural black people are dependant at least partially for a livelihood on such schemes and that half of these schemes are located in the Limpopo Province (Perret and Touchain, 2002 and Perret, 2004). According to Perret and Touchain, 2002 it is believed that in spite of such a relatively small contribution, those schemes could play an important role in rural development, since they can potentially provide food security, income and employment opportunities. In the Limpopo Province it is acknowledged with great concern that most smallholder irrigation systems are declining and have been inactive for many years (Perret 2004, quoting Bembridge, 2000), creating a major challenge for rehabilitation, revitalization programs and transfer policies in South Africa. Figure 1.1 shows where the Limpopo Province and all other provinces are located in South Africa.

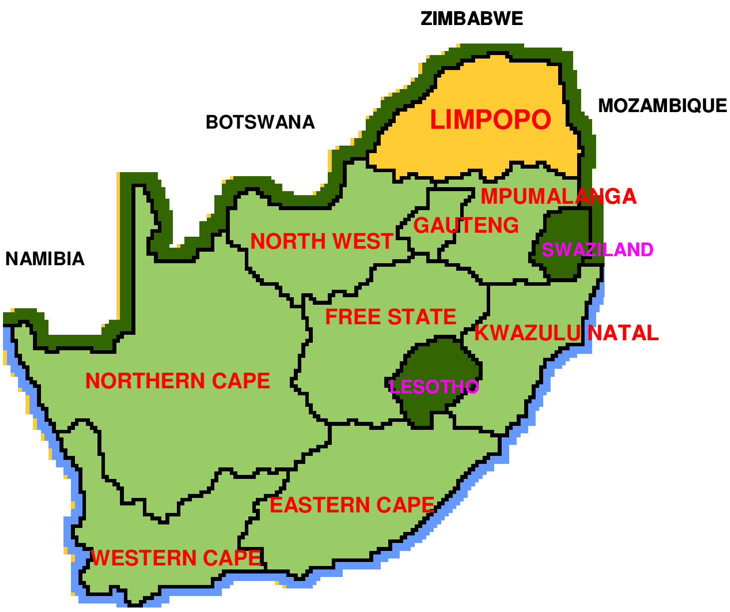


Figure 1.1 The Republic of South Africa and its provinces and neighboring countries

1.2 Rehabilitation and revitalization in the Limpopo Province

In the Limpopo Province, the Limpopo Department of Agriculture (LDA) has initiated a rehabilitation and revitalization process since 1998. The "Planning and Implementation of Irrigation Schemes", commenced with three pilot schemes: Thabina (Lowveld region), Boschkloof (Southern region) and Morgan (Northern region). As described by LDA, 2002 (a), the main objective of the program is the transfer of ownership of the irrigation schemes to the community. Furthermore, it is sought to empower the community to be able to take ownership of the schemes, to rehabilitate, construct and manage infrastructure and conservation works properly. Before transfer takes place, the LDA is committed to assist in finance, equipment and technical know-how to revitalize such schemes.

Water Care Program and RESIS

In April 2000, the "Water Care Program" (WCP) was implemented and included a new set of schemes of which one is Mauluma, the case study of this research. In September 2002 the Revitalization of Smallholder Irrigation Schemes (RESIS) Program was prepared to follow up the Water Care program and started operating in 2004. Besides new schemes, all schemes under the Water Care Program have been integrated in the RESIS program so that the revitalization work can be completed adequately. In total, RESIS aspires to fully attend approximately 130 smallholder irrigation schemes in the Limpopo in 4-year programs over a consecutive period of 6-9 years. At the same time, economic viability and overall sustainability of the schemes have to be established in order for schemes to qualify for the establishment or set up of WUAs by the Department of Water Affairs and Forestry (DWAF). These issues will be repeatedly discussed throughout this document. The RESIS program structure features a multi-disciplinary team, consisting of government and private sector staff responsible for the provision and/or management of key specialist services to the program, which is described in RESIS, 2004 (a). Furthermore, different task teams for example on water availability, sustainability and WUAs, have been established to assemble expertise by including various members involved in water management in South Africa (e.g. representatives of the Water Research Commission, DWAF, the University of Pretoria, private consultants, etc.).

1.3 Research objectives

Since 2001, smallholder irrigation schemes in South Africa (mainly Limpopo Province) have been thoroughly investigated by research teams of CIRAD, a French research organization[2] and the University of Pretoria (UP). These research projects have developed and used a *multi-disciplinary & action-research approach* to address economic and financial viability and

[2] CIRAD is a French research organization, specialized in cooperation on agriculture, animal sciences, forestry, food processing and development support for the developing countries (Perret and Touchain, 2002). CIRAD stands for "Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement".

overall sustainability of smallholder irrigation schemes experiencing and implicated in the IMT process.

In this context, the CIRAD & UP research objectives have developed and matured considerably over time. This valuable progress is presented below, by the prior research, complementary research and finally the current and latest research objectives, which are most relevant for the comprehension of this research document.

Prior research objectives

As described by Perret, 2004, the main objective of the *multi-disciplinary & action-research approach* is to help investigating the sustainability of smallholder irrigation schemes in a context of IMT and to accompany and support decisions and actions undertaken by development operators. The approach makes use of the SMILE tool, as a model and as a simulation platform. Through SMILE, the approach promotes collective solution seeking through scenario testing. In general and in this research document, the approach is mostly referred to as the "SMILE approach". Figure 1.2 shows the four different phases of the approach.

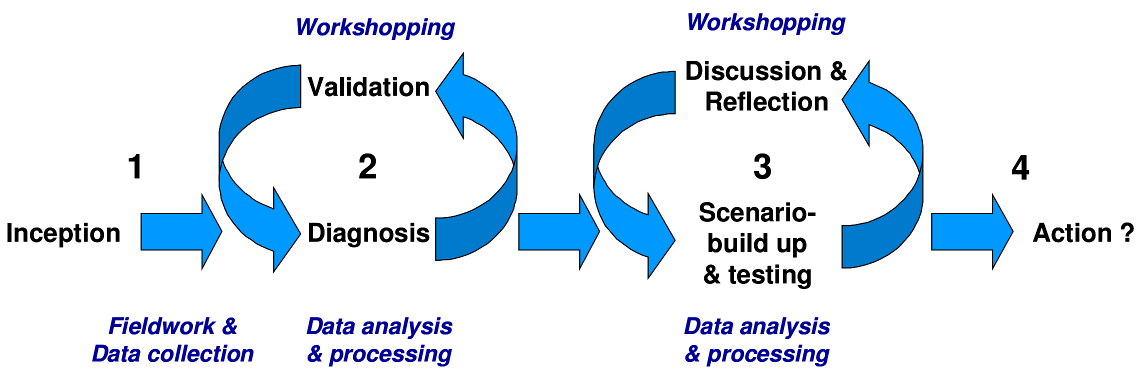


Figure 1.2 The SMILE approach: scheduling the action-research process (Perret, 2004)

As explained by Perret, 2004, the first phase consists of *fieldwork & data collection* at household and scheme level of one given scheme. In the second phase, information system development takes place through *data analysis & processing*, which requires typologies of crops and farmers. Finally, in the third phase SMILE is run on a scenario testing basis and the impact of certain measures or decisions, certain farmers' strategies on agricultural and production features, land allocation, costs and cost recovery and sustainability related indicators can be evaluated through further *data analysis and processing*. The fourth phase can be seen as a "reaction" to the outcomes of the SMILE approach, which imply *actions*, which address the concerns and other issues that have come forward in phases two and three.

Complementary research objectives

Since 2004, the RESIS program has shown great interest in using the SMILE approach for economic viability studies on smallholder irrigation schemes, which are to be revitalized. Consequently, the approach has identified additional and more specific objectives, which aim to inform the RESIS program through case study analysis and the set up and transfer of adapted methodologies and support their pre-revitalization surveys.

Current and latest research objectives

The objectives for current research, which recently took place (April – November 2004) and of which the results are presented in this document are actually a more detailed follow-up of the already developed objectives described above. However, a very important aspect had not been addressed sufficiently in the research performed until now: institutional analysis. More precisely, a clear methodological framework for institutional analysis had not yet been investigated and developed. Therefore, the main objective for this research is:

> Development of a **combined methodological approach**, which includes economic viability studies and institutional analysis.

In order to fulfill this main objective and former ongoing ones, this research was done on a case study basis. Therefore, the Mauluma irrigation scheme in the Limpopo Province was selected. More precisely, the objectives of this research can be defined as follows:

- Applying the SMILE approach to Mauluma to gain knowledge on the scheme's farming practices, water consumption and economic and financial viability;
- Use the SMILE approach as a vehicle for farmer participation and awareness;
- Update and test the online version of the SMILE database through case study analysis;
- Develop and test a methodological framework for institutional analysis complementary to the SMILE approach and applicable to further research;
- Apply the developed methodological framework to Mauluma to gain knowledge on individual farmer irrigation practices and strategies, on collective scheme maintenance activities and on existing regulations and institutions on water management at scheme level;
- Design and test a simplified and time saving SMILE approach, suitable, useful and sufficiently accurate to be included in the RESIS program; and
- Capacitate and facilitate RESIS representatives in performing and fulfilling simplified SMILE approach independently.

Looking at figure 1.2, it can be confirmed that this research only goes through the first loop of the process, fulfilling the first two phases. The *buildup and testing of scenarios* was not feasible in the scope of time available for this research. Furthermore, after reporting back and validating the SMILE results in phase two, it could be concluded that drafting up scenarios with the Mauluma scheme members would have been premature and irrelevant at this stage, which is discussed in greater detail in chapters 4 and 6.

1.4 Report outline

Chapter 2 describes the methodological framework used for analysis in this research. As the research objectives concern both economic and financial viability and institutional analysis, the framework consists of two approaches: the SMILE approach and the IADF approach. The Ostrom "8 design principles" for efficient and sustainable irrigation schemes are added to the IADF approach. Together these approaches form a *combined methodology* for the analysis performed in this research.

Chapter 3 gives general and background information on the Mauluma irrigation scheme, the case study of this research. Therefore, the integration of Mauluma in the revitalization programs of the Limpopo Department of Agriculture is highlighted. This is followed by a brief history on the former Venda region, where Mauluma is located. Furthermore, background information on the Nzhelele irrigation scheme cluster, Mauluma's hydraulic characteristics, history, farmers and water is given.

Chapter 4 presents the fieldwork and analysis results obtained from the SMILE approach applied to Mauluma. Therefore, the cultivated crops, crop management styles, farmer typologies and the results on economics and water at crop, farmer and scheme level for Mauluma are discussed. The chapter ends with some conclusions and recommendations for the scheme.

Chapter 5 gives the fieldwork and analysis results obtained from the IADF approach applied to Mauluma. Hence, the action arena, patterns of interaction and actor behavior, three levels of rules and Ostrom's "8 design principles" are discussed for the scheme. This chapter also ends with some conclusions and recommendations for Mauluma.

Chapter 6 ends with conclusions and discussion on the application of the methodologies addressed in this research. First, the application of the SMILE approach and methodology is discussed by addressing the interests and limitations for both RESIS and future research. This is followed by a short interlude on the application of a simplified SMILE approach for RESIS on the Morgan irrigation scheme. Here, results and future use of the simplified approach are discussed. Thereafter, the application of the IADF approach and methodology is also discussed through interest and limitations for RESIS and future research. The chapter ends with final general conclusions and recommendations and some reflections on the *combined methodology for analysis* forthcoming from this research.

2 METHODOLOGICAL FRAMEWORK FOR ANALYSIS

In this chapter a methodological framework for the analysis of financial/economic viability and institutional sustainability and strength of smallholder irrigation schemes is described. To cover both aspects, two approaches – the SMILE simulation platform based approach (paragraph 2.1) and the Institutional Analysis and Development Framework (IADF) methodological approach (paragraph 2.2) – are used for this framework and combined with Ostrom's "8 design principles" for analyzing the sustainability and self-management of an irrigation scheme (paragraph 2.3). These approaches joint together form a *combined methodology for analysis*, which is introduced in paragraph 2.4. This methodology is used for the Mauluma case study of this report and could be applicable to any other smallholder irrigation scheme in the Limpopo Province or in other provinces of South Africa or even elsewhere. The research and analysis results of this combined methodology are presented in chapters 4 and 5.

2.1 The SMILE simulation platform based approach

As explained on the Internet website www.smile-cirad.co.za, SMILE stands for *Sustainable Management of Irrigated Lands and Environment*. This model helps to assess the financial/economic viability and the operation and management features of smallholder irrigation schemes. It also provides several sustainability indicators. From the Internet it can be run on a case study basis. SMILE, also referred to as a simulation platform, is in the first place a data capturing and in the second place a calculation tool. The model first helps developing a database and then it can be used for scenario testing on the specific case study. SMILE was first developed in 2001 and the latest version accessible on the Internet has been updated in November 2004. Refinement and adjustments are still ongoing.

Prior to the Internet version, SMILE has been developed and used on spreadsheet basis in different CIRAD & UP research projects for a number of South African smallholder irrigation schemes in the Limpopo Province. Examples are the schemes of *Dingleydale-New Forest* (Perret and Touchain, 2002 and Lavigne and Stirer, 2003), *Mphaila & Mphepho* (Challet, 2002) *Thabina* (Perret *et al.*, 2003 and Lavigne and Stirer, 2003) and *Zanyokwe* (Ntsonto, 2004).

2.1.1 Conceptual framework of SMILE

Among other aspects, Le Gal *et al.*, 2003 discuss the need for implementing water-pricing systems to ensure sustainability and efficient water use of self-governing irrigation schemes in various countries over the world. Hereby they argument these systems should enhance water cost recovery and encourage farmers to adopt more efficient behavior. Le Gal *et al.*, 2003 explain that choosing a relevant water charge system is not easy, as different factors need to be taken into account although they can be contradicting (i.e. main objectives scheme manager, farmers' incentives to be implemented and farmers ability to pay). Furthermore, such a choice also calls for detailed information at several levels of the scheme: assessment of the costs over various time-scales (e.g. long-term maintenance), assessment of farmers' incomes and evolution of their water demand with a different water charge.

Le Gal *et al.*, 2003 argue that it is crucial for decision support to provide a clear and logical framework to enable stakeholders to negotiate on a more objective basis. Therefore, modeling and simulation of virtual scenarios are useful tools to achieve this, as they make it possible to look at a large range of potential solutions and to assess their effects on indicators such as the recovery rate of the water charge, farmers' incomes or the recovery of water costs (Le Gal *et al.*, 2003 quoting Geus, 1992). As a result the simulation tool SMILE was developed to address the choice of a water charge system. SMILE is based on three main concept components (Le Gal *et al.,* 2002): (a) the *water costs module* or manager's cost function, (b) the *farmers' income module* or farmers' cost function and (c) the *water charge module* or definition. These components are represented in the conceptual framework shown in figure 2.1. Furthermore, these components are also reflected in the more detailed and developed SMILE conceptual framework in figure 2.2 and are also explained in more detail and referred to in the SMILE users' guide in appendix 2 A. The complete background of this conceptual framework, which focuses on the operation of an irrigation scheme, can be found in Le Gal, 2001. The schematic representation of this framework is presented in appendix 2 B.

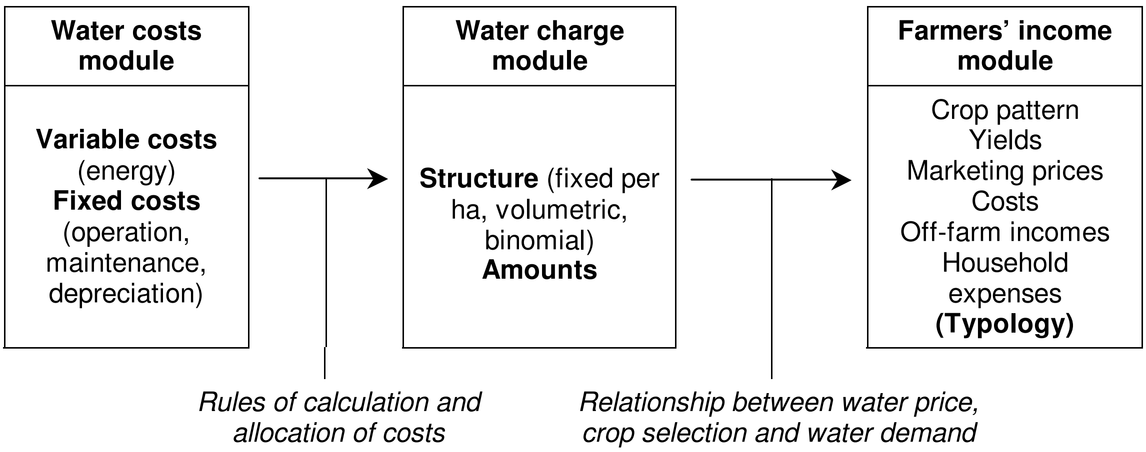


Figure 2.1 Conceptual basis and framework of SMILE (Le Gal et al., 2003)

2.1.2 The three stages of SMILE

The SMILE approach implies three phases (Perret and Touchain, 2002):

1. Data collection on *socio-economic and technical circumstances at household level* including:
   - Literature review on infrastructures, crops, farming systems, markets, local institutions, etc.;
   - Field visits and field work; and
   - Farmers' (and operators') interviews: *household survey* through results of prepared questionnaires including on household composition, land tenure, cropping system, farm expenditures/production costs, crop calendar, livestock description, finances, and occasionally on scheme and water users association (WUA) management. This data is recorded in SMILE questionnaires (an example questionnaire used for this research is presented in appendix 2 C).

2. Data processing and model development through *setting up the SMILE database*, which will be able to evaluate costs regarding scheme management and cost recovery. However, before running SMILE a typology of farmers' strategies and practices needs to be developed (see paragraph 2.1.3);

3. Running the model on a *scenario-testing basis*, which will help to evaluate the impact of certain farmers' strategies and practices on production, land allocation, costs and cost recovery, etc.

The application of the SMILE approach is actually based on *intervention-research*, which is a form of *action-research* specialized in management issues, with a strong emphasis on the direct intervention of research operators (Perret *et al.,* 2003). This kind of methodology provides facilitation of collective learning and negotiated agreement, as defined by Perret and Touchain, 2002, quoting Liu (1994), which can support local development. It means the researcher is actually involved in a common work with the individual and collective stakeholders. However, it is essential to implement the participation of stakeholders, not only while collecting data but also during recurrent, interactive workshops dealing with information sharing, discussions about scenarios (phase 3), solution seeking, etc. (Perret and Touchain, 2002). All together, this methodology represents an iterative learning process for both researcher and stakeholder and will result in a joint construction of the SMILE database and representation of the scheme (Perret *et al.,* 2003).

2.1.3 Farmers' strategies identified by a typology of farmers

As described in Perret and Touchain, 2002, quoting Sardan, 1995 a strategy can be defined as the combination of processes (plans, decisions and acts) that individuals or groups of individuals develop purposively to change their social, economic and/or physical environment. These processes combine resources and/or techniques, knowledge and know-how. Furthermore, Perret and Touchain, 2002, quoting Yung, 1998, add that farmers develop strategies as responses to a changing and uncertain environment, in order for them to reach a given life style that corresponds to an objective. The crops, crop management sequences, cropping systems, farming systems, etc. that the farmers combine and mobilize reflect such strategies.

Perret and Touchain, 2002 explain that within and irrigation scheme, diverse strategies may develop, depending on each household's history, composition, objectives, etc. Lavigne and Stirer, 2003, quoting Perret, 1999, also mention that in fact it can be supposed that there are as many strategies as farmers. However, it is difficult to consider each and every strategy, but also inappropriate to consider the scheme as homogeneous. Therefore, a typology that groups farmers with similar strategies and characteristics, with regard to a given objective could be an alternative and more workable compromise. Such a typology helps to analyze the scheme as a heterogeneous whole, which needs to be used in SMILE.

2.1.4 The six input modules for simulation in SMILE

As explained by Perret *et al.,* 2003, SMILE consists of six input modules, which are based on the concepts described in paragraph 2.1.1. These modules form the basis of the information system as interfaces for data capturing and simulation by the user (see SMILE user's guide summarized in appendix 2 A and www.smile-cirad.co.za) and are presented in the SMILE conceptual framework (Perret *et al.*, 2003) in figure 2.2, consisting of:

1. *Scheme module*, containing general information on the scheme (not shown in figure 2.2);
2. *Costs module*, containing figures on maintenance and operation costs of the scheme;
3. *Crops module*, enclosing economic, agronomic and water related figures on the scheme's different cropping systems;

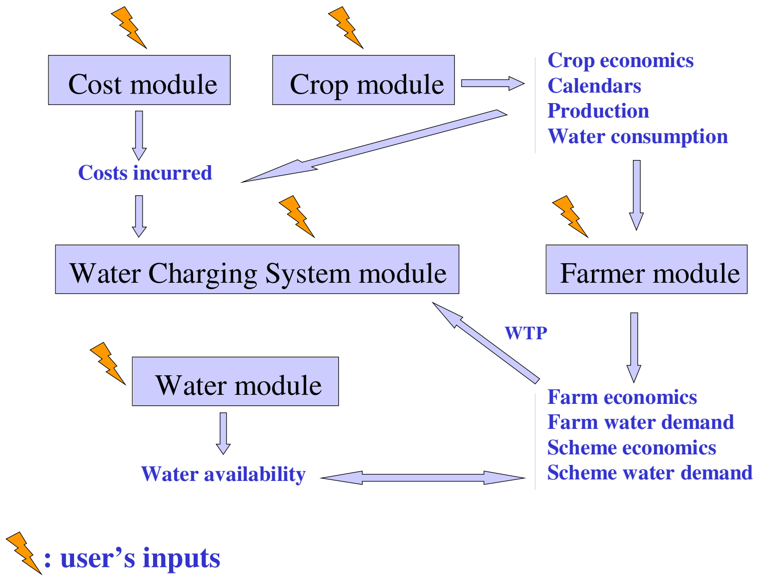


Figure 2.2 The SMILE structure and framework (Perret et al., 2003)

4. *Farming systems module*; holding information on existing farm types within the scheme;
5. *Water balance module*, containing all information water demand and water consumption of the scheme; and
6. *Water charging system module*, showing all information related to cost recovery of the scheme.

The initial inputs for these modules form the *base scenario*, which supposes to reflect the current situation of the scheme. Additional scenarios may be tested through capturing non-real/prospective data (i.e. alternative crops and cropping systems, emerging farmer types, changes in scheme management patterns, etc.). Appendix 2 A gives a more detailed explanation of each module and a summary of the SMILE users' guide, available on the Internet and thoroughly describing how the modules are used and applied in the SMILE database.

2.2 The IADF methodological based approach

The SMILE approach alone gives a good basic insight on the current situation of the analyzed irrigation scheme, but purely on technical farming and economical/financial aspects. To be able to say something more about such a scheme regarding its management, efficiency and sustainability, it is necessary to complement the SMILE approach with some form of institutional analysis. The *Institutional Analysis and Development (IAD) Framework* developed by Elinor Ostrom and her colleagues can be used as a methodological approach for this purpose.

Firstly, paragraph 2.2.1 discusses the meaning of *ecosystem-based management*, seeing that the IAD Framework is applied to examine institutional arrangements (i.e. irrigation scheme management committees and water users' associations), which are introduced to implement *ecosystem-based management programs*. Afterwards, in paragraph 2.2.2 it is explained why the IAD Framework is suitable for such institutional analysis. Finally, the methodological approach of the IAD Framework is described in paragraph 2.2.3.

2.2.1 Ecosystem-based management and institutional analysis

As described in the review by Imperial, 1999, during the last 25 years, there is a better understanding of the cause-and-effect relationships underlying many environmental problems as well as the interrelated nature of these problems. Accordingly, there is greater recognition that a system of interrelated problems should be managed as a system (or ecosystem) instead of as a series of isolated problems. This has taken root by the shift away from managing individual resources to the broader perspective of ecosystems and the use of *collaborative decision making*. This ensures that values as *equity* and *justice* are considered in the same way as *efficiency* into environmental decision making.

However, Imperial, 1999 explains that although these concepts of *ecosystem-based management* and *collaborative decision making* may lead to improved management of natural resources, they are subject to a wide range of institutional and administrative challenges. Furthermore, they can create various potential coordination problems and create opportunities for conflict. Imperial, 1999, quoting Grumbine, 1994 and Slocombe 1993 stresses that when addressing problems associated with changing organizational arrangements and incorporating human values into decision-making processes, it is crucial not to ignore such institutional and administrative issues.

The need for an explicit theoretical framework and methodological approach

The ecosystem-based approach, although relatively new and still evolving, has been used in a variety of research settings to address a wide range of resource management problems. The review by Imperial, 1999 explains that much of this research argues that the use of collaborative decision making, strong public participation and a focus on incorporating scientific findings into decision making appear to enhance program success. However, Imperial, 1999 underlines that the major weakness of these studies is that an *explicit theoretical framework* is rarely used to examine questions related to institutional design and performance.

Furthermore, Imperial 1999 clarifies in his review, that from an institutional perspective, ecosystem-based management can be seen as an explicit attempt to build, manage and maintain inter-organizational networks, which can be seen as the development of an institutional ecosystem. However, there is no consensus on definitions, concepts or on the methodological approach to studying the structure of inter-organizational networks. It is unclear how networks influence the behavior of actors within a network and how one "manages" or changes an inter-organizational network. Moreover, it is unclear how one measures the performance or success of implementation in networked settings

2.2.2 A promising approach to institutional analysis: The IAD Framework

In his review, Imperial, 1999 considers the *Institutional Analysis and Development (IAD) Framework* developed by Elinor Ostrom and her colleagues as a promising methodological approach to institutional analysis, paying closer attention to the important unanswered questions surrounding institutional design and performance of an institutional arrangement (see paragraph 2.2.1) and which improves the understanding of the relationship between science and human values in decision. This approach can be used to examine institutional arrangements and inter-organizational networks used to implement ecosystem-based management programs[3] (such as management programs of smallholder irrigation schemes).

Institutions and institutional analysis

Imperial, 1999 explains that the IAD Framework of Crawford and Ostrom, 1995 defines *institutions* as "enduring regularities of human action in frequently occurring or repetitive situations structured by rules, norms and shared strategies as well as by the realities of the physical and biological world. The rules, norms and shared strategies are constituted and reconstituted by human interaction in frequently repetitive situations." Furthermore, Imperial, 1999 quotes Firmin-Sellers, 1995 who discusses that institutional arrangements also promote socially beneficial outcomes by helping actors resolve "social dilemmas", which result when individually rational actions aggregate to produce socially irrational outcomes.

According to Imperial, 1999 quoting Ostrom, 1986 the IAD Framework differentiates *institutional analysis* from other forms of organizational analysis by focusing on formal and

[3] Management of smallholder irrigation schemes can be seen as an *ecosystem-based management program* as the scheme seeks for improved management of natural resources and are subject to a wide range of institutional and administrative challenges (as defined in the review by Imperial, 1999).

informal rules, which are an implicit or explicit attempt to achieve order and predictability among humans. In his review, Imperial, 1999 adds that both formal and informal rules are formulated in human language and subject to problems of lack of clarity, misunderstanding and varied interpretations. Thus the stability of rule-ordered relationships depends upon the development of shared meaning of rules, which requires building trust and monitoring and enforcing rules (Imperial, 1999, quoting Ostrom, *et al.*, 1994).

Imperial, 1999 summarizes in his review, the meaning of institutional analysis in the IAD Framework by quoting Ostrom, 1990:

"Institutional analysis is therefore an attempt to examine a problem that a group of individuals (or organizations) face and how the rules they adopt address a problem. This requires understanding something about the nature of the problems, the nature of the individuals (culture) and the institutional setting that the individuals are embedded within."

2.2.3 Methodological approach: using the IAD Framework

Below, the methodological approach for institutional analysis in accordance with the IAD Framework of Ostrom, *et al.*, 1994 discussed by Imperial, 1999 is described on a step-by-step basis (frames 2.1, 2.2 and 2.3). The conceptual framework for this institutional analysis is illustrated in figure 2.3.

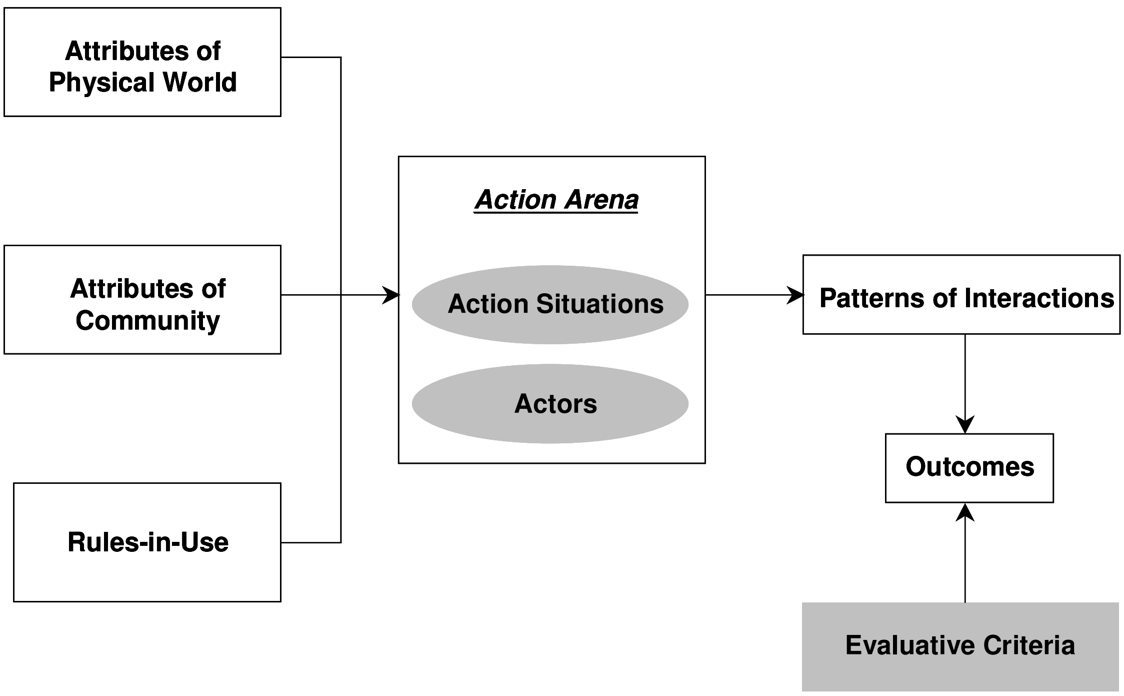


Figure 2.3 A framework for institutional analysis (Ostrom, et al., 1994)

Action arena

The main conceptual unit of analysis in the IAD Framework is an "action arena" (see figure 2.3). This term includes those individuals and organizations that make resource management decisions based upon information about how actions are linked to possible outcomes and the different costs and benefits attached to actions and outcomes. In other words, the action arena can be seen as a mix of actors (individuals or organizations), which interact and make decision that impact the "health" of an ecosystem.

Frame 2.1 Step 1 of IAD Framework

I. The **first step** in institutional analysis is to identify the *action arena* and its set of *actors* within a specific or several *action situations*.

Besides de *actor* component, action arenas also include an *action situation* component. The action situation component, refers to the social space where individuals interact, exchange goods and services, engage in appropriation and provision activities, solve problems, or fight. Seven clusters of variables characterize this component: (1) participants, (2) positions, (3) actions, (4) potential outcomes, (5) a function that maps actions into realized outcomes, (6) information, and (7) the costs and benefits assigned to actions and outcomes.

Patterns of interaction

Each of the seven variables, mentioned above and thus the action arena is constituted and affected by combinations of the following attributes:

- Underlying physical and biological settings, which vary and impose important constraints on the development of rules;
- Attributes of the community/nature of the community ("culture") within which the arena occurs and actors are located; and
- Explicit and implicit assumptions about the rules[4] used to order relationships between individuals or organizations.

Furthermore, these attributes also influence the next conceptual unit "patterns of interaction", which characterizes the action arena and generates specific outcomes. This influence on both conceptual units is also shown in figure 2.3.

The conceptual unit "patterns of interaction" also includes the *individual pattern of behavior* of a specific actor, as this behavior influences the pattern of joint results that may be produced (outcomes). This leads back to the *actor component* of the action arena, referring to the participants in an action situation. To predict how actors (individual or group functioning as a corporate actor) will behave, four clusters of variables must be taken into account: (1) individual preferences, (2) individual information-processing capabilities, (3) individual selection criteria and (4) individual resources.

[4] According to Imperial, 1999 quoting Ostrom, *et al.*, 1994 a rule is a prescription that forbids, permits or requires some action or outcome and the sanctions associated with failing to follow a rule. They can be formal (i.e. laws, policies, regulations, etc.) or informal (i.e. behavioural norms). In other words, a rule is an institution.

Frame 2.2 Steps 2 & 3 of IAD Framework (Imperial, 1999 and Ostrom, et al., 1994)

II. The **second step** in institutional analysis is to identify the *pattern of interactions* among individuals and organizations in the action arena by:

- Analyzing how the institutional arrangement allows participants to develop, monitor, enforce and alter rules in response to changes in environmental conditions;
- Analyzing "culture", i.e. generally accepted norms of behavior, homogeneity of individual preferences, distribution of resources among members of an action arena, etc.; and
- Identifying and understanding the rules and the rule-system structure that individuals refer to when asked to explain and justify their interactions with fellow participants in an action arena (rules-in-use).

III. The **third step** in institutional analysis is to analyze or predict the *behavior* of an actor by analyzing:

- The preference evaluations that actors assign to potential actions and outcomes;
- The way actors acquire, process, retain and use knowledge contingencies and information;
- The selection criteria actors use for deciding upon a particular course of action; and
- The resources that an actor brings to a situation.

Multiple levels of analysis: three levels of rules

Another feature of the IAD Framework is that it recognizes that action arenas are linked across different levels of analysis. According to Imperial, 1999, quoting Kiser and Ostrom, 1982 rules are often nested in another set of rules that define how the first set of rules can be changed. This interconnectedness has important implications, as it means that in order to understand the rule and rule-system structure of an ecosystem and how an ecosystem is "managed", it is important to identify how the various formal and informal rules interact with one another.

The IAD Framework distinguishes between three levels of rules that cumulatively affect the action and outcomes obtained in any setting (Imperial, 1999, quoting Kiser and Ostrom, 1982, Ostrom, 1990 and Ostrom *et al.*, 1994), which is illustrated in figure 2.4. The three levels of rules are:

1. *Operational rules*, include decisions about when, where and how to do something: who should monitor the actions of others, how actions should be monitored, what information should be exchanged or withheld and what rewards and sanctions will be assigned to combinations of actions and outcomes;

2. *Collective-choice rules*, influence operational activities and outcomes by determining how operational rules can be changed and who can participate in these decisions; and

3. *Constitutional-choice rules* also influence operational rules and outcomes by determining who is eligible to participate and the rules used to develop and change collective-choice rules.

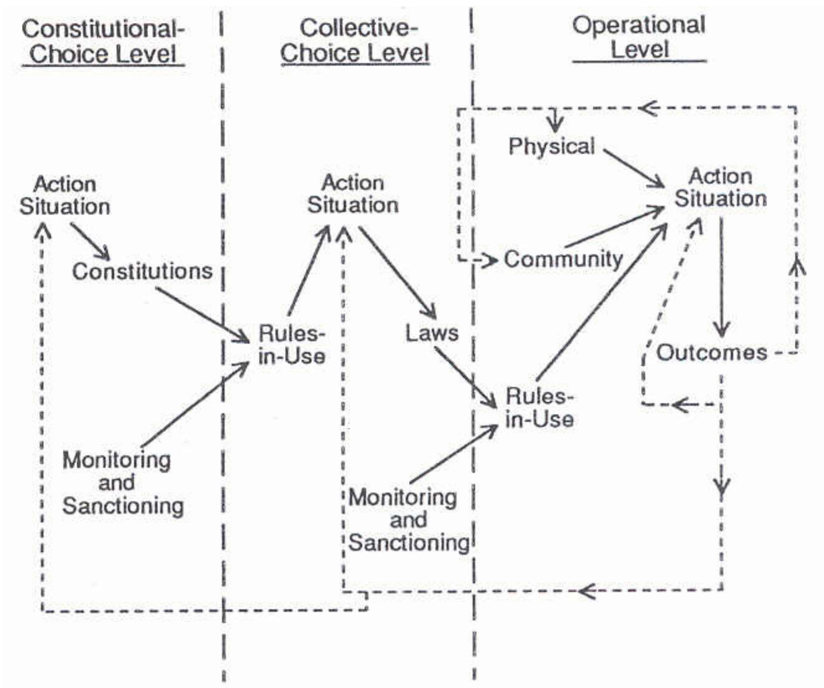


Figure 2.4 Linking levels of analysis through three levels of rules (Ostrom, et al., 1994)

Frame 2.3 Step 4 of IAD Framework (Ostrom, et al., 1994)

IV. The **fourth step** in institutional analysis is to analyze the three levels of rules in the action arena:

- Identify the operational rules, which directly affect day-to-day decisions made by the participants in any setting (i.e. processes of appropriation, provision, monitoring and enforcement);
- Identify who can participate in altering operational rules (i.e. policy making, management and the adjudication of decisions) and how this is accomplished; and
- Identify who is eligible to participate in developing and altering collective-choice rules (i.e. governance and modification of constitutional decisions and collective-choice rules).

In his review, Imperial, 1999 concludes that ecosystem-based management is as much a problem of "governance" involving multiple organizations located at different levels of government, as it is a question of science and designing effective policies for managing natural resources. Therefore, Imperial, 1999 emphasizes the importance of *institutional* and *interorganizational management* questions, as addressed in the IAD Framework, when performing programs based on the principles of *ecosystem-based management* and *collaborative decision making*.

2.3 Ostrom's eight efficiency and sustainability principles

After having discussed both the SMILE and the IADF approaches, Ostrom's "8 design principles" for sustainable irrigation institutions complement very well the theoretical/conceptual framework for analyzing the economic/financial viability and institutional strength of smallholder irrigation schemes described in this chapter.

According to Ostrom, 1993 the most important question related to water resource development and management is that of *institutional design* rather than engineering design. Ostrom, 1993 explains this through "crafting institutions", referring to an ongoing process that is enhanced when both the users and the suppliers of irrigation water are involved in the design process. Crafting institutions related to the supply and use of irrigation systems require skills in understanding how rules, combined with particular physical, economic and cultural environments, produce incentives and outcomes. To obtain this, requires considerable investment of time and resources in learning more about the effects of various institutional rules on the behavior of participants and the results they can achieve. In other words, one needs to think about the choice of institutions as an ongoing investment process in an uncertain environment (Ostrom, 1993). How "crafting institutions" is taking place in South Africa is briefly pointed out in frame 2.4.

Frame 2.4 "Crafting institutions" in South Africa

In South Africa **crafting institutions** has been introduced through the IMT process and the new National Water Act. As a result, the implementation of CMAs and WUAs is one of the government's main objectives in the process and development of sustainable and efficient water management in the country. This issue is addressed in more detail in paragraph 1.1.

Ostrom's theory can help to analyze if certain irrigation systems and their institutions can be successful in sustaining the physical works and in gaining the compliance of generations of users to the rules in use. This can be done by reviewing Ostrom's core "design principles" identified in prior research as characterizing long-enduring (irrigation system in operation for at least several generations), self-organized irrigation systems/institutions throughout the world. In other words, these principles can be used as "evaluative criteria" (see figure 2.3) in institutional analysis. Ostrom, 1993 expresses that even though it is impossible to evaluate the efficiency of these systems precisely, the repeated willingness of users to invest large amounts of labor and other resources, is strong evidence that individual farmers receive more benefits from these systems than the costs they assume for maintaining them.

The eight Ostrom principles (or evaluative criteria) for sustainable and efficient irrigation institutions are:

1. *Clearly defined boundaries*
   This is a foundation for collective action and the presence of boundaries distinguishes "common property" institutions from "open access" institutions. In addition to closing the boundaries, rules limiting use and/or mandating provision are needed whenever water scarcity is present.

2. *Proportional equivalence between benefit and costs*
   Adding well-tailored appropriation and provision rules to boundary rules helps to account for the sustenance of irrigation systems themselves. Those who receive the highest proportion of water are also required to pay the highest proportion of the costs (fiscal equivalence).

3. *Collective-choice arrangements*
   Individuals who directly interact with one another and with the physical world can modify their rules over time so as to better fit them to the specific characteristic of their setting; user participation in collective choice. This should enhance effective operating rules, as long as the costs of changing these rules are relatively low.

4. *Monitoring*
   Usually, no external authority has sufficient presence to play any role in the day-to-day enforcement of rules. However, irrigators who make substantial investments in monitoring and sanctioning activities themselves, achieve compliance to rules. Monitoring can also work as a natural by-product (water rotation systems).

5. *Graduated sanctions*
   The participants themselves, who are accountable to all users, undertake monitoring and sanctioning (active audit of physical conditions and irrigator behavior). Individuals willingly comply to provide a collective benefit by contributing resources, as long as they are confident that others are cooperating and joint benefits are being provided. In many instances, irrigators create their own internal enforcement to a.) deter those who are tempted to break rules and thereby b.) assure quasi-voluntary compliers that others also comply.

6. *Conflict resolution mechanisms*
   If individuals are going to follow rules over a long period of time, some mechanisms for discussing and resolving what is or is not a rule infraction, is necessary to the continuance of rule conformance itself. In many irrigation systems, conflict resolution mechanisms are informal and those who are selected as leaders are also the ones responsible of resolving conflicts.

7. *Minimal recognition of rights to organize*
   Many water-user groups organize in a de facto manner but are not recognized by national governments as legitimate forms of organization. Without official recognition of the right to organize, it is quite difficult to hold either user-group officials or members accountable

for their actions. An effective irrigator organization lacking formal recognition may crumble rapidly when its authority to make legitimate rules for its own members is challenged and not supported by the formal government of a regime.

8. *Nested enterprises*
   By nesting layers of organizations or the fusion or amalgamation of different levels of organization with different roles within one another, irrigators can take advantage of many different scales of organization. By utilizing more than a single scale of organization, many farmer-managed irrigation systems have sustained large-scale irrigation systems for long periods of time relying primarily on their own resources without extensive help from external agencies.

Even though, these design principles are good ways to create successful and sustainable irrigation systems and institutions, Ostrom, 1993 concludes with one last remark:

"The proportion of successful self-organized systems can be greatly increased by the investment of central governments in general institutional facilities that enhance the capabilities of those directly involved to learn new ways of governing and managing their systems, to create enforceable rules and to sanction behavior contrary to these rules."

2.4 Combined methodology for research analysis

In conclusion, the combination of the SMILE and IADF approaches presented in this chapter, form a methodology for analysis, wherein both aspects regarding agronomy and economics of irrigation schemes and institutional strength and water management are addressed. This *combined methodology* forms a most suitable framework for the continuation of CIRAD & UP research that has been ongoing in South Africa. Furthermore, these approaches provide a generally applicable methodology, which is suitable for any other research projects on irrigation schemes in South Africa and elsewhere. As described in chapter 1, as a first "trial and investigation" of this combined methodological framework, the Mauluma case study was selected. The following chapters will go more into detail in the chosen irrigation scheme, the application of the SMILE and IADF approaches and present and discuss the results.

3 RESEARCH CASE STUDY: MAULUMA IRRIGATION SCHEME

This chapter presents general and background information on the case study of this research: the Mauluma irrigation scheme in the Limpopo Province. Therefore, firstly in paragraph 3.1 some background information on how Mauluma was included in the rehabilitation and revitalization programs (WCP and RESIS) initiated by the Limpopo Department of Agriculture (LDA) is given. Paragraph 3.2 gives a brief history on the former "homeland" Venda, where Mauluma is located. Thereafter, in paragraph 3.3 the cluster of 13 smallholder irrigation schemes of the Nzhelele Valley, of which Mauluma is one, is presented. Paragraph 3.4 provides general and some hydraulic information on the scheme, its history, its farmers and the scheme's water scheduling system. Finally, in paragraph 3.5 the main arguments for choosing the Mauluma scheme for this research are given.

3.1 Mauluma under WCP and RESIS

Paragraph 1.2 explains how and with which objectives the LDA has initiated rehabilitation and revitalization programs in the Limpopo Province. After having done rehabilitation work in three pilot schemes, the Water Care Program (WCP) was launched in 2000. As described in LDA, 2002 (a), a next group of schemes was included under this program: Dingleydale and New Forest at Bushbuckridge (Eastern district), Metz and Madeira near Afcolaco (Eastern district) and Capes Thorn near Louis Trichardt (Vhembe district). In January 2002, a second phase of the Water Care Program started with the Nzhelele Cluster (13 schemes in the Nzhelele Valley), Matsika and Makuleke (Vhembe district), Homu near Giyani (Mopani district) and Tswelopele (Sekhekune district). Figure 3.1 shows a map of the Limpopo Province, with the main towns to give an idea of the location of these schemes. Appendix 3 A shows a district and population density map of the Limpopo Province.

Figure 3.1 Map of the Limpopo Province, with main towns (Mouse HTS Map, 1998)

RESIS Program and Mauluma

As explained by LDA, 2002 (b), in September 2002, a Master Plan for the expansion of the revitalization program to include all viable smallholder irrigation schemes in the Limpopo Province was prepared. As a result a new Business Plan evolved under the name "Revitalization of Smallholder Irrigation Schemes" (RESIS), which has been discussed more thoroughly in paragraph 1.2. The case study of this research, Mauluma irrigation scheme, was formerly included in the second phase of the Water Care Program, but as this program was completed at the end of 2003, all "pending" schemes were reincorporated into the RESIS program. Revitalization programs last for a period of approximately four years per scheme and as Mauluma has been involved for two years in the Water Care Program, the scheme still has two years to go with RESIS.

3.2 Brief history Venda, a former homeland

As presented by Lahiff, 1997, the former "homeland" or "Bantustan" of Venda is situated in the northeastern corner of the Limpopo Province, see figure 3.2, which also shows the Gazankulu, Lebowa, S. Ndebele and Kangwane homelands. Homelands were created under the apartheid period (1948-1994) as being the traditional "tribal" areas to which all members of the Black population (representing 76 % of the population) were allocated and where the Black population would have "rights" which they were denied in "white" South Africa (Berry, 1996). In 1979, Venda was declared to be the "homeland" of all speakers of the Venda language (Lu Venda or tshi Venda) and consisted of two separate territories, completely surrounded by South Africa. Venda was nominally "independent" but was not recognized by any other country in the world (except Israel). On the 27th of April 1994, Venda as all other nine homeland/Bantustans areas ceased to exist and was reincorporated into the Republic of South Africa. Its administration was absorbed into the new provincial structure and formed part of the new Northern Province (now: Limpopo Province). Today, Venda has no administrative significance.

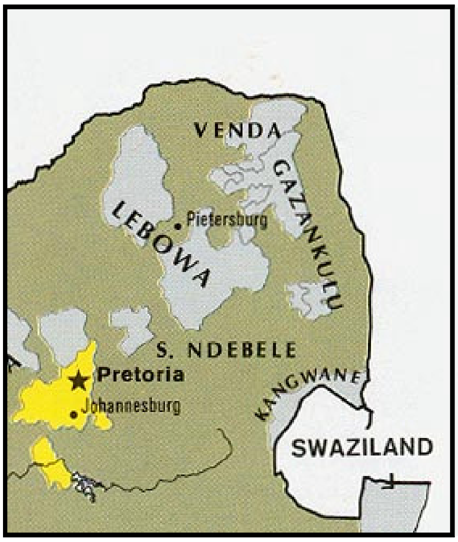


Figure 3.2 The former Venda "homeland" (US-CIA)

The ancestors of the Venda people (Vha Venda or Ba Venda) are said to have migrated from the north, such as areas like the Great Lakes area of East Africa (Lahiff, 1997). After having stayed amongst the Karanga of Zimbabwe for some time, they are believed to have crossed the Limpopo River and dominated the inhabitants of the Soutpansberg in northern South Africa towards the end of the 17th century (Lahiff, 1997 quoting Warmelo van, 1940 and Lestrade, 1932).

The main town and capital of former homeland, Venda is Thohoyandou. However, Venda depends for much of its services on the towns of Makhado (Louis Trichardt) and Mussina (Messina) and to a lesser extent, the provincial capital of Polokwane (Pietersburg) (see figure

3.1). Compared to the adjoining "white" areas of South Africa, Venda can be described as underdeveloped in terms of infrastructure, economic activity, health, welfare and education services and general standards of living (Lahiff, 1997)

Venda covers approximately 680,700 ha (6,807 km^2) (Lahiff, 1997 quoting Development Bank of Southern Africa 1991). For administrative purposes, the Venda territory was divided into four magisterial districts; Dzanani (north-west), Mutale (north-east), Thohoyandou (centre and south-east) and Vuwani (south-west). According to the 1991 Census, the population of Venda was 558,797.

3.3 The Nzhelele scheme cluster

To the northeast of Makhado and the Soutpansberg Mountains, intersected by the R 523 lies the Nzhelele Valley. In this valley the Nzhelele schemes – a cluster of 13 smallholder irrigation schemes – are located (761 ha), which all receive water for irrigation from the Nzhelele River or its tributaries (LDA, 2002 (a)). Figure 3.3 gives a schematic overview of the location of the 13 schemes in the valley. All schemes, except for one (Mphaila) use flood furrow irrigation. The 13 schemes are divided into southern and northern (from the Nzhelele River) schemes (see tables 3.1 and 3.2) and are described below. Only the Ralipaswa scheme is located to the south of the Nzhelele River and is considered as a northern scheme, as it is interconnected to two other northern schemes (see below).

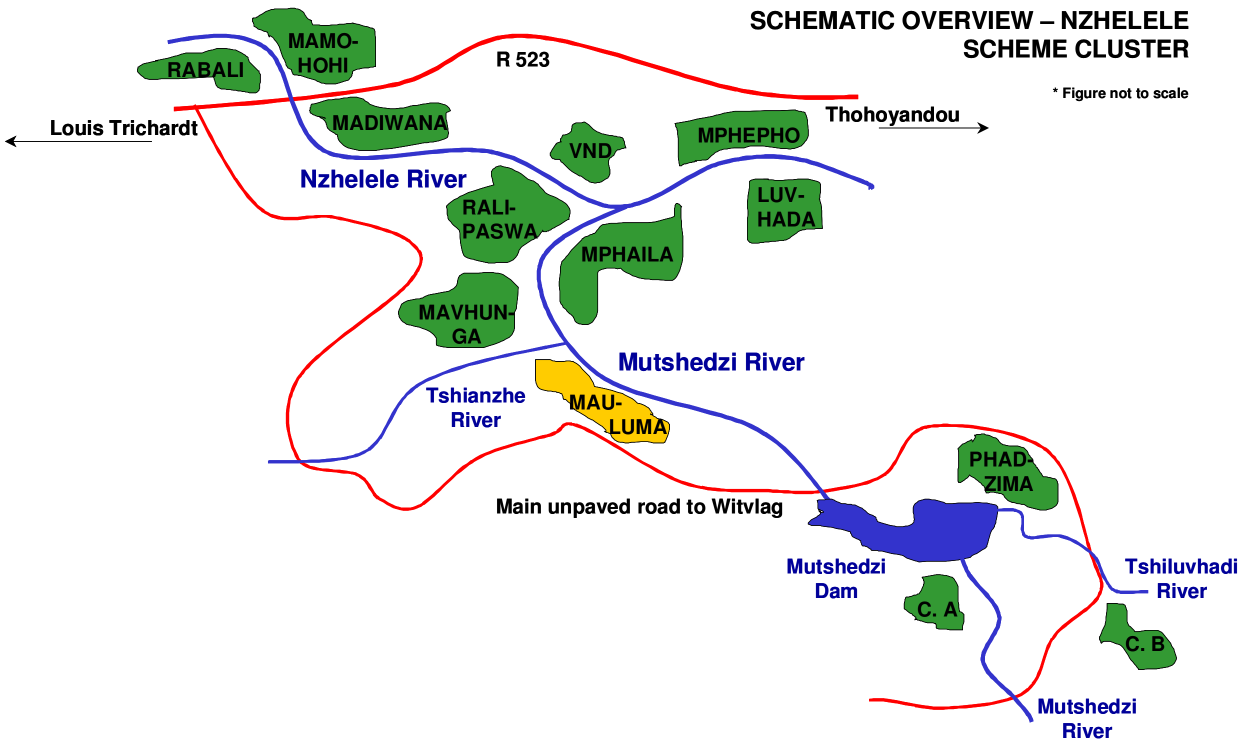


Figure 3.3 The Nzhelele Valley and the Nzhelele Scheme Cluster

Southern schemes

The southern schemes can be divided into three groups: (a) Cordon A, Cordon B and Phadzima, (b) Mavhunga and Mauluma and (c) Mphaila and Luvuhada. Each group has a general management committee but each scheme also has their own scheme committee. Furthermore, each group shares one extension officer.

Table 3.1 Southern schemes in the Nzhelele Valley (LDA, 2002 (a))

SOUTHERN SCHEMES

Scheme name	Number of farmers*	Approximate surface [ha]
Mphaila	70	72
Luvuhada	79	28
Mauluma (Beaconsfield)	29	29
Mavhunga (Diepkloof)	31	39
Phadzima (Mpzema)	64	82
Cordon A	13	73 (Cordon A & B)
Cordon B	36	73 (Cordon A & B)

** In each scheme there are also non-registered farmers, the so-called rejected land farmers (see paragraph 3.4.3), who are not included this table.*

Cordon A, the smallest and most upstream scheme of the Nzhelele cluster receives plenty of water from a weir in the Mutshedzi River (which according to the farmers has a high discharge, even in the dry season). From the weir water is piped and after led into the main canal of the scheme. There is a night storage dam, which is still leaking but is being repaired.

Cordon B and Phadzima, unlike Cordon A, receive water from the Tshiluvhadi River, which is a semi-perennial river (thus dry from October-November). There is a weir in the river from where water is directly led to Cordon B during the day. During the night water is led to the night storage dam located in Cordon B, but serving Phadzima the next day. The farmers proposed to place an underground pipe from the Mudzinga River to provide both schemes with more water, but they are still looking for funding.

Mavhunga receives water from a weir in the Tshianzhe River (tributary of Mutshedzi River). From the weir a pipe leads water to a small night storage dam, from where the water is divided into two pipes leading to three gate valves. From there water is led into three canals and to the fields.

Mauluma receives its water from the most upstream weir in the Mutshedzi River, from where water is led into the main canal of the scheme. There is also a night storage dam, located at the far end of the scheme, which provides the last secondary canal with water. As Mauluma is the case study of this report, a more detailed explanation of the scheme and its farmers is given in paragraph 3.4.

Mphaila, located further downstream also gets water from the Mutshedzi River. At the Mphaila Weir, water is pumped into a night storage dam, from where water is led into the scheme's pipe system by gravity and brought to the crops by sprinklers. Mphaila is the only scheme in the Nzhelele cluster using the sprinkler irrigation system.

Luvhada, in between Mphaila and Mphepho has its own history as formally they used to only have dry land farmers and were not included in the Water Care Program. The farmers noticed a mountain spring and created a small dam and an earth canal, which led water from the dam to their plots. Later they managed to get funding and with additional farmer contribution they placed a pipe from the dam and constructed a concrete main canal to lead the water to their plots. Also a fence was built around the scheme. As they were an active scheme and had formed their own management committee, the Luvhada scheme was added to the Water Care Program.

Northern schemes

Of the northern schemes, Ralipaswa, Madiwana and VND (also referred to as the Ramavhu schemes) are somehow interconnected as they share the same water source, which is created through the most downstream weir the Mutshedzi River, referred to as Raliphaswa Weir. Besides their own scheme committees they have also formed a general management committee and share the same extension officer. Besides these three schemes, the Mamohohi scheme also receives water from this source.

Ralipaswa is the scheme that first receives water from the Ralipaswa Weir. The water is led into the Ralipaswa night storage dam from where water is led into the main canal.

Vhutuwa Nga Dzebo (VND) has a similar history to Luvhada as they also had only dry land farmers and were not part of the Water Care Program. As water was being led across their land from the Mutshedzi River to neighboring schemes, they decided they also wanted to be part of the program and formed their own scheme committee. VND was accepted and they got their own extension officer. Due to this history the scheme has 3 different water sources and three main canals, which join together downstream of the scheme. First, water is led from the Mphepho weir in the Nzhelele River into the night storage dam of VND and from there into their northern main canal. Second, water is led from the end of the Ralipaswa main canal into their center main canal and third, water is directly led through a pipe from the Ralipaswa night storage dam into their southern main canal.

Madiwana is the last scheme in this group and gets its water from the canal, which before it reaches Madiwana connects VND's three main canals. From here, water is led into the scheme.

Mamohohi is located on the other side of the R 523. The scheme has its own management committee, but shares the same extension officer as the Ramavhu schemes. Furthermore, Mamuhohi is the final scheme in the chain of schemes that receives water from the Ralipaswa Weir. From the end of the Madiwana main canal, water is led into their own night storage dam from where water is led into the scheme. It is even possible to lead water from this night storage dam back up to the Madiwana scheme. Being the last scheme in the chain, the Mamohohi scheme could suffer most from lack of water.

Mphepho is located upstream of the Ramavhu schemes and has its own management committee and extension officer. They will receive water from the Mphepho weir in the Nzhelele River, which is still under construction, but from where water will be led into the main canal of the scheme. There are also two night storage dams from where water can be led into the secondary canals.

Rabali is the most southern one of the northern schemes and as Mamohohi is located on the other side of the R 523. The scheme has its own management committee and extension officer. The scheme will receive water from the Nzhelele Weir in the Nzhelele River, which has almost been completed. A temporary pump was installed, but it cannot provide enough water for the entire scheme.

Table 3.2 Northern schemes in the Nzhelele Valley (LDA, 2002 (a))

NORTHERN SCHEMES

Scheme name	Number of farmers*	Approximate surface [ha]
Rabali	68	88
Mamohohi	60	78
Madiwana	40	52
Ralipaswa	13	+15
Mphepho	89	114
Vhutuwa Nga Dzebo (VND)	60	18

** Also here, there are so-called rejected land farmers (see paragraph 3.4.3), who are not included this table.*

The Nzhelele schemes have all suffered from the heavy rains and floods that occurred in the summer of 2000, which caused extensive damage to scheme infrastructures (LDA, 2002 (a)). As a result most schemes have been inactive for 2-3 years. In 2002, the second phase of the Water Care Program commenced in the Nzhelele Valley, which among others initiated rehabilitation works and farm and scheme management training programs. Hence, most schemes have started to farm and irrigate again since 2003 and 2004 and are continuing the revitalization program with RESIS since mid 2004.

3.4 Mauluma: history, hydraulics, farmers and water

Mauluma (formerly known as Beaconsfield) is one of the 13 schemes located in the Nzhelele Valley, northeast from the town Makhado (Louis Trichardt), see figure 3.1. According to interviews with local farmers and LDA, 2002 (a), the Mauluma scheme originates from 1938, when the government initiated the irrigation project and land was allocated in cooperation with tribal authorities.

More on the scheme's history context is described below in paragraph 3.4.1. Thereafter, paragraph 3.4.2 gives a schematic overview of the scheme and some hydraulic figures. From interviews with farmers, Mauluma's management committee (MC) and the extension officer, knowledge has been gained on the scheme's farmers, their land and the water scheduling system. This is presented in paragraphs 3.4.3 and 3.4.4.

3.4.1 Scheme history context

After 1950 and the publication of the Tomlinson Commission's report on socio-economic development of the Bantustans most irrigation schemes in the former Bantustans areas were started (Perret, 2002 quoting Union of South Africa, 1955). Most schemes were developed for social and food security purposes (Perret, 2002). In 1962, the scheme was officially established and in 1963 the canals were cemented (LDA, 2002 (a)). The Tomlinson report and the implementation of some of its recommendations had a major effect on settlements, land use patterns and irrigation development in black rural areas, which are still noticeable today[5] (Perret, 2002 quoting Averbeke van, *et al.*, 1998). Mauluma like many other smallholder irrigation schemes in the country was functioning with the support of government capital, but in 1994 the first post-apartheid government removed these state subsidies (Perret *et al.*, 2003, Perret, 2002 and Veldwisch and Perret, 2004 quoting Hope and Gowing, 2004?). Consequently, Mauluma and many other schemes either stopped functioning properly or became inactive and hence collapsed in the period of 1994-1996 (Perret, 2002 quoting NP-DAE, 2000).

Since the late 1990s, provincial governments have set up rehabilitation and management transfer programs across the country (see paragraph 1.1). As explained in paragraph 3.1, in the Limpopo Province this program was launched in 1998. In 2002, the Nzhelele cluster and thus Mauluma was included in the second phase of the "Water Care Program" (LDA, 2002 (a)).

3.4.2 Schematic and hydraulic scheme overview

As described in paragraph 3.3, Mauluma is an independent scheme with its own water source; the weir in the Mutshedzi River. Figure 3.4 shows the scheme with its canals and infrastructures. The main canal of the scheme supplies water to a total of seven secondary canals by broad crested weir outlet structures (similar to the outlet structures in the Thabina irrigation scheme), see appendix 3 B. As shown in figures 3.4 the night storage dam only supplies the last (7^{th}) canal with water. In order for the dam to fill up, all the valves to the secondary canals have to be closed at night and re-opened in the morning.

[5] For example, based on information collected from existing schemes, the Commission suggested that irrigated holdings of 1.3-1.7 ha were adequate to "provide a family with a living that would satisfy them, whereby the whole family would work on the holding" (Perret, 2002 quoting Union of South Africa, 1955)

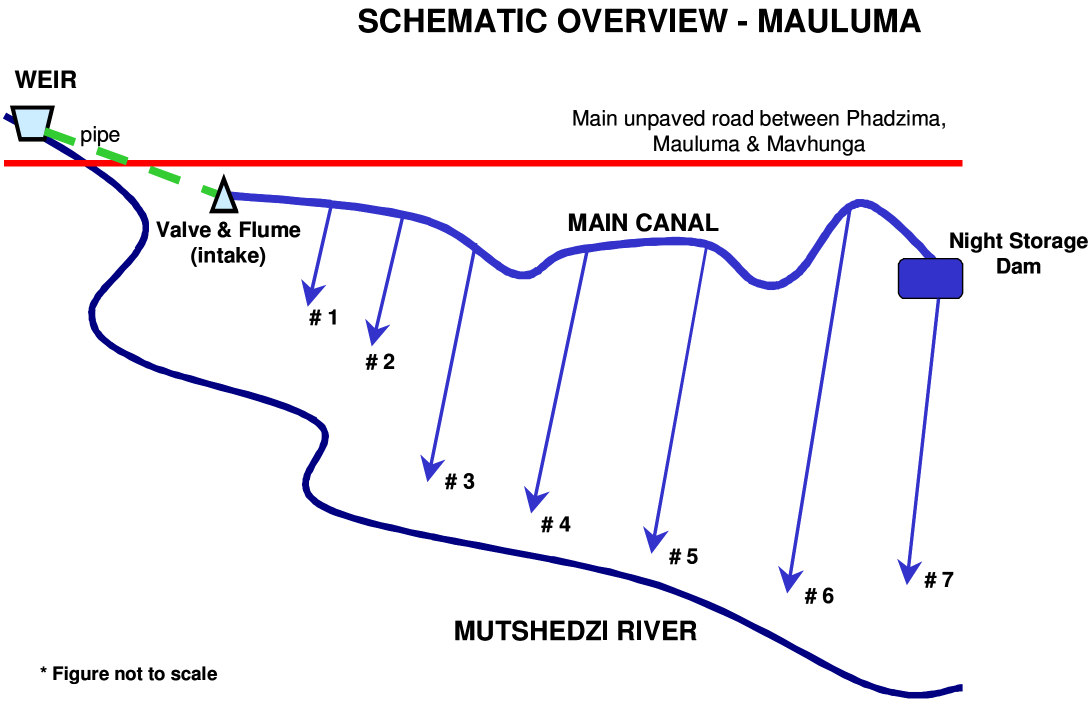


Figure 3.4 Schematic representation of the Mauluma scheme and infrastructures

A few hydraulic figures taken from the technical plan for rehabilitation (LDA, 2003) are presented in table 3.3. The average flow in the main canal has been estimated at 300 m^3/hour, which is equal to 83.3 l/s, through rough calculations with consultants from Rural Integrated Engineering (RIENG). This firm was partly in charge of the technical plan under the Water Care Program in 2003.

Table 3.3 Some hydraulic figures for the Mauluma scheme (LDA, 2003)

	Total length [m]	**Outlet capacity [l/s]**	**Flow capacity [l/s]**
Main canal	1868	-	83.3
	Secondary canals	*Outlets from main to secondary canals*	*Secondary canals*
No. 1	86	7.2	18.9
No. 2	111	7.2	18.9
No. 3	214	7.2	18.3
No. 4	286	7.2	20.0
No. 5	383	7.2	18.9
No. 6	500	12.2	19.7
No. 7	340	14.4	30.3

Water Management Plan

RIENG, 2004 explains that the two main focus areas of rehabilitation in the Water Care Program's were capacity building and physical rehabilitation of infrastructure. Physical rehabilitation was performed and mostly completed, but the *Water Management Plan* (WMP), which was designed as part of the capacity building process was only introduced and presented to the schemes and in some cases training sessions were held. It is thought, that these plans will be reincorporated into the RESIS program.

According to RIENG, 2004 the main purpose of the WMPs is to provide the management and technical committees of each specific scheme with a "tool" to do water scheduling, water sharing and scheme management. These plans can also help with the planning of water allocation during times of water shortages or droughts to share the available water in an equitable manner. The WMPs were designed for each specific irrigation scheme, according to its uniqueness in terms of infield irrigation practices (evaluated and quantified by infield measurements), existing infrastructure, generally accepted irrigation norms and cultivation practices (RIENG, 2004). Collected data and current scheduling practices were discussed with the management and technical committees of the schemes and outcomes were used to make a WMP design, based on crop requirements. At the moment, the first draft WMPs have been handed to the specific schemes, including Mauluma and it depends both on the scheme's MC and on RESIS if these plans will be tested, refined and implemented.

The WMPs consist of two main items, namely the *plate inventory* and the *recommended irrigation schedul*e for each secondary canal on a specific scheme. A system of steel plates with different orifice or hole sizes is recommended for each secondary canal and these plates are to be placed at the point of outlet to a specific plot. Consequently, the orifice in the plate will allow the right flow through to the farmers downstream on the same canal, who are irrigating at the specific time. Details on the plate system and the recommended irrigation schedule can be consulted in RIENG, 2004.

3.4.3 The Mauluma farmers and their land

Mauluma has a total of 76 farmers with 78 plots (two farmers have two plots). Only 30 of those are official registered plots with a legitimate PTO (permission to occupy) and the owners – the *registered irrigated land farmers* – pay R12/year for their land to the local district office for agriculture, representing the LDA. These farmers have a specific water scheduling system according to which they irrigate their crops. Besides these farmers, there are 39 plots, which are not "officially" registered, the so-called *rejected irrigated land farmers* who are allowed to use the "left over" unallocated land in the scheme. These farmers do not pay any fees and only have an informal permission to occupy via the tribal chief. These farmers are fully accepted by the management committee and even the LDA and are allowed to irrigate their crops only in the weekends or whenever water is plenty (so not in critical months: August/September till January/February). The remaining nine farmers are *dry land farmers*, who occupy the land (nine plots) under the same conditions as the rejected land farmers. However, their plots are situated above the main canal and therefore they cannot irrigate from the secondary canals (too far or upstream). This is why they are not included in the water scheduling system and why they are totally dependent on rain. The registered land plots are located along the secondary canals (see table 3.4) and the rejected land plots are mostly located at the beginning or at the far end of secondary canals (near the river) and at the far east side of the scheme after the night storage dam, literally occupying the "leftover" land, which was not allocated from the start.

The total scheme area is approximately 48 ha. Most registered land farmers have a plot of approximately 1 ha, which is usually divided into an average of 11-12 beds[6] (one bed is approximately 0.092 ha). As the scheme performs short furrow flood irrigation, a bed is divided into scales and a scale into furrows, as shown in the schematic overview of an irrigation plot in figure 3.5. It needs to be taken into account that not all beds within a plot are always the same size. The rejected land farmers' plots are approximately 0.4 ha with an average of four beds. The dry land farmers have very small plots of approximately 0.2 ha, consisting of approximately two beds.

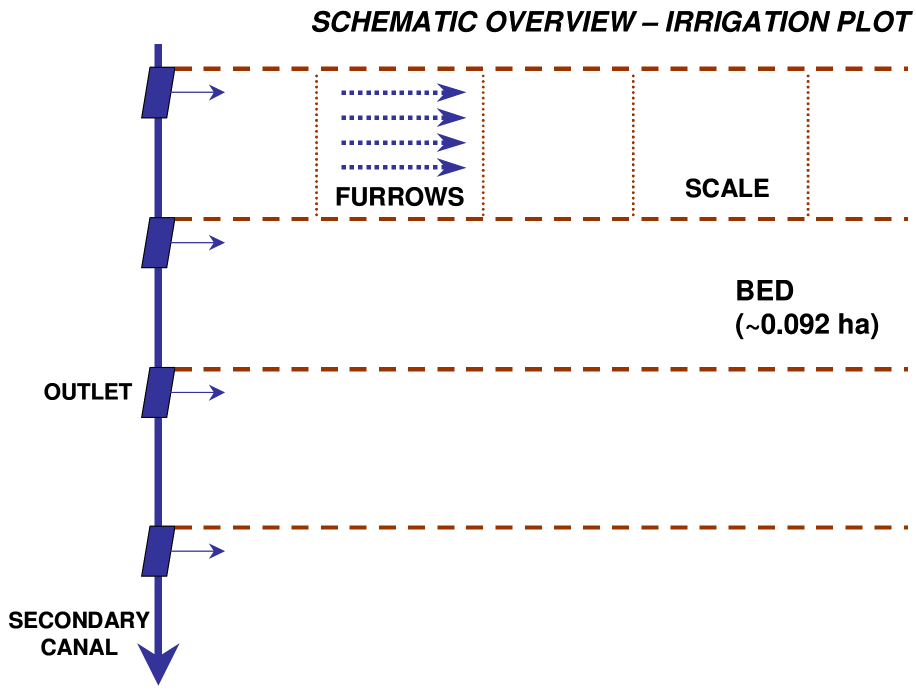


Figure 3.5 Schematic overview of an irrigation plot, including beds, scales and furrows

As all the schemes in the Nzhelele Valley, Mauluma's scheme infrastructure was also severely damaged during the floods of February 2000. The weir was broken and the pipe was washed away. After continuous repairs and works performed by the Water Care Program in the scheme in 2002, farmers have only been able to start farming and irrigating again since mid 2003.

[6] Beds go across the plot and measure approximately 138 m x 6.6 m. They are separated by contours in the plot. The number of beds per plot can be easily counted while walking along the secondary canal, which corresponds to the plot; a bed is situated between two outlets in the canal. In other schemes in South Africa beds are also called "levies".

3.4.4 Mauluma's current water scheduling system

As explained in paragraph 3.4.2, the recommended water scheduling and plate system of the WMP has been presented to the Mauluma scheme members. Furthermore, some workshops have been held to train the farmers in using the plate system. However, the plates have not been delivered yet and most probably training will have to be repeated in the RESIS program. At the moment, the Mauluma farmers are still irrigating by their own original irrigation schedule. According to that currently used water scheduling system, each secondary canal has its own day for irrigating. This schedule works from Monday till Friday and only includes the registered farmers. On weekends, the rejected land farmers can irrigate whenever they please. This water scheduling system is most strict in the dry season (September-February), as that is when water is less abundant. In the other months of the year, the scheduling system is more flexible as usually plenty of water is flowing through the canals and farmers can even irrigate on other days. Table 3.4 shows the water scheduling system per canal for registered plots only.

Table 3.4 Water scheduling system for registered plots in Mauluma

Canal	Plot number*	No. of plots	Day
1	1	1	Friday
2	2	1	Friday
3	3, 4, 5 & 7	4	Friday
4	8, 9, 10, 11 & 12	5	Thursday & left over water on Friday
5	13, 14, 15, 16, 17, 18 & 19	7	Wednesday & left over water on Thursday
6	20, 21, 22, 23, 24 & 12	6	Monday & Tuesday
7	25, 26, 27, 28, 29 & 30	6	Any day

The rejected land farmers who are located to the right of the dam and the plots supplied by the 7th canal can use water every day, as there are a few natural springs running to the Mutshedzi River. These springs always carry plenty of water, thus these rejected land farmers actually form an independent group of plots within the scheme, as they are not relying on water from the canal or the dam. In weekends however, they are allowed to use water from the dam, as well as when water is plenty and the dam is full. Rejected land farmers located at the far end of the 5th, 6th and 7th canal also benefit from these natural springs.

In times of drought the water scheduling system does not really change, but it can happen that farmers can only irrigate half a day instead of a whole day. Furthermore, farmers decide to plant less beds than usual. It has occurred that during drought the Mauluma farmers, upon request of the Mphaila scheme did not use water for a certain amount of time. They had to let the water run back into the Mutshedzi river so that the Mphaila scheme situated more downstream would still have some water to irrigate their plots.

3.5 Mauluma, a case study for research

In conclusion, the Mauluma irrigation scheme creates an interesting case study for this research. Moreover, as the scheme is not too big and does not include too many farmers, making it easier and less time consuming for one researcher to apply both the SMILE approach and IADF approach. In addition, the scheme cultivates a diversity of crops, making the inputs for the SMILE database and thus the results more interesting. The scheme was also selected, as it is known to belong to the group of most active schemes in the Nzhelele valley and for not having major problematical institutional problems, making the "testing" of the IADF approach easier (however, in the end, as clarified in chapters 5 and 6, the institutional issues in Mauluma were rather too straightforward than too complex). Another major incentive to perform this research in Mauluma, was the recommendation and proposal done by representatives of the RESIS program, who considered the Nzhelele scheme cluster as the current "hot-spot" for research and analysis as almost all schemes had completed the rehabilitation works, farmers had started to cultivate and irrigate again since the floods of 2000 and RESIS was just entering a new phase of institutional development and strengthening.

4 THE SMILE APPROACH: FIELD WORK & ANALYSIS

The results of the SMILE simulation platform based approach applied to the case study of the smallholder irrigation scheme Mauluma are described and discussed in this chapter. All results have been obtained through interviews with farmers (see appendix 2 C for an example SMILE questionnaire, used in this research) and SMILE calculations.

In paragraph 4.1 the basic SMILE input data for Mauluma is presented. The different crops, crop management styles and farmer typologies of the scheme are discussed in paragraphs 4.2 and 4.3. Hereafter, in paragraph 4.4 the SMILE results concerning economics and water are presented at crop, farmer and scheme level as well as results on crop irrigation requirements. All these results are discussed and compared to results on the Thabina irrigation scheme (see Perret *et al.*, 2003). Finally, paragraph 4.5 gives a short conclusion on the results of the SMILE approach and some recommendations for the Mauluma irrigation scheme.

4.1 SMILE input - Mauluma

In paragraphs 3.3 and 3.4, most general information on Mauluma's farmers and the scheme has already been given. Below, general scheme data relevant for the SMILE approach is summarized in table 4.1. The table shows the different kinds of plots (land status) present in the scheme, the number of farmers for each kind of plot and the average plot area (showing the average amount of beds/plot; 1 bed = 0.092 ha, see paragraph 3.4.3). The scheme list, including the official registered land plot numbers and rejected and dry land numbers (non-official number, as these plots are not registered) estimated plot surfaces (in beds and ha) is given in appendix 4 A.

Table 4.1 Farmers in the Mauluma scheme

Plot type	Number of farmers	Average plot area
Registered land (30 plots)	28	1 ha (11-12 beds)
Rejected land (39 plots)	39	0.4 ha (4 beds)
Dry land (9 plots)	9	0.2 ha (2 beds)
TOTAL (78 plots)	76	**SCHEME:** 48.38 ha

In order to gather data for the different SMILE modules, interviews with farmers were carried out in the field. However, not all farmers were interviewed. A sample of farmers was chosen, consisting of 18 registered land plots, 9 rejected land plots and 3 dry land plots. The selection of farmers was accomplished with the help of members of the scheme's MC. Selection criteria were: type of plot, location in the scheme (head-end and tail-end plots) and gender. Interviews were performed in two rounds of field visits, whereby in the second round the newly defined farmer typology (see paragraph 4.3) also became a selection criterion.

SMILE modules used for Mauluma
For the case study of Mauluma, only the *scheme, crops, farming systems and water balance modules* have been used. The *costs* and *water charging system module*s are not relevant at this

stage, as the scheme still has to complete the last two years of the RESIS program and is thus not functioning independently yet. In addition, the scheme has not really had any maintenance or operation costs to cover, as most costs were subsidized by government (e.g. the water bailiff was hired and paid by LDA), and technical repairs and works were part of the Water Care Program, which is now followed up by RESIS. Also, the scheme does not have any personnel or electricity costs at the moment. Furthermore, any scheme plans incurring costs (e.g. building of toilets at gathering place for MC and general meetings), have always been discussed in meetings until now and usually all members would agree to contribute a certain amount of money. In short, no fees for cost recovery of management and maintenance and operation of the scheme have been implemented yet. However, as soon as the scheme will be independent and responsible for its own cost recovery and operation and maintenance and even more so when establishing a WUA, such costs will have to be taken into account and the scheme will have to make sure such costs are covered through a water charging system. Once such a charging systems is implemented and in function, the remaining two modules will have to be filled in to get a thorough "SMILE" result and a complete picture of the scheme's financial situation.

4.2 Crops cultivated in Mauluma

From interviews, it was possible to distinguish the various crops cultivated in the scheme. In this paragraph the major crops and existing crop management styles in Mauluma are presented and discussed.

4.2.1 Presentation and discussion of major crops

The graph in figure 4.1 shows the planted crop surface for each crop in Mauluma. Even though, this graph only represents the interviewed farmers (so only 30 from 78 plots), it gives a good representation of what is being cultivated in the scheme.

From the graph, it can be concluded that the five most popular crops in descending order are: maize, tomato, beans, groundnut and sweet potato. The graph also distinguishes between crops planted on registered land plots (rg. ld), rejected land plots (rj. ld) and finally dry land plots (dry ld), which only cultivate maize as they depend on rain and consequently only plant in summer.

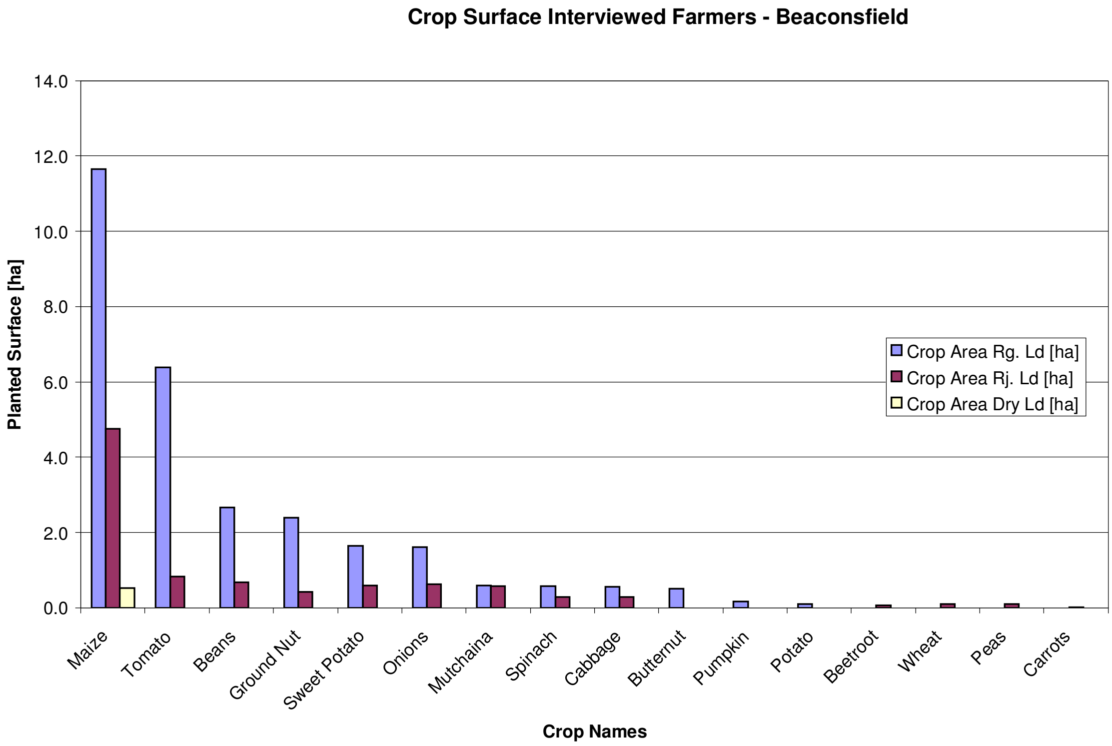


Figure 4.1 Planted crop surface in Mauluma of interviewed farmers

Discussion and comparison with Thabina crops

As shown above, maize is the major crop in Mauluma. Maize is mostly grown in summer, as that is when the rains start. However, irrigation is usually still needed and the possibility to irrigate makes planting dates for farmers more flexible. Nevertheless, farmers who do not have access to irrigation, cultivate maize on dry lands (in Mauluma: dry land farmers). It is not surprising that maize is the major crop, as this is the case in various smallholder irrigation schemes in South Africa. Examples are Thabina (Perret *et al.*, 2003) and Dingleydale-New Forest (Lavigne and Stirer, 2003). Maize is mainly grown from home consumption and is the most important component of household meals, which is one of the reasons for maize being the priority crop. From the graph in figure 4.1, it is clear that in Mauluma vegetables are grown, but compared to maize the cultivated surface in the scheme is much lower. From this it can be concluded that like in Thabina and Dingleydale-New Forest, farmers in Mauluma are mostly active in summer (which is confirmed by the farmer typology in paragraph 4.3), meaning that even though farmers have access to water and irrigation, they are hesitant to take risks and do not cultivate much in winter when water is less abundant. This seems to be characteristic for smallholder schemes in South Africa.

The tomato factory (GIANTS) in the Nzhelele Valley creates an easily accessible market, making tomato the second most cultivated crop in Mauluma. In Thabina, tomatoes are cultivated, being a possible vegetable for farmers to grow in winter, thus not more different from any other vegetables. The GIANTS factory was already buying from the Nzhelele schemes before the floods of 2000. Recently, as the schemes are functioning again due to the rehabilitation works completed by the Water Care Program and RESIS, it seems farmers are willing to target the GIANTS market again. Compared to other schemes, such as Thabina, Mauluma is quite unique in having a tomato market nearby. Unfortunately, the Mauluma farmers do not realize how important the quality of their tomatoes is, which often do not meet the GIANTS standards and requirements. Another major limiting factor, which is related to this problem brought forward by the farmers themselves, is their lack of skills and know-how in applying fertilizers and pesticides to crops. For tomato this is crucial, as it is a vulnerable and risky crop, especially regarding diseases, which is another reason for most smallholder schemes to choose for other vegetables instead of tomato.

4.2.2 Presentation and discussion of crop management styles

For the SMILE *crops module* (see paragraph 2.1.4 and the SMILE users' guide summarized in appendix 2 A), a series of *crop management styles* were defined for the crops cultivated in Mauluma. The criteria *planting date* and *yield* were chosen to define these styles and were identified in interviews with farmers (see example SMILE questionnaire, appendix 2 C). Through comparison, it was discovered that different ways of cultivating a certain crop exist, thus diverse management styles per crop. For example, maize can either be planted in spring or summer and yields can either be high or low. For each farmer that was interviewed, their crop management style per crop was identified and allocated. In appendices 4 B and C, the different management styles per crop are shown, along with the corresponding *planting date*, *yield/bed*, *yield/ha*, *product price/unit*, *total revenue/ha* and the *number of farmers* performing each style. Yield, product price and total revenue are presented as averages per crop management style. These averages are calculated with figures given by all the interviewed farmers belonging to the crop management style in question (e.g. for *spring maize - high yield*, the yield of 53.63 bag/ha represents the average yield of all 10 farmers performing this crop management style). It is important to note that, averages hide the diversity between the figures; therefore the standard deviation is given for both *yield/ha* (appendix 4 B) and *total revenue/ha* (appendix 4 C). For the meaning of the used economic terms such as product price and total revenue related to yield, see frame 4.1. Table 4.2 gives a few examples of crop management styles with their characteristics (figures are rounded off, when comparing to appendices 4 B and C) for the five major crops cultivated in Mauluma.

Frame 4.1 Economic terminologies (Perret, et al., 2003 and SMILE users' guide)

For SMILE and this report a certain economic terminology is being used, implicating that:

Total revenue = Product Price * Yield

In an example for maize, this results in:

*Total revenue maize = R 180/bag * 20 bags/ha = R 3600/ha*

It must be noted that all production is turned into revenue, regardless of marketing or self-consumption. To allocate a monetary value to all production, product prices are applied to all crops/products. Hereby the following assumption is taken: *a self-produced product, which is self consumed at family level generates an income, related to the product price and the costs that should be paid if the same family had to buy this product.*

<u>* Note:</u> The South African Rand equals to approximately 8 €.

Continuation of economic terminology in frame 4.2

Table 4.2 Examples of crop management styles in Mauluma

Crop Name - CM Style	No. Farmers	Planting Date	Yield* [unit/ha]	Price* [R/unit]	Total Revenue* [R/ha]
Maize *Spring - high yield*	10	01-Sep	54 bags	172	9288
Tomato *Fall - high yield*	5	15-Mar	1112 crates	31	34472
Beans *Fall - low yield*	7	01-Mar	11 bags	735	8085
Groundnut *Spring - low yield*	4	15-Sep	37 bags	200	7400
Sweet Potato *All year - low yield*	5	15-Apr / 01-Nov	140 buckets	25	3500

** Figures are rounded off, for more detailed information see appendices 4 B and C.*

Comparison between Mauluma and Thabina CM styles

Unlike in Thabina, in Mauluma, the crop management styles could not be based on farmers' strategies regarding level of intensification, where intensive refers to "high inputs" and extensive to "low inputs" (Perret *et al.*, 2003). This is because in Mauluma, the data gathered on input costs was not very reliable as farmers had difficulties remembering how much they invested in inputs and even more so to remember which fertilizers they applied. This made level of intensification unsuitable as a criterion for crop management styles. This issue is discussed more in paragraph 4.4.

In comparison to Thabina, some interesting links between crop management styles can be made. In table 4.3, some examples of comparison are given for maize, tomato and groundnut.

Table 4.3 Examples of comparisons between Mauluma and Thabina CM styles

Crop Name	CM Style	Yield* [unit/ha]	Price* [R/unit]	Total Revenue* [R/ha]
MAIZE	***Mauluma***			
	*Spring/Summer high yield***	64 bags	171	10944
	*Spring/Summer low yield***	24 bags	180	4320
	Thabina			
	High yield	18 bags	154	2772
	Low Yield	7 bags	166	1162
TOMATO	***Mauluma***			
	Fall - high yield	1112 crates	31	34472
	Fall - low yield	531 crates	25	13275
	Thabina			
	Intensive	510 boxes	24	12240
	Extensive	130 boxes	23	2990
GROUNDNUT	***Mauluma***			
	*Spring/Summer high yield***	64 bags	200	10944
	*Spring/Summer low yield***	33 bags	150	4320
	Thabina			
	Intensive	18 bags	225	4050
	Extensive	10 bags	222	2220

** All figures are rounded off, compared to appendices 4 B and C and original Thabina data (Perret et al., 2003).*

*** For Mauluma, the averages of the spring and summer CM styles are shown, compared to appendices 4 B and C.*

From table 4.3, it can be concluded that the product prizes for maize, tomato and groundnut are quite similar for both schemes. However, there are major differences in yield/ha and therefore also in total revenue/ha. In general, Mauluma has much higher yields compared to Thabina. For example for tomato and groundnut, Mauluma's total revenues/ha for low yield are almost equivalent (but still a bit higher) to Thabina's total revenues/ha for high yield. It is difficult to say what the reasons for these differences could be. Firstly, the amount of water available to the scheme is a very important factor. From Veldwisch and Perret, 2004, it is clear that in Thabina a lot of water is lost because of lack of maintenance. Meaning that less water is available for irrigation of crops, resulting in lower yields. Another reason could be farmers' skills, meaning that farmers in Mauluma could be more experienced in farming and therefore obtaining higher yields. Finally, it is crucial to take production costs into account, as this is an important indicator of farmers' will or possibility to invest in inputs, which can be linked to poor access to input markets, low farming budget and/or skills. Furthermore, input costs determine the gross margin earned per crop. These aspects are considered in paragraph 4.4.

4.3 Farmer typologies

As input for the *farming systems module* (see paragraph 2.1.4 and the SMILE users' guide summarized in appendix 2 A), a typology of farmers was established for Mauluma. During field visits and as discussed in paragraph 4.2, it can be perceived that in Mauluma all farmers are active in summer and mostly plant their whole plot with maize and some beds with groundnut. On the other hand, in winter only a certain number of farmers are active, planting vegetables. In order to capture this important scheme characteristic, the farmer typology for Mauluma was defined by the farmers' winter planting activities. As a result three major farmer types were identified (taking into account that in summer these farmers are all active and alike, in other words, it is assumed that in Mauluma, farmers' strategies can not be clearly distinguished from one another during summer):

1. *Specialized summer farmers*, who are active in summer (cultivate almost whole plot with maize and a few beds with groundnut) but not or hardly active in winter. Meaning that these farmers may cultivate 1-2 beds of vegetables in winter, but definitely cultivate fewer beds in winter than in summer;

2. *Diversified winter farmers*, who are active in summer and also active in winter. Meaning that these farmers may cultivate 3-4 beds of different kinds of vegetables in winter (same/fewer beds cultivated than in summer); and

3. *Specialized winter farmers*, who are active in summer and mostly specializing in a certain crop in winter. Meaning that these farmers may cultivate 4-5 beds of one/two crops (either tomato or beans) and the rest of their plot with other vegetables. Usually, their whole plot is being used; both in summer and winter. Sometimes these farmers even cultivate more beds in winter than in summer.

From interview results, discussions with members of Mauluma's management committee and farmers, all farmers (thus plots) were allocated to a certain type. Table 4.4 shows the number of farmers per type and distinguishes between registered and rejected land plots (excluding dry land plots, as these can all be identified as specialized summer farmers). It can be concluded that most farmers in Mauluma fall under the *specialized summer type* (54 %). The *diversified winter type* comes second (27 %) and finally the *specialized winter type* (8 %).

Table 4.4 Representation of farmers per farmer type for Mauluma

Farmer Type	**Specialized Summer**	**Diversified Winter**	**Specialized Winter**
Registered land plots	13	13	4
Rejected* land plots	29	8	2
TOTAL (69 plots)	**42** (54 %)	**21** (27 %)	**6** (8 %)

** Refers to plots, which are not officially registered, see paragraph 3.4.3.*

4.3.1 Farmer sub-typology

As the three types described above, are still broad and diverse regarding more social criteria such as age, a sub-division per type has been made, resulting in a farmer sub-typology for Mauluma. Each type has been split up into two sub-types: *pensioners* and *non-pensioners*. However, for the rejected land plots, this distinction was not made, as most rejected land farmers (more than half) are pensioners, making such sub-division unnecessary. Pensioners are those farmers within a type who receive a pension of R 740/month from the government (male: above 65 and female: above 60) and non-pensioners do not. It was possible to classify all farmers into one of these sub-types, as from the interviews it is known, which farmers are pensioners and which are not. Also, as the list of farmers, provided by Mauluma's management committee and extension officer, includes all birth dates, pensioners and non-pensioners in the scheme could even be identified without conducting an interview. The latter was done for the remaining farmers, who were not interviewed. As a result, ten[7] sub-types are used as input for the *farming systems module*. Table 4.5 shows these types, the number of farmers per type, the average plot size per type, the total area the type represents in the scheme and the representation percentage of this type in the scheme.

Table 4.5 Farmer sub-typology of Mauluma

Farmer sub-type*	Number of farmers in type**	Average plot size** [ha]	Total area in scheme** [ha]	Type scheme representation** [%]
Spec. sum. - p	5	1.19	5.81	12
Spec. sum. -np	8	0.92	7.74	16
Spec. sum. - rjld	29	0.40	11.61	24
Div. wint. - p	5	1.00	4.84	10
Div. wint. - np	8	0.92	7.74	16
Div. wint. - rjld (big)	3	0.83	2.42	5
Div. wint. - rjld (small)	5	0.21	0.97	2
Spec. wint. - p	3	1.23	3.39	7
Spec. wint. - np	1	1.00	1.00	2
Spec. wint. - rjld	2	0.55	1.10	2
TOTAL	**69**	**-**	**46.62**	**96*****

** p = pensioner, np = non-pensioner and rjld = rejected land*
*** Data calculated by SMILE.*
**** This figure does not equal 100 %, as the nine dry land farmers representing the remaining 4 % are excluded in this calculation.*

[7] For the *diversified winter - rejected land type*, a distinction has been made between farmers with an average plot area of 0.83 ha (big) and 0.21 ha (small). This sub-type was applied, so that the significant difference in plot area would not be overlooked, resulting in ten sub-types instead of nine.

It is important to note, that in table 4.5 the data calculated by SMILE does not exactly match up. This is because only *average plot size* is variable input data, which the user/researcher needs to adapt in order to obtain the right number of farmers per type, which is known exactly from field observations and is decided when establishing the farmer typology and allocating the farmer types. Furthermore, the total area a type represents in the scheme does not exactly equal the *number of farmers * average plot size*, as SMILE is not consequent in showing exact or rounded off figures.

4.3.2 Monograph farmer types

Although not all farmers of Mauluma were interviewed, it was nonetheless possible to represent the "average" situation of each farmer type in the *farming systems module* by applying the *monograph approach* (see the SMILE users' guide summarized in appendix 2 A). Therefore, for each main farmer type a representative *monograph farmer type* was identified, by judging the quality and completeness of his/her answers in the interview performed before on the field. Furthermore, a farmer only qualifies to be a monograph farmer type if his/her way of farming is adequately representative of all other ways of farming existing in his/her type. As ten farmer sub-typologies were defined for Mauluma, also ten monograph farmer types were selected and used in the *farming systems module*. As the identity of the interviewed farmers is confidential, the monograph farmer types will be referred to as: monograph 1, monograph 2 - monograph 10 (in the same sequence as in table 4.5, thus *spec. sum. - p = monograph 1* and *spec. wint. - rjld = monograph 10*).

4.3.3 Discussion and comparison farmer typologies

A major difference between the farmer typologies in Mauluma and Thabina is that in the latter the level of marketing is taken into account, distinguishing between commercial and subsistence oriented farmers (Perret *et al.*, 2003). This is an interesting criterion, but can only be used if during interviews, farmers can answer questions on how much of the yield is sold or self-consumed. In Mauluma, such questions were mostly impossible for farmers to answer as they do not keep records and often do not remember how much of the yield they took home. Farmers therefore usually roughly estimated the answers to these questions. Nevertheless, a typology was created, but based on less quantitative criteria than in Thabina. However, for the just barely reactivated farming and irrigation situation (by the Water Care and RESIS programs) in Mauluma, the established sub-typology distinguishing between registered and rejected land farmers, combined with *planting periods* and *age* related to pensioners and non-pensioners seems to be the most suitable and appropriate typology to be defined at this point in time and at this development stage of the scheme.

Finally, unlike in Thabina and a lot of other smallholder irrigation schemes (e.g. Dingleydale-New Forest, see Lavigne and Stirer, 2003) in South Africa (Perret *et al.*, 2003), in Mauluma no land in the scheme is left unused, except in winter when some plots are left uncultivated, representing those farmers who are only active in summer. However, in summer all plots in the scheme are cultivated with maize and hardly any unplanted piece of land exists. This means there is a major difference between Thabina and Mauluma, as in Thabina there is a large proportion of non-farming land occupiers and in Mauluma all plot occupiers are active in farming, but not throughout the year.

4.4 SMILE results on economics and water

SMILE results can be divided into economic results and results regarding water demand and actual water consumption. These results can be analyzed at three different levels: crop, farmer and scheme level, which is done in the following paragraphs.

4.4.1 Results and discussion at crop level

Regarding the crops cultivated in Mauluma, it is interesting to identify the crop "profitability". Therefore, three different economic variables; *total revenue, production costs* and *gross margin* (see frames 4.1 and 4.2 for definitions) for each crop and crop management style can be analyzed. These figures (except *total revenue*) have been calculated by using the monograph approach and are shown in appendix 4 D. In addition, for each crop management style, the crop water irrigation requirement has been calculated by using SAPWAT (see paragraph 4.4.4), which is also shown in appendix 4 D. A more detailed presentation of these figures is given in appendix 4 E.

Frame 4.2 Additional economic terminologies (Perret, et al., 2003 and SMILE users' guide)

Continuation frame 4.1: other economic terminology are:

Gross margin/Accounting profit = Total revenue – Production costs

In the example for maize, this results in:

Gross margin maize = R 3600/ha – R 2500/ha = R 1100/ha

Gross margin differs from the economic profit as it does not include implicit costs such as opportunity costs associated with employing resources. Gross margin corresponds with what is left in the farmer's pocket, before paying taxes, financial charges, etc. Total revenue and gross margin apply at crop, farm and scheme level. However, it must be taken into account that gross margin is not equal to the net income gained at farm level as further charges such as taxes, water fees, land fees, depreciation of capital, loans etc. are excluded.

Most "profitable" crop

To be able to compare the different crops, it is simpler to temporarily disregard the different crop management styles (evidently, comparison between the styles can also be done, but as the monograph approach is used in this analysis, such detailed comparison is not as valuable). Consequently, to identify the most "profitable" crops (thus not most "profitable" crop management styles), the three economic variables for each crop have been calculated by averaging the economic variables of all crop management styles. However, as the monograph approach is applied, only values of the monograph farmer types are available for *production* *costs* and *gross margin*. Therefore, these values are used for calculation, whereas for *total revenue* averages of all interviewed farmers can be compared to averages of the monograph farmer types, as shown in table 4.6.

Table 4.6 Average total revenue and STDEV

CROPS	*Using data of all interviewed farmers*		*Using data of monograph farmer types*	
	Av. Total Revenue [R/ha]	**STDEV**	**Av. Total Rev. [R/ha]**	**STDEV**
Maize	6,895.23	*4,038.91*	7,148.48	*3,702.51*
Tomato	**25,954.30**	*18,825.50*	**26,587.45**	*26,367.65*
Beans	13,581.92	*9,766.23*	14,425.48	*12,241.62*
Groundnut	10,549.74	*6,584.73*	8,666.40	*3,629.40*
Sw. Potato	9,912.97	*9,032.82*	5,371.09	*5,026.41*

Table 4.7 shows the average values for production costs (excluding labor costs) and gross margin, as well as the average water requirement for the five major crops cultivated in Mauluma. As the figures given for the economic variables during interviews are quite diverse, the standard deviation (STDEV) is given in both tables 4.6 and 4.7.

Table 4.7 Average production costs, gross margin and water requirement and STDEV

CROPS	*Using data of monograph farmer types*					
	Av. Prod. Costs [R/ha]	**STDEV**	**Av. G. Margin [R/ha]**	**STDEV**	**Av. Water Req. [mm]**	**STDEV**
Maize	4,624.74	*1,047.92*	2,523.74	*3,444.02*	931.33	*119.66*
Tomato	23,374.26	*1,005.97*	**3,213.19**	*26,674.18*	995.50	*155.91*
Beans	12,836.50	*524.87*	1,588.98	*12,068.19*	**464.00**	*19.63*
Groundnut	7,729.70	*186.37*	936.70	*3,574.82*	1,084.00	*112.66*
Sw. Potato	**4,444.77**	*94.38*	926.32	*5,054.39*	614.83	*54.28*

High versus low STDEV

The high STDEVs in table 4.6 indicate that there is a high diversity in farmer performances regarding total revenue, but can also imply that there is a high uncertainty regarding the data collected from the field through interviews. Both possibilities are probable, although the latter is most plausible, as farmers had major difficulties answering quantitative questions regarding crop yields, sales and costs. In table 4.7, the STDEVs for productions costs are relatively low, meaning that there is a low diversity in input use among the farmers. However, the relatively high STDEVs for gross margin indicate that at the same time there is a high diversity in income generated from sales, so indirectly the obtained yields differ considerably. As mentioned for table 4.6, another reason for high STDEVs could be a high uncertainty in collected data. However, as all farmers seem to do the same regarding input costs, the high STDEV for gross margin could also indicate that somehow certain farmers suffer from a lack of skills, causing a high diversity in performances and thus gross margin. For the average water requirement in table 4.7, the STDEV is relatively low, indicating that farmers mostly plant their crops at the same time of the year and thus need the same amount of water for irrigation.

Discussion and comparison with Thabina crops

From both tables, it can be concluded that tomato is the crop with the highest total revenue but also the crop with the highest production costs. This is very comparable to the Thabina scheme (Perret *et al.*, 2003), as there *tomato-intensive* is the crop with the highest total revenue (~ R 12,000/ha) and highest production costs (~ R 4,000/ha). It is interesting to note however, that for Mauluma the total revenue is approximately twice as high and production costs almost six times as high (excluding labor). This could mean that farmers in Mauluma are over-investing in production costs. Nevertheless, as mentioned in paragraph 4.2, tomato remains the second most popular crop in Mauluma, which can be linked to the presence of a market; the GIANTS factory. Sweet potato on the other hand has the lowest production costs, but is also one of the crops with the lowest total revenue, which explains its position of fifth most cultivated crop. Most farmers have at least one or two beds of sweet potato, as it is also used for self-consumption. In Thabina, sweet potato is not grown at all.

When looking at gross margin, tomato is definitely the most “profitable” crop, which is another reason for farmers to cultivate this crop, even though input costs are high. In Thabina, *tomato-intensive* also scores highest in gross margin with ~ R 8,500/ha, which is almost three times higher than the gross margin earned in Mauluma. This confirms that farmers in Mauluma are spending much more on input costs than in Thabina and end up with a much lower gross margin. This could mean that the Thabina farmers are much better skilled in growing tomatoes or somehow have had fewer problems regarding for example diseases, climate, etc.

In Mauluma, maize comes second in gross margin and has the lowest production costs. This makes maize a very interesting crop, as crop investments regarding production costs have to be done before any income can be generated and benefited from. Some farmers might not be able to invest that much money at once and therefore might choose crops with low input costs over the ones with high input costs (like maize over tomato), regardless of the higher gross margin, which can be earned at the end. However, regarding maize, it is more likely that the main incentive for farmers to specialize in this crop is to ensure food security (see paragraph 4.2). In Thabina, maize generates a gross margin of approximately R 1,200/ha, which is about half of what is earned in Mauluma. Surprisingly, the production costs in Thabina are almost three times lower (~ R 1,600/ha). Consequently, the total revenue is much lower (~ R 2,800/ha), which can be explained by the much lower product price of R 154/bag. Most probably in Thabina the price for maize has increased over time to about R 180/bag, meaning that their gross margin must have increased to approximately R 1,600/ha, which is only R 400 more than before. This could mean, that in Mauluma, farmers are better skilled in growing maize, although it needs to be taken into account that in Thabina a lot of water is lost due to lack of maintenance, which decreased the water availability and consequently yields. Furthermore, in Mauluma, labor costs still need to be subtracted from the gross margin.

Regarding water requirements for irrigation, beans have the lowest value and at the same time come third regarding gross margin. However, the production costs are quite high, which could make the crop less attractive. Nevertheless, a lot of farmers mentioned that beans generate “good money” and plant at least one to two beds a year. Groundnut has the highest water requirement, a relatively average gross margin and average production costs, making this crop less attractive. However, most farmers tend to combine groundnut with maize in summer.

Crop water requirements in Thabina are much different, due to the difference in geographical location and climate (see paragraph 4.4.2).

It is interesting to note, that the three most interesting or most "profitable" crops are also the crops with the highest planted surface in figure 4.1, namely maize, tomato and beans. These conclusions on crop "profitability" in Mauluma were discussed with the farmers, see frame 4.3.

Frame 4.3 Farmers' feedback on crop "profitability"

During the report-back session, the most "profitable" crop was discussed:

Farmers agreed that tomatoes generate a good gross margin, but emphasized that often their crates get sent back by GIANTS, due to quality deficiencies. In this regard, many farmers commented on vulnerability of tomato to diseases and that they do not know how to avoid this or treat this appropriately with pesticides. Another problem they mentioned was fertilizers; they are not sure what and how much to use.

Furthermore, they mentioned that beans and groundnut also generate a very good income, as they are expensive to buy, so when they sell their harvest, they make a lot of money at once.

Regarding water, farmers said that tomato only need lots of water at the beginning and that beans do need a lot of water to be sure of high yields.

** Comments:*

From this feedback, it can be concluded that farmers lack skills regarding the use of fertilizers and pesticides, not only on tomato, but on all crops.

Furthermore, regarding beans and groundnut, they seem to forget that even though high incomes are generated through sales, investments have been made before. However, it is true that farmers tend to keep seeds for the next planting season and only plant a few beds, keeping the input costs relatively low.

Regarding water, farmers seem to know when the plant needs more water, like for tomato at the beginning, but do not realize that the figures resulting from SAPWAT consider the total amount of water requirement over the whole year.

In general, it was difficult to make the farmers understand that the figures shown were based on "averages", which hide the diversity between the farmers. Furthermore, farmers mentioned that the product prices, which were given during interviews, were already outdated, as a bag of maize had an average price of R 180, but had apparently increased to R 200.

4.4.2 Results and discussion at farmer level

Through combining data of the *crops module* with data of the monograph farmer types in the *farming systems module*, SMILE calculates the three economic variables mentioned in paragraph 4.4.1 for each defined farmer sub-type. As for the crops, by comparing these variables, the most "profitable" farmer type can be identified. These results are shown in table 4.8 as well as the water consumption and the estimated return to water (meaning the amount of money a farmer earns per m^3 water he uses, based on gross margin) per sub-type. It is important to take into account that as in production costs, *hired labor* is not taken into account, although it is an important figure, which affects the gross margin. Figures for hired labor are available for the monograph farmer types from interviews and are shown in table 4.8

for comparison's sake. However, because of the uncertainty of these figures (too erratic), they have not been further used in the SMILE calculations (see below for further explanation). Nevertheless, the hired labor figures were discussed with the farmers, see frame 4.4.

Table 4.8 Economic variables and water consumption results per farmer sub-type

SPECIALIZED SUMMER	*Monograph 1* **Pensioner**	*Monograph 2* **Non-pensioner**	*Monograph 3* **Rejected land**	**AVERAGE**
Total Revenue [R/ha]	2,628.86	17,003.42	8,661.69	*9,431.32*
Production Costs [R/ha]	1,651.94	2,819.84	2,001.25	*2,157.68*
Gross Margin [R/ha]	976.92	14,183.58	6,660.44	*7,273.65*
HIRED LABOUR	653.87	14,712.11	2,490.94	*5,952.31*
Water consumption [m3/ha]	**12,284.74**	**8,535.05**	**8,317.63**	***9,712.47***
Estimated return to water [R/m3]	0.08	1.66	0.80	*0.85*

DIVERSIFIED WINTER	*Monograph 4* **Pensioner**	*Monograph 5* **Non-pensioner**	*Monograph 6* **Rjd. ld. (big)**	*Monograph 7* **Rjd. ld. (small)**	**AVERAGE**
Total Revenue [R/ha]	4,766.08	7,576.17	10,212.40	11,328.65	*8,470.83*
Production Costs [R/ha]	**1,656.93**	**2,708.60**	**1,562.36**	**1,582.26**	***1,877.54***
Gross Margin [R/ha]	3,109.15	4,867.57	8,650.04	9,746.39	*6,593.29*
HIRED LABOUR	0.00	7,410.55	4,358.88	4,358.88	*4,032.08*
Water consumption [m3/ha]	9,980.17	10,832.81	11,980.42	11,969.52	*11,190.73*
Estimated return to water [R/m3]	0.31	0.45	0.72	0.81	*0.57*

SPECIALIZED WINTER	*Monograph 8* **Pensioner**	*Monograph 9* **Non-pensioner**	*Monograph 10* **Rejected land**	**AVERAGE**
Total Revenue [R/ha]	**18,837.72**	**12,298.89**	**13,467.94**	***14,868.18***
Production Costs [R/ha]	2,461.28	2,690.70	1,698.77	*2,283.58*
Gross Margin [R/ha]	**16,376.44**	**9,608.19**	**11,769.17**	***12,584.60***
HIRED LABOUR	1,198.76	4,876.02	7,492.28	*4,522.35*
Water consumption [m3/ha]	12,147.30	9,691.55	9,659.65	*10,499.50*
Estimated return to water [R/m3]	**1.35**	**0.99**	**1.22**	***1.19***

Discusion and comparison with Thabina farmer types
From table 4.8 and the average values, it can be concluded that the specialized winter farmers have the highest total revenue and especially the farmers with a pension. However, the specialized winter farmers are also the ones with the highest production costs. It is interesting to note though, that production costs are around R 2,000/ha for all farmer types. In Thabina this is approximately R 1,400/ha (SMILE database, www.smile-cirad.co.za), which is just a bit lower. This could be linked to either less developed farmer skills, lower access to input markets or lower budgets in Thabina.

Looking at gross margin, evidently the specialized winter farmers are the most "profitable" type. In addition, these farmers make about four times more than Thabina's most "profitable" type *commercial pensioner farmers* (~ R 3,000/ha). Even when the uncertain costs for labor are subtracted, the Mauluma specialized winter farmers would still make almost three times more. Also the specialized summer and diversified winter farmers, having a gross margin of approximately R 6,000/ha seem to do much better than the Thabina farmer types (ranging from R 60/ha to R 3,000/ha). As mentioned in paragraph 4.4.1, this could be related to either better skills or more water availability. However, more interesting is the uncertainty around labor costs in Mauluma, as even when subtracting the average labor costs (~ R 5,000), which was obtained through interviews, would leave these two types with about R 1,000/ha. This would be more comparable to the Thabina gross margin figures per farmer type.

Furthermore, it is interesting to note that in Mauluma, the specialized summer and diversified winter farmers clearly make about half of what the specialized winter farmers make. According to these figures, it could be concluded that the small minority of six specialized winter farmers (see table 4.4) can be seen as the most advanced, most skilled and most commercially oriented farmers of Mauluma. This seems probable, as these farmers are active in summer and even specializing in winter crops. Therefore they generate income in both seasons, whereas the majority in Mauluma is concentrating on one season. The diversified farmers however, seem to start moving closer to the specialized winter farmer, but somehow are still learning, as their gross margin is even lower than the specialized summer farmers.

Water consumption for all farmers is around 10,000 m^3/ha, which is considerably high, compared to Thabina (~ 4,000-5,000 m^3/ha, see SMILE database, www.smile-cirad.co.za and Perret *et al.*, 2003). This difference can be partly explained by the geographical location, as Mauluma is located in an area with a much lower average annual rainfall (371 mm, see paragraph 4.4.4, compared to 790 mm in Thabina, see Perret *et al.*, 2003). Furthermore, as mentioned before, in Thabina canals are not well maintained, resulting in low water availabilities for irrigation. In Mauluma, the diversified winter farmers consume most water, which is probably due to the different winter crops they plant.

Finally, looking at the estimated return to water (profit/m^3), the specialized winter farmers come first with R 1.19/m^3, followed by the specialized summer farmers with R 0.85/m^3 and the diversified winter farmers come last with only R 0.57/m^3. Compared to Thabina these figures are relatively comparable, as there the *commercial pensioner farmers* score highest with R 0.53/m^3 and the *subsistence farmers* lowest with R 0.01/m^3 (figures in between range from R 0.34/m^3 to R 0.14/m^3, see Perret *et al.*, 2003). However, in Mauluma all figures lie above R 0.50/m^3, from which can be concluded that the water productivity in Mauluma is less diverse and mostly higher among the different farmer types.

Hired labor

According to interview results and as shown in table 4.8, all farmers said to spend approximately R 5,000 on hired labor. This figure is quite high, if comparing it with the average production costs of R 2,000/ha. Most probably, farmers have overestimated their labor costs, as such costs are quite difficult to remember, especially as a lot of laborers are given part of the harvest or even a few beds to work on themselves, instead of being paid a salary. However, most farmers' answers did coincide on salary, which was said to be between R 20-30/day. This uncertainty is essential to take into account, as labor costs will significantly influence the gross margin per crop and also per farmer type.

Frame 4.4 Farmers' feedback on most "profitable" farmer type and hired labor costs

During the report-back session, the most "profitable" farmer type was discussed:

Farmers agreed that cultivating in both summer and winter is more "profitable" but argued that it is very difficult for them to prepare the whole land. Firstly, as it is costly (~ R 90/bed) and secondly, as there are not enough tractors in Mauluma to do the job, resulting in farmers waiting for long periods to have their land prepared.

Farmers agreed that only summer farming is not beneficial for the scheme and mentioned that they are encouraging each other to also become active in winter. However, they mentioned that a lot of farmers are old and farming in winter is usually too heavy for them.

Also the uncertainty around hired labor was discussed:

Farmers agreed that the figures resulting from the interviews were much too high and that they must have overestimated the labor costs.

A very important point brought forward by the farmers themselves was, that they realized that keeping records is essential. They confirmed that they have difficulties remembering for example how much they planted, how much they harvested from one bed, how much they sold and most importantly, how much money they have left in the end.

<u> Comments:</u>*

From these reactions, it can be concluded that farmers are quite willing to cultivate in winter, but somehow lack funds, tractors and sometimes are too old. If these constraints can be addressed properly by the farmers themselves and with some help of RESIS, it seems that there is potential for an increase in active farmers during winter.

Regarding hired labor, the feedback shows that somehow farmers either did not remember how much they spent on labor or did not want to tell what they spent. This could either be linked to lack of trust from the farmers' side during the interview or perhaps farmers wanted to create the impression that they hire a lot of labor with the standard salary of R 20-30/day.

This confirms the necessity of record keeping by farmers, as at the moment farmers' answers cannot be verified anywhere. The farmers' realization on this point of improvement for themselves and the scheme shows that somehow the report-back session created awareness around this issue and on the importance of having reliable data.

4.4.3 Results and discussion at scheme level

Finally, by combining the farmer sub-typology results and amalgamating these according to the correct representation of each type (see tables 4.4 and 4.5) in the scheme, SMILE calculates the same economic variables at scheme level (all on annual basis). Along with some general results and the results on water demand and consumption, the economic results are presented in table 4.9.

Table 4.9 SMILE results at scheme level (calculated on annual basis)

GENERAL	
Number of farmers	69
Scheme area [ha]	48.38
Number of irigation farmers	69
Potentially irrigated area [ha]	46.44
ECONOMICS	
Total revenue [R]	**560,646.79**
Average total revenue per farm [R]	8,125.32
Average total revenue per cultivated ha	**9,416.67**
Gross margin [R]	**432,879.41**
Average gross margin per farm [R]	6,273.61
Average gross margin per cultivated ha	**7,270.68**
Estimated return to water [R/m3 gross margin]	**0.72**
WATER	
Crop water demand [m3]	521,513.00
Actual water consumption [m3]	**602,347.42**
Average water consumption per farm [m3]	8,783.81
Average water consumption per cultivated ha	**9,643.02**

Discussion and comparison with Thabina
From table 4.9 it can be concluded that 69 farmers are irrigating 46.44 ha of the total scheme area of 48.38 ha. The remaining nine dry land farmers, who are dependent on rainfall, are using the remaining 1.94 ha.

Furthermore, the total revenue of the whole scheme is approximately R 561,000 with an average total revenue of approximately R 9,000/ha. In Thabina, these figures are respectively approximately R 141,000-R 192,000 and R 2,400/ha (SMILE database, www.smile-cirad.co.za and Perret *et al.,* 2003), which are much lower. Also, Mauluma's gross margin of about R 433,000 with an average gross margin of R 7,000/ha are significantly higher compared to approximately R 59,000-R 74,000 and R 675-R 1,000/ha in Thabina (SMILE database, www.smile-cirad.co.za and Perret *et al.,* 2003). From this it can be concluded that the Mauluma scheme is doing much better, producing higher yield, selling at higher prices and in the end making more money out of farming than Thabina. However, it needs to be taken into account that in Mauluma labor costs are not included and could have a major negative effect on the calculated gross margin. At the moment, the costs at scheme level for

Mauluma are approximately R 128,000 and in Thabina only R 82,000-R 118,000, including labor costs. In addition, the costs in Thabina even include operation and maintenance costs (e.g. electricity, personnel, etc.), which are not yet relevant in Mauluma (see paragraph 4.1).

The ratio between total revenue and gross margin indicates how much is invested (from total revenue) at scheme level. In Mauluma this is 77 % and in Thabina only 39 %-42 %. Again, this can indicate either better farmer skills, better access to input markets or higher farming budgets in Mauluma.

Looking at water, the actual water consumption of the scheme is around 10,000 m^3/ha with a total of 602,000 m^3 for the whole scheme on an annual basis. This total amount of water consumption is higher than the crop water demand of 522,000 m^3, due to the different kinds of water losses, which have been accounted for in the *water balance module* (see paragraph 4.4.4 and appendix 2 A). In Thabina, the total annual water consumption is between 535,000 and 668,000 m^3 (see SMILE database, www.smile-cirad.co.za and Perret *et al*., 2003), which is practically the same or a bit higher than in Mauluma. This seems peculiar, as the water consumption per farmer type (~ 4,000-5,000 m^3/ha) is much lower than in Mauluma. Furthermore, as pointed out before, due to lack of maintenance and more rainfall, the water availability is lower and lower consumption of water would be expected. An important characteristic of the Thabina scheme has however not been brought forward before, that is the much bigger scheme area of 235 ha with 149 farmers. However, only 84 farmers (compared to 69 in Mauluma) are actually farming, resulting in an irrigated area of approximately 138 ha (Perret *et al*., 2003), which is almost three times as big as Mauluma. This explains the proximity of the figures for annual water consumption of both schemes.

Finally, the differences in gross margin in relation to the comparable water consumptions of both schemes, is also shown through the estimated return to water. From this it can be concluded that Mauluma's water productivity of R 0.72/m^3 is much higher compared to R 0.11/m^3 in Thabina (SMILE database, www.smile-cirad.co.za).

4.4.4 SAPWAT crop irrigation requirement results

As already mentioned in paragraph 4.4.1, all crop water irrigation requirements have been calculated in SAPWAT (downloaded version April 2003 from www.sapwat.org.za): a crop and irrigation planning and management tool originating from research projects of the Water Research Commission (WRC), South Africa. As mentioned in the SMILE users' guide (see appendix 2 A and www.smile-cirad.co.za), SAPWAT has been designed to provide information on monthly irrigation water requirements for most crops and climatic regions in South Africa. SAPWAT provides a free access to rainfall data over a large number of stations throughout the country, but also provides net crop irrigation water demands including rainfall and losses at plot level. This data is useful and essential for the SMILE database.

Weather station used for Mauluma

In SAPWAT the adequate weather station has to be chosen, in order to start calculations; for Mauluma this station is called: Venda – Rabali (reference no. 19996). SAPWAT gives the reference evaporation and average rainfall for all stations. The average summer (334.6 mm for October-March) and winter rainfall (36.8 mm for April-September) for this weather station is shown in the graph in figure 4.2. The average annual rainfall at this station can be estimated at 371 mm.

Average summer & winter rainfall for Venda - Rabali (period: 1986 - 1999)

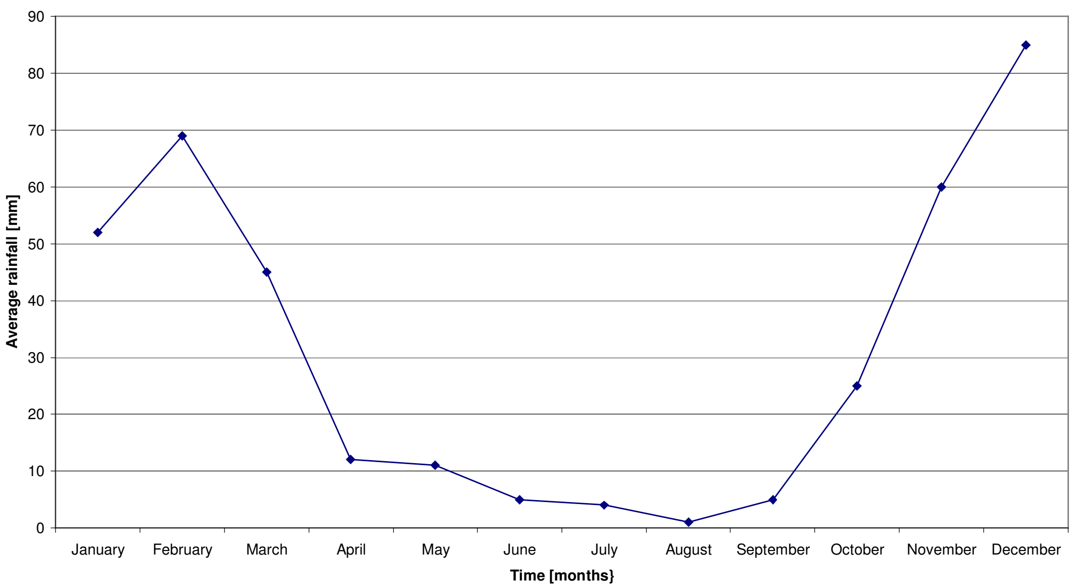


Figure 4.2 Average summer and winter rainfall for the Venda - Rabali weather station

SAPWAT input data

In order for SAPWAT to calculate the crop water irrigation requirement for Mauluma's crops, the corresponding planting dates for each crop management style were entered. Also, the adequate crop type for each crop management style was selected from the SAPWAT options (e.g. *mealies* for maize and *patats* for sweet potato, see appendix 4 E). Furthermore, the geographical region "Lowveld" characteristic to Mauluma, and the options "flood-furrow irrigation", "normal season" and "normal yield" were chosen. For all crop management styles a cover of 100 % at full growth and a wetted area of 100 % was chosen, as these factors only affect SAPWAT's calculations minimally.

SAPWAT results

With this input data, SAPWAT gives crop factors, crop evapotranspiration and crop irrigation requirements after rainfall on a monthly basis. As a "flood furrow" irrigation system is chosen, losses are considered and a system efficiency of 65 % is applied. Also, as "normal yield" is chosen as target yield, a distribution uniformity of 85 % is considered. Furthermore, it is possible to do calculations on irrigation scheduling in SAPWAT.

The irrigation requirements per crop management style for Mauluma are shown in appendix 4 E, along with the chosen planting date per crop management style and the SAPWAT crop option. If a planting date given by the farmers, was not available in SAPWAT, a date as close as possible to the original planting date was chosen, which is also shown in appendix 4 E.

SAPWAT and the SMILE water balance module

In SMILE's *water balance module*, three levels of losses have to be entered (see appendix 2 A). For *bulk conveyance losses* 10 % is entered, as the main canal is < 2 km long (according to LDA, 2003: 1868 m) and made of concrete. This enhances a relatively fast flow and hence low losses. For the *scheme conveyance losses* only 5 % is entered, as the secondary canals are also concreted and even shorter (according to LDA, 2003: between 86-340 m, see paragraph 3.4.2). In addition, the secondary canals lie on a high slope, which ensures even faster flows and thus lower losses. As SAPWAT results already take *in field irrigation losses* into account (system efficiency of 65% and distribution uniformity of 85 %) a value of 0 % is entered in SMILE.

Furthermore, rainfall data has been kept at 0 in SMILE, as SAPWAT results already take this into account. However, the average flow in the main canal has been estimated at 300 m^3/hour (see paragraph 3.4.2) and is used in the *water balance module* to project crop water demand in relation to water availability in the scheme. These trends are shown in graphs in figures 4.3 and 4.4 on annual basis. Note however, that these graphs are based on data obtained from the field and thus show what has occurred in the scheme at this point in time and thus do not represent an average year. Furthermore, it is assumed that the flow in the river is constant throughout the year, as farmers and other scheme members have confirmed this. Therefore the flow in the main canal is also constant (300 m^3/hour).

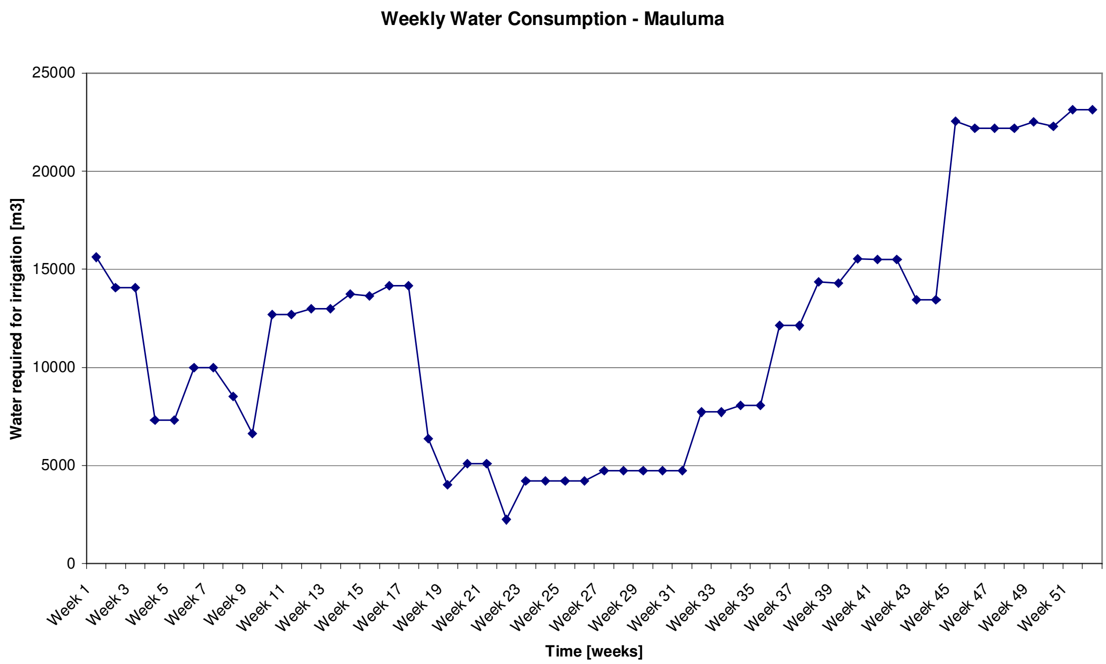


Figure 4.3 Water consumption [m^3/week] in Mauluma (from SAPWAT crop water demands)

The graph in figure 4.3 shows two peaks for water consumption in the scheme throughout the year. The first peak can be explained by the planting of tomatoes in March (weeks 10-13). As this is the second major crop in Mauluma, the planting of tomato has an increasing effect on the water consumption of the scheme, which causes the first peak in March and April (weeks 14-17). From May (weeks 18-22), the water consumption starts going down, as not all farmers are active in winter and only few crops are cultivated. Then in August (weeks 32-35), the water consumption starts going up again, leading to the second peak, which can be explained by the end of the dry season just before the rains start and also by the planting of maize in September (weeks 36-39). As soon as the rains have started, in November (weeks 45-48) the water consumption only slightly increases and starts decreasing in January (weeks 1-5), as then irrigation is only needed in addition to rain.

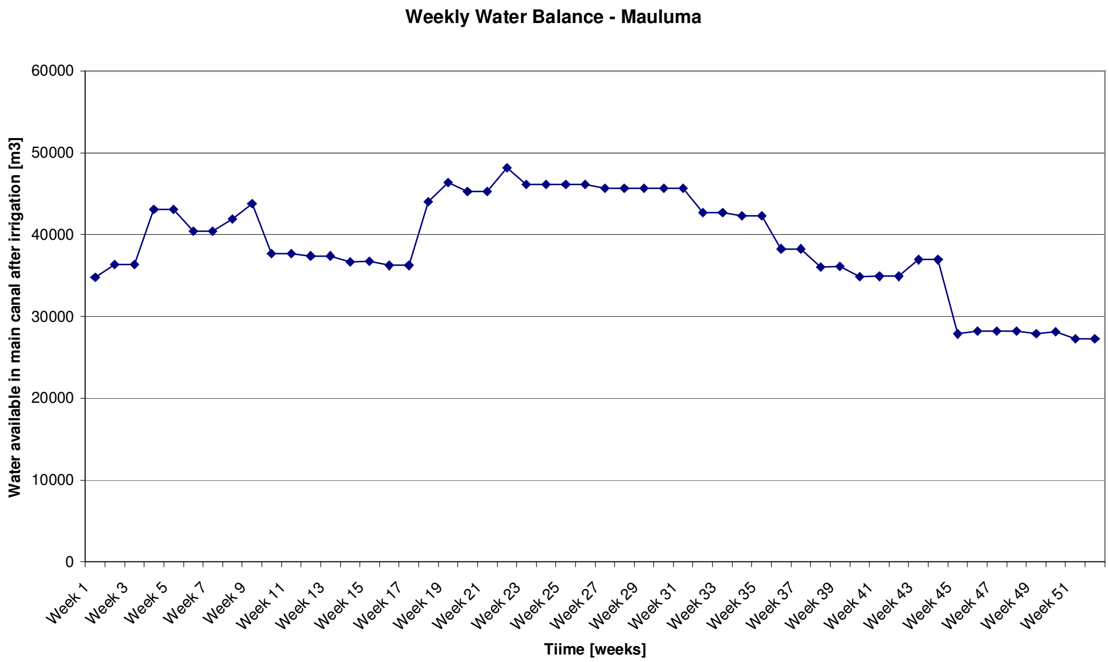


Figure 4.4 Mauluma's weekly water balance, showing water availability after irrigation

The graph in figure 4.4 shows the water balance of the scheme on annual basis. In fact, the graph shows the water availability in the main canal after farmers have consumed the water they needed for irrigation (water availability in the canal subtracted by water consumption of the farmers). This graph shows that even after irrigation, the canal is never empty and the lowest flow is only slightly below 30,000 m^3, which is equal to approximately 179 m^3/hour (~ 50 l/s). This confirms what farmers have said, that there is enough water throughout the year and that a lot of water flows back into the river at the end of the secondary canals. However, it needs to be taken into account that no accurate nor continuous measurements have been done on the main canal to be sure of the flow and to confirm if the flow is constant throughout the year. Furthermore, for now it is assumed that the SAPWAT crop requirements exactly reflect what farmers are doing on the field, as there are no measuring devices to be sure of how much water the farmers are actually using for irrigation. However, from field observations and from farmers' opinions, these graphs seem to represent the situation in Mauluma fairly well and give a good first global idea of water availability and water consumption in the scheme.

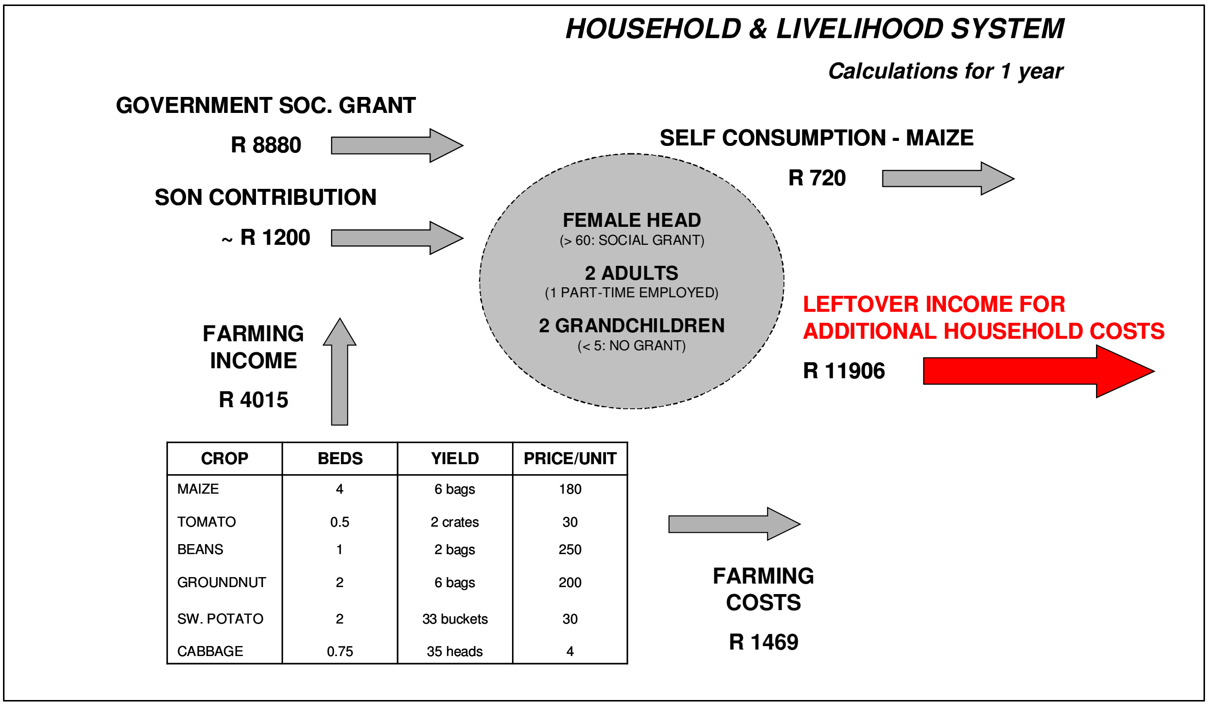
4.5 Conclusion and recommendations Mauluma

From the SMILE approach results on Mauluma, presented in this chapter, different economic and agronomic aspects and the use of water for irrigation have been brought to light at crop, farmer and scheme level. In this concluding paragraph, a few main points are reemphasized and refined with recommendations.

Record keeping and training
Firstly, from fieldwork, interviews, data analysis and finally the report-back session of results to the farmers, the most important recommendations for the Mauluma scheme consider the need for record keeping and training on the use of fertilizers and inputs. At the moment, farmers have only a vague idea of how much they invest in farming and how much they actually make. Record keeping could be of major support and make the financial situation of all farmers in the scheme more transparent. This will be of even greater importance once a water charging system will be implemented, as farmers will have to be aware of how much they will be able or willing to contribute to this charge in relation to how much money they are making by farming. Furthermore, farmers have confirmed that they are not very well aware of which fertilizers and pesticides are the best to use to ensure high and good quality yields. This has especially been emphasized concerning tomatoes as the GIANT factory nearby often does not accept the tomatoes farmers supply. It could be interesting to set up some form of dialogue or communication between the farmers and the factory, as they can both benefit from each other. GIANTS has confirmed to be interested in helping out in training sessions to ensure good yields as the factory prefers to buy from local people in the area than elsewhere. Furthermore, they have a history of buying from the farmers in the Nzhelele Valley.

Household and livelihood analysis
Secondly, in relation to farmers' willingness to pay for water charges and operation and maintenance costs in the future it is crucial to have an idea of how important the farming income is compared to other incomes. This refers to the household and livelihood level, which is actually disregarded in the SMILE approach. Furthermore, the contribution of the farming income to a household also affects the farmer's motivation and interest to be active in the scheme. In the end, this reflects on the scheme as a whole: if farming does not bring much to a household, farmers will not really be motivated to be active in the scheme and therefore the scheme will not be used optimally, resulting in uncultivated plots and low maintenance. However, other incomes could on the contrary be sufficient to sustain farming activities and motivate farmers to invest in farming and become more active. As an example, in frame 4.5 a simplified household and livelihood system is represented and the different incomes and expenditures are calculated. Known figures are taken from an existing farmer in Mauluma and unknown figures are estimated, by consulting the Fertilis irrigation scheme case study (Chiron, 2004), also located in the Limpopo Province.

Frame 4.5 Schematic representation of simplified household and livelihood system



CROP	BEDS	YIELD	PRICE/UNIT
MAIZE	4	6 bags	180
TOMATO	0.5	2 crates	30
BEANS	1	2 bags	250
GROUNDNUT	2	6 bags	200
SW. POTATO	2	33 buckets	30
CABBAGE	0.75	35 heads	4

The schematic overview in frame 4.5 represents the household and livelihood system of an elderly female-headed household in Mauluma. The figures are calculated for one year. It can be concluded that the farming income is 28 % of the total income and the government social grant is 63 %. The son's contribution with a part-time job is minimal (9 %). Finally, the leftover income of almost R 12,000 seems a lot, but other costs such as rent (~ R 500), household maintenance and food (~ R 2800), village funerals (~ R 300) and others like maize seed processing, livestock, social activities etc. still need to be subtracted (Chiron, 2004). For this household it seems that farming is less important when looking at income, although it provides food security. However, it seems feasible that other incomes such as social grants could help invest in farming activities. It remains unclear how many other expenditures this household has and a more complete analysis is needed to be able to draw more meaningful conclusions.

Scenario building and testing

Finally, the SMILE approach has another phase, which was not completed in this research: the build up and testing of scenarios. With the current SMILE results on Mauluma, the SMILE database is ready to be used for scenario testing. Unfortunately, in this scheme no time was left for this last phase. Furthermore, after the report-back session it was obvious that farmers agreed with most of what was said, but it was only the first time they were confronted with such a reflection of their scheme and their own farming situation. Therefore, it was obvious that building scenarios right away would have been very difficult and perhaps irrelevant at this stage as the scheme still has two more years to complete with the revitalization program of RESIS. As a result, a lot of things regarding farming practices are still sensitive to change. Nevertheless, from what came forward from the SMILE approach now, scenarios such as *a shift of farmers from the specialized summer type to the diversified and specialized winter type* could be interesting, especially regarding the results at scheme level. Furthermore, regarding cropping systems, it could be interesting to see what the effects would be of *more farmers specializing in tomato*, meaning that tomato could become the most “popular” crop instead of maize.

5 THE IADF & OSTROM APPROACH: FIELD WORK & ANALYSIS

The results of the IADF approach applied to the case study of the smallholder irrigation scheme Mauluma (Beaconsfield) are described and discussed in this chapter. Therefore, the different steps described in the methodological approach in paragraph 2.2.3 have been used as guidelines for the fieldwork on institutional analysis performed in Mauluma. All results have been obtained through interviews with farmers and others implicated in the scheme.

Paragraph 5.1 deals with the first step concerning the analysis of the *action arena*, its *actors* and specific *action situations*. Results on steps 2 and 3 are presented in paragraph 5.2, where the *patterns of interaction* among actors and their *behavior* are described. There after, in paragraph 5.3 results on step 4 are presented by discussing the different *rules-in-use*. All steps mainly focus on farmers' irrigation practices, strategies on water management & scheme maintenance and water sharing & control in comparison to collective rules and present institutions. Finally in paragraph 5.4, Mauluma's efficiency and sustainability as a scheme are challenged according to Ostrom's "8 design principles" (see paragraph 2.3). The chapter ends with a short conclusion on the performed institutional analysis and some recommendations for the scheme in paragraph 5.5.

5.1 Action arena

In order to analyze the "Mauluma irrigation scheme" action arena, firstly the *actor component* (paragraph 5.1.1) needs to be addressed. Hence, the set of actors (individuals and organizations) that have an impact on the Mauluma "ecosystem" will be presented. Afterwards, analysis will focus on the *action situation component* in paragraph 5.1.2. Finally, in paragraph 5.2.3 the findings on the action arena are discussed.

5.1.1 Actor component

All the different actors implicated in the action arena "Mauluma irrigation scheme" form an *actor arena*, which actually transforms into an action arena, as soon as the action component (thus actors' actions) is considered. However, before analyzing actions, it is important to have a clear picture of the actor component. Therefore firstly, Mauluma's *actor arena*, which is illustrated in figure 5.1, is discussed on its own. The actor arena is composed of four sub-arenas. In other words, there are four different categories of actors: the public sector (government), actors involved in intervention (indirectly linked to the public sector), scheme members (users) and actors who are not really part of the scheme (private sector), but surely linked to it. The arrows in figure 5.1 represent the interaction levels between actors in the arena. All actors are discussed below, but it is important to keep in mind that the emphasis of this analysis lies with the farmer actor group, belonging to the scheme member category.

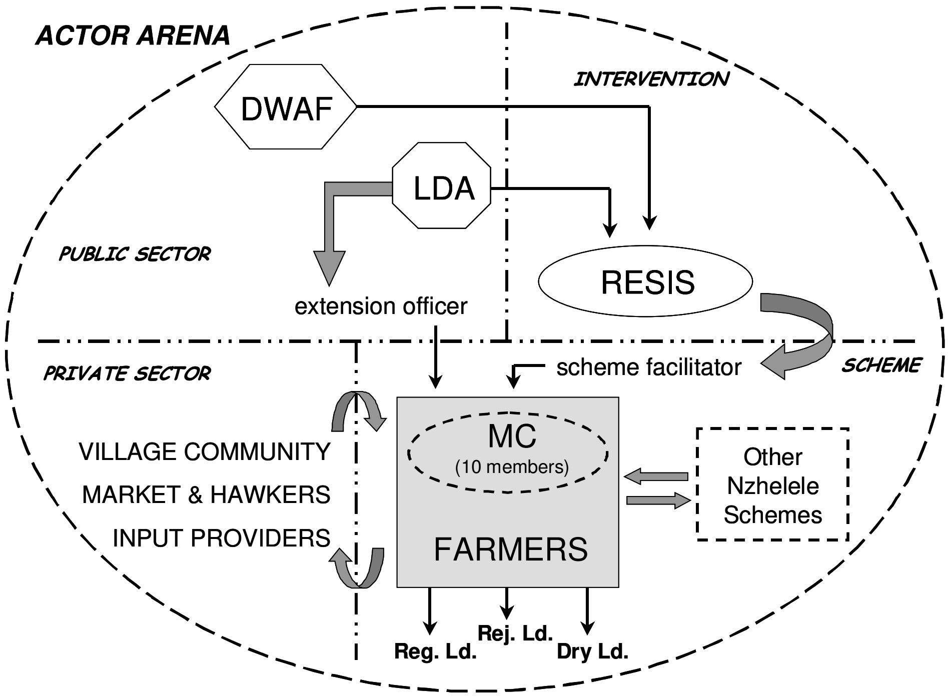


Figure 5.1 The Mauluma irrigation scheme actor arena, consisting of four sub-arenas

Public sector and intervention: DWAF, LDA and RESIS
The public sector (government) is involved in the scheme from a higher and indirect level (see figure 5.1), but is more implicated through the Department of Water Affairs and Forestry (DWAF) and the Limpopo Department of Agriculture (LDA), as described in chapter 1. Mostly, government is directly linked to the scheme through the RESIS team, performing intervention activities and working in close collaboration with LDA, as explained in paragraphs 1.1 and 3.1. Therefore, RESIS, although at a more distant level than the farmers is a main actor, with significant influence on the "ecosystem". Although, RESIS consists of numerous different actors (i.e. policy makers, economists, consultants, etc.), this analysis does not incorporate a detailed actor analysis of RESIS. RESIS is therefore considered as one single actor in Mauluma's actor arena. Nonetheless, the organizational structure of RESIS has briefly been discussed paragraph 1.2.

Scheme assistants: extension officer and scheme facilitator
At a level between RESIS and farmers, two other significant actors are active. Firstly, the extension officer, thus representative of government, who stays near the scheme and is in direct contact with the farmers. Secondly, the scheme facilitator, a relatively new actor introduced by RESIS since September 2004, whose task is to be the cord of communication between the RESIS program and the farmers. This person is elected and is either a farmer or a member of the village community, standing close to the farmers.

Scheme members: farmers
The actors directly linked to the scheme or "ecosystem", which provides them with infrastructure and water for irrigation are the users, or more specifically the farmers, shown in

gray colored block in figure 5.1. As explained in paragraph 3.4.3, these farmers can be split up into registered land, rejected land and dry land farmers. Furthermore, the scheme's management committee (MC), consisting of ten elected members representing the farmer community, also forms part of this actor group. When considering the whole Nzhelele Valley, the other twelve schemes (see paragraph 3.3) form their own "ecosystems" with their own actor arena's, including their own but comparable farmer actor group.

Community members: villagers and tribal authorities
Although not really forming part of the scheme, the village community and the tribal authorities, including the chief do have some influence on this "ecosystem". This actor group can be linked to the more social issues that play a role in the village and indirectly affect the scheme.

Private sector: Markets and input providers
Markets for the farmers' products, hawkers and input providers have major impact on the scheme, even though they are not part of it. Farmers are in continuous contact with this actor group, which creates a significant although indirect link with the "ecosystem".

5.1.2 Action situation component

For the *action situation component* the "current situation" of the scheme is analyzed. For this research three particular action situations are of interest:

1. General water management and agriculture (WM&A);
2. Individual irrigation (II) at plot or farmer level;
3. Collective maintenance (CM) at plot and scheme level

The first action situation (WM&A) concerns all actor groups, but as the farmer actor group is most directly involved in the scheme, two more specific action situations have been studied for this actor group: II and CM. In order to understand how the three action situations take place in the Mauluma scheme or "ecosystem", the characteristic variables mentioned in paragraph 2.2.3 need to be addressed. In this analysis, only the first four variables are discussed: *participants & positions* and *actions & potential outcomes*, as they are most relevant to the "current situation" of the "ecosystem" and the defined action situations. The last two action situations (II and CM) are only relevant for the farmer actor group and are therefore not discussed for the other actor groups. The IADF questionnaire, used for this analysis are based on the three action situations and the four variables mentioned above, see example questionnaires for II and CM in appendix 5 A. Figure 5.2 gives a schematic illustration of the Mauluma action arena, including the actor component and the three specific action situations (colored dark gray) with their characteristic variables (colored light gray).

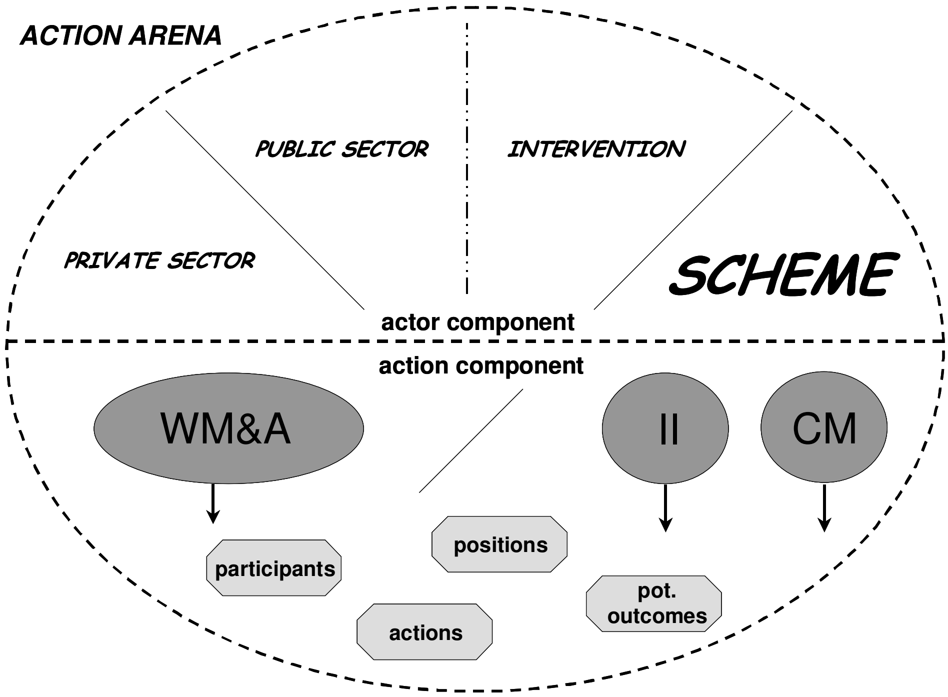


Figure 5.2 The Mauluma irrigation scheme action arena, with actor and action components

Participants & positions

The participants of each actor group have already been identified and introduced in paragraph 5.1.1. However, only the Mauluma scheme is considered in this analysis, thus excluding the other existing "ecosystems", that is the remaining twelve schemes of the Nzhelele Valley. The position and specific responsibility of each participant within each actor group is described in this section. In this analysis, the position of each actor refers to the "status" (i.e. user, provider, capacity builder, etc.) and/or the kind of "role" (i.e. institutional, decision-making, financial, etc.) an actor has in the action arena.

Public sector and intervention: DWAF, LDA and RESIS
In this actor group, RESIS plays the most important role as a participant. To give a complete picture, table 5.1 shows the position and responsibility of all three "governmental and intervention" actors regarding the first action situation (WM&A).

Table 5.1 Position and responsibilities per participant of the PS and intervention actor group

ACTOR GROUP: Public sector (PS) and intervention

Participant & position	**Responsibilities**
PS: Department of Water Affairs and Forestry (DWAF) National policy maker, financial subsidizer & legislator	**WM&A:** - Builds and finances main structures (i.e. weirs) - Legitimizes water users' associations (WUAs) (see paragraph 1.1) - Subsidizes WUAs (see paragraph 1.1)
PS: Limpopo Department of Agriculture (LDA) Provincial policy maker, project/program subsidizer & implementer	**WM&A:** - In charge of rehabilitation and revitalization of schemes - Provides agricultural support and extension - Annually receives land fees - Implements, subsidizes and involved in RESIS program
Intervention: RESIS Institutional role, capacity building & support	**WM&A:** - Implements rehabilitation and revitalization programs - Conducts training programs for farmers on scheme management, farming methods, marketing etc. - Gives institutional guidance and support - Helps in application for WUA certificate (see paragraph 1.1)

Scheme assistants: extension officer and scheme facilitator
The extension officer and scheme facilitator are two important participants of the actor arena regarding WM&A of the Mauluma scheme. Their positions along with their responsibilities are presented in table 5.2.

Table 5.2 Position and responsibilities per participant of the scheme assistants actor group

ACTOR GROUP: Scheme assistants

Participant & position	**Responsibilities**
Extension officer Advisor & communication link with LDA	**WM&A:** - Advises farmers on how to apply fertilizers, which ones and how much and on prices - Advises farmers on planting choices and methods - Is communication cord between farmers and LDA
Scheme facilitator Mediator and communication link with RESIS	**WM&A:** - Is the mediator between scheme members and if necessary community members - Is mediator between farmers and MC - Represents farmers of the scheme and makes sure their needs are heard by extension officer, LDA & RESIS - Is communication link between scheme and RESIS program

Scheme members: farmers
Within this actor group, the farmers of the scheme are the most important participants. However, even though composed of farmers, the MC is also a very significant participant on its own and is therefore considered as one actor in this actor group. The position and responsibilities of each actor regarding the last two action situations (II and CM) are presented in table 5.3.

Table 5.3 Position and responsibilities per participant of the farmer actor group

ACTOR GROUP: FARMERS

Participant & position	Responsibilities
Registered land farmers Plot holder & water user (irrigator)	**II:** - Irrigate crops according to needs - Respect water schedule - Respect fill-up night storage dam **CM:** - Participate in collective maintenance of fence & main canal - Maintain & keep own stretches in secondary canals clean
Rejected land farmers Plot holder & water user (irrigator)	**II:** - Irrigate crops according to needs - Only irrigate in weekends, unless water is plenty - Respect fill-up night storage dam **CM:** - Participate in collective maintenance of fence & main canal - Maintain & keep own stretches in secondary canals clean - If using spring water, maintain and keep springs clean
Dry land farmers Plot holder	**II:** - None, because dependant on rain **CM:** - Participate in collective maintenance of fence
MC Institutional role & support	**II:** - Sets up rules in accordance with farmers - Enforces rules and sanctions or penalties (ranges between R 5, R10 and R 20) - Moderates conflicts **CM:** - Sets up rules in accordance with farmers - Organizes collective actions - Enforces rules and sanctions penalties (ranges between R 5, R 10 and R 20) - Moderates conflicts

To have a clear understanding of the functioning of the MC, the specific position and responsibilities of each MC member are described in frame 5.1. In addition, figure 5.3 gives a schematic illustration of the organizational structure of Mauluma's MC. The MC's organizational structure shows that the chairperson, vice-chairperson, secretary, vice-secretary and treasurer actually form the core of the committee. The other members complement and strengthen the "core committee" with their so-called specific "portfolios", referring to special responsibilities and tasks, as explained in frame 5.1.

All information on the organization structure of the Mauluma MC and their responsibilities has been obtained through meetings with MC members and interviews with farmers (figure 5.3 shows a few members of the MC). In general, most smallholder irrigation schemes that are integrated in the RESIS program have a similar MC structure, as according to RESIS such institutional arrangements are essential to sustainable management of the scheme. Therefore, a well-established MC structure is a prerequisite for schemes to be incorporated in the revitalization program and eventually to meet the requirements for the legitimization and implementation of WUAs (see paragraph 6.1)

Figure 5.3 Some MC members of Mauluma during a fieldwork data meeting

Frame 5.1 Position and responsibilities of MC members

Core members:

Chairperson

Responsible for planning (dates) and chairing meetings, makes final decisions in case of a draw in votes, signs documents, forms link between all portfolio members, is main contact person for farmers and is responsible for good overall functioning of MC.

Vice-chairperson

Takes over chairperson's responsibilities in case of absence.

Secretary

Responsible for organizing meetings (invitations, letters, venue, etc.) and taking minutes at meetings, writes letters for applications or requests for donations, is chairperson's first assistant, keeps keys to the seven secondary canal outlets and night storage dam, keeps records of payments, contributions, fines and penalties and hands money over to treasurer, is responsible for checking presence of scheme members at meetings and collective maintenance activities and distribution of warnings and/or penalties.

Vice-secretary

Takes over secretary's responsibilities in case of absence.

Treasurer

In charge of managing money and bank account of the scheme, receives money from secretary and responsible for bringing it to the bank, is authorized to get money only in presence of chairperson or secretary.

Portfolio members:

Human resources

Responsible for human needs in the scheme like: forming the link between farmers, MC members, training programs etc., resolving disputes between farmers, between hired labor on plots, etc.

Technical team

In charge of infrastructure and maintenance, responsible for contacting contractors and/or hire people form community, check up on contract works/repairs, keeps material in safe place, identifies canal flow problems, etc.

Services

Forms link between service providers (i.e. input markets) and scheme, helps farmers order inputs, organizes tractors, etc.

Natural resources

In charge of management of all resources in the scheme: checks water schedule system and water wastes, resolves water sharing problems, makes sure there is no erosion, tree cutting, fire, etc.

Non-farmer

Forms link between scheme and non-farmers: organizes people who are willing to work in scheme, organizes hawkers, encourages house gardens, encourages ladies to get together and sell scheme products, etc.

** Note: MC meetings are held once a week on Tuesdays and general meetings to which all members have to attend take place once a month on Wednesdays. Decisions are taken by counting votes and majority wins. MC elections are held every year in March.*

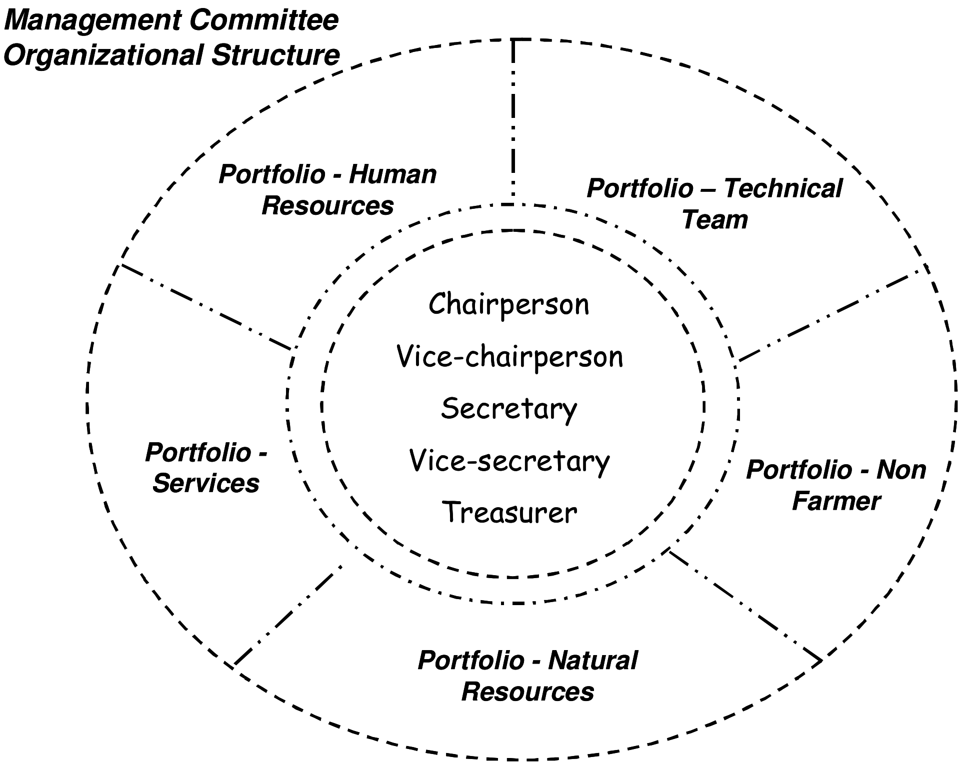


Figure 5.3 Maulama's MC organizational structure, including core and portfolio members

Community members: villagers and tribal authorities

The indirect involvement of the community in the scheme is shown by the position and responsibilities the participants of this actor group have regarding WM&A in the scheme. These are described in table 5.4.

Table 5.4 Position and responsibilities per participant of the community actor group

ACTOR GROUP: Community members

Participant & position	**Responsibilities**
Village residents Scheme clients	**WM&A:** - Buy products from the scheme - Can provide labor for the scheme - Occasionally use water from the canals for household purposes
Tribal authorities (i.e. chief) Land owner & tribal governing role	**WM&A:** - Give tribal permission to occupy land - Perform municipal tasks (e.g. organize village parties, register inhabitants in tribal office, etc.) - Moderate conflicts in village and scheme

Private sector: markets and input providers
Markets and input providers also have a position and responsibilities regarding WM&A in the scheme. For this actor group, these are shown in table 5.5.

Table 5.5 Position and responsibilities per participant of the private sector actor group

ACTOR GROUP: Agricultural links

Participant & position	Responsibilities
Markets (neighbors & hawkers) Influencing economics of farmer	**WM&A:** - Ensure farmers that their products can be sold or not - Ensure farmers to have a farming income or not
Input providers (local shops) Influencing quality of agricultural products	**WM&A:** - Ensure farmers to be able to buy inputs for their crops - Help farmers to improve the quality of their products - Give farmers advice on which inputs to apply and when - Control input prices and thus influence farmers' investments - Tractor owners availability influence farmers' planting dates

Actions & potential outcomes
The previous section on "participants & positions" portrays very well which actors are involved in the scheme, at what level they are implicated (position) and how they can impact on the scheme (responsibilities). The next step, is to look at the "actions & potential outcomes" of the chosen action situations (see figure 5.2). However, as this analysis is more focused on farmers in the Mauluma "ecosystem" and the last two action situations (II and CM), this section only considers the farmer actor group for II and CM. The different actions that can be expected from the participants in the farmer actor group resulting from their position and responsibilities and the potential outcomes of such actions are described in table 5.6. Table 5.6 does not repeat the functioning of Mauluma's water scheduling system, which is already explained in paragraph 3.4.4 and table 3.4.

Table 5.6 Actions and potential outcomes per participant of the farmer actor group

ACTOR GROUP: FARMERS

Participant	Actions & Potential outcomes
Registered land farmers	**Actions** **II:** Irrigate plot on scheduled day (once/week) by opening outlet between main and secondary canal and by partly blocking secondary canal with stones to have water flow into furrows in plot. After irrigating, close outlet and remove stones. Canal # 7 can irrigate any day. **CM:** Attend collective maintenance activities (several times per year) to cut grass near fence and clean main canal. Therefore, is allocated part of fence and main canal to maintain. Takes care of own side and stretch of the corresponding secondary canal. When necessary, group of farmers target any day to do minor repairs on fence/canals. **Potential outcomes** **II:** There is enough water for farmers of the same secondary canal to irrigate on the same day. However, sometimes one day is too short in time to irrigate a whole plot and farmers either have to use “leftover” water from other canals the next day or wait for next irrigation turn (one week later). The latter can prevent farmer from using whole plot. **CM:** Scheme fence, the main canal and secondary canals are well maintained.
Rejected land farmers	**Actions** **II:** Irrigate plot on weekends and only on weekdays when water is plenty or “leftover”. If possible, make use of secondary canals and outlets, if not use own removable pipe/hose. Those who make use of natural springs can irrigate any day. **CM:** Same as above, unless only make use of natural springs, then only attend maintenance activities for fence and keep springs clean. **Potential outcomes** **II:** In case of need, ask other farmers to use “left over” water on weekdays. **CM:** Same as above, but in addition natural springs are well maintained.
Dry land farmers	**Actions** **II:** None, because are dependant on rain. **CM:** Same as above, but only for fence. **Potential outcomes** **II:** None, because are dependant on rain. **CM:** Same as above.

Table 5.6 Continuation actions and potential outcomes for MC of farmers actor group

ACTOR GROUP: FARMERS	
Participant	**Actions & Potential outcomes**
MC	**Actions** **II:** Sets up water scheduling system and enforces with sanctions to make sure all farmers follow the schedule. In case of conflicts between farmers, matters are settled in a specific meeting. **CM:** Decides on the collective maintenance activities to be performed and when. Enforces with sanctions to make sure all farmers participate in these activities. In case of complaints or conflict, problems are discussed and solved. **Potential outcomes** **II:** All farmers respect the water scheduling system or negotiate alterations with each other, therefore conflicts and penalties are minimum. **CM:** All farmers attend collective maintenance activities or if necessary send replacement or apologies, consequently complaints and penalties are limited.

5.1.3 Discussion action arena

In this paragraph the Mauluma action arena is discussed by looking at the main and most interesting points brought forward by the variables *participants & position* of certain actors and *actions & potential outcomes* regarding individual irrigation (II) and collective maintenance (CM) of the scheme, influencing the arena.

Participants & positions

In the described actor arena of Mauluma the public sector is directly linked to the scheme through the RESIS program. However, it needs to be taken into account that as soon as the establishment of WUAs will take place, DWAF will play a much more important role, as RESIS can only help schemes to meet the requirement for WUAs, but does not have the power to legitimize them.

Extension officer and scheme facilitator

When considering the scheme assistants, the extension officer has various responsibilities regarding support and facilitation of farmers. However, in practice these responsibilities are hardly carried out. In Mauluma, it was observed that the extension officer was not updated on developments in the scheme (e.g. outdated farmers' and plot size lists). Such information was found with the MC secretary instead. Furthermore, the extension officer seemed to have some idea on fertilizer and pesticide use by the farmers, but was obviously not advising the farmers anything. Even product prices had to be discussed in presence of the MC secretary and a farmer. Farmers themselves do not really feel the need to consult the extension officer and rather ask neighbor farmers advise on such issues. In addition, the extension officer stays close to the neighboring scheme (Mavhunga) and Mauluma farmers have to walk all the way there in order to contact him. The extension officer himself does not seem to come to Mauluma that often. From this, it can be concluded that somehow the role of the extension officer is vague and becoming less important. Such a situation also exists in Thabina

(Veldwisch and Perret, 2004) and this seems to be the case in many smallholder irrigation schemes affected by the IMT process and revitalization programs. However, a difference is that schemes incorporated in the RESIS program seem to be better off, as it may very well be that the responsibilities of the extension officer will be taken over by the scheme facilitator, who is selected and trained by RESIS.

Farmers

Most farmers seem to fulfill their responsibilities well, as during field observations and interviews no major problems were identified. However, it needs to be taken into account that important more social related responsibilities like for example sustaining the household through good yields and sales, are not mentioned in table 5.3, as here only scheme and plot related issues are addressed. Regarding the MC, the responsibilities and organizational structure seems much more straightforward and developed, compared to schemes, which were addressed before the RESIS program. For example in Thabina, complicated and overlapping structures exist within the scheme. There is a general MC, but also four ward committees, managing series of secondary canals exist and seem to be much more important for management of the scheme than the MC (Veldwisch and Perret, 2004). This confirms the difference in approach between the Water Care Program, which was focusing more on technical aspects, and the RESIS program, which puts a lot of emphasis on institutional strengthening and development.

Individual irrigation - actions & potential outcomes

Regarding individual irrigation (II), it seems all farmers are "acting" according to the current water scheduling system. This seems unrealistic, as in many smallholder irrigation schemes, for example in Thabina, this is not the case at all. However, as the scheme has been left without water for 2-3 years after the 2000 floods, farmers have been extremely content with the repairs and works completed on the scheme by the Water Care Program and later on RESIS. Unlike in Thabina, the Mauluma irrigation infrastructure is in very good condition at the moment and farmers keep on repeating that there is enough water and that there are no major problems regarding irrigation turns, as the majority of the farmers accept and abide by the water scheduling system. It could be said that in fact, the scheme is still "new" and that it has not experienced major setbacks after the floods. Furthermore, Mauluma is still under guidance of RESIS, whereas Thabina had been left on its own without any guidance or support after completion of rehabilitation works, making the scheme vulnerable to mismanagement.

Another major difference between Mauluma and Thabina is that due to low water availability in the main canal (as a consequence of lack of maintenance), the issue of disadvantaged farmers downstream (tail-enders) because of advantaged upstream farmers (head-enders) taking water first had a major effect on II in Thabina (Veldwisch and Perret, 2004). In Mauluma, this is not the case at all, as firstly enough water is flowing through the main canal to reach downstream secondary canals and in addition there is a night storage dam which is filled up during the night (as no night irrigation occurs) supplying the last canal (# 7) with water during the day (see figure 3.4).

In Mauluma, there was a drought after the floods, but somehow the farmers coped quite well, as they agreed not to plant too much and to irrigate only half days. Furthermore, the scheme was not fully active yet, as repairs were barely finished. The only major problem farmers brought forward was when they were asked not to irrigate at all, to make sure water would flow back into the river and ensure some water for irrigation for the Mphaila scheme downstream, but this was more a scheme problem than an individual one.

Furthermore, surprisingly the rejected land farmers are fully integrated in the scheme and the registered farmers do not feel threatened by the rejected land farmers, as they only irrigate on weekends or when water is plenty. In fact, during field observations it was often noted that rejected land farmers were irrigating on weekdays, but when questioned it was confirmed that they consulted the registered land farmers irrigating from the same secondary canal first. Furthermore, water was usually flowing "abundantly" through the canals and often just flowing back into the river. This could be linked to the fact that observations were done in winter and only 35 % (see paragraph 4.3) of the farmers are active in that season. Farmers also confirmed that in summer the rejected land farmers are more bound to irrigating in weekends. This raises the question on what would happen if the percentage of farmers would increase in winter and how this would affect "actions and potential outcomes" regarding II.

Collective scheme maintenance - actions & potential outcomes
Regarding collective maintenance of the scheme, it seems farmers are very respectful of attending collective cleaning actions of the main canal and the fence around the scheme. All farmers confirm, that each and every one of them is present to clean their corresponding stretch of the canal or fence. The "actions" of the MC plays an important in CM as farmers know that the MC checks their presence in case of no valid apology or replacement a penalty is to be paid. However, it seems this sanction system is not the only incentive for farmers to attend CM actions, as during interviews farmers repeatedly mentioned that it is necessary to clean the canals to be sure of a constant flow. Furthermore, the secondary canals are also kept clean, even though no real control system has been implemented. Farmers seem to be quite responsible and somehow have a great sense of ownership of the scheme, contrary to other smallholder irrigation schemes. A good example is Thabina, as there the lack of maintenance is the major problem for low discharges in the main canal and consequently secondary canals (Veldwisch and Perret, 2004). In Thabina, there is no real sense of ownership, as farmers keep on mentioning that the government has to come and clean and repair their canals, contrary to the Mauluma scheme where farmers, including the rejected land ones do it themselves. This could be the effect of the changes in the rehabilitation and revitalization programs, which are now focusing a lot on issues such as farmers' sense of ownership of the scheme, irrigation management and collective maintenance.

5.2 Patterns of interaction and actor behavior

After having completed *step 1* of the IAD Framework methodology in paragraph 5.1 and having gained a good understanding of the "Mauluma irrigation scheme" action arena, the *patterns of interaction and actor behavior* in the action arena have to be identified and analyzed (steps 2 and 3, see frame 2.2). As previously mentioned, this analysis mainly focuses on the farmer actor group, thus only the participants belonging to this group are addressed for the two main action situations: II (paragraph 5.2.1) and CM (paragraph 5.2.2). Paragraph 5.2.3 ends with a brief discussion of the findings on steps 2 and 3.

5.2.1 Individual irrigation and water sharing

As explained in paragraph 2.2.3, three attributes impact on the conceptual units: "action arena" and "patterns of interaction". To identify the patterns of interaction among the participants of the farmer actor group regarding individual irrigation (II) and water sharing, these three attributes (A, B & C) are discussed below. As an actor's behavior is closely related and intertwined with the "patterns of interaction" in the action arena, the third step of the IAD Framework on *actor behavior analysis* (frame 2.2) is described below, following the third attribute.

A. Environmental settings
According to the farmers, in Mauluma the environmental settings are quite favorable for individual irrigation and water sharing. According to farmers, there are never problems of water shortage, as the Mutshedzi River never runs dry. As repairs have recently been done (see paragraph 3.4.3), water is always flowing in the main and secondary canals.

Drought
However, farmers did mention that once in a while a drought occurs. When this happens or in the dryer months of the year (August-January), the scheme makes an effort to use less water and all farmers participate herein. As explained in paragraph 3.4.4, farmers plant less beds, only irrigate half a day and sometimes even let water flow back into the river, so that schemes downstream are still able to irrigate. Such alterations in water use practices and irrigation strategies are discussed and decided during MC and general meetings. However, during drought farmers often practice these water saving methods on own initiative.

Presence of baboons
A completely different environmentally linked problem is the abundant presence of baboons, as their habitats are the mountains alongside the Mutshedzi River. Farmers with plots near the river especially suffer from baboons coming on their plots to eat from the crops. Therefore, these farmers are forced to guard their plots the whole day, especially during summer.

B. Attributes of community or "culture"
From interviews, it can be concluded that the Mauluma farmers seem to be quite tolerant and cooperate towards one another regarding the water scheduling system of the scheme.

Flexible water scheduling rules
Even though farmers have their own specific day to irrigate, often when they do not manage to finish irrigating their plots, farmers agree amongst each other to finish their plots on another day, thus in fact not respecting the water scheduling system. For example, in the field farmers often meet each other and discuss the state of their crops and agree that when their crop is in desperate need of water, they can use each others "leftover" water. Also, when certain farmers are not even irrigating, as they didn't plant, others can benefit from that and irrigate instead of them. In times of drought, the water scheduling rules are less flexible, but nevertheless farmers seem to relate quite well to one another on the water issue and therefore manage to share water even in times of drought.

Rejected land farmers
In general, the rejected land farmers also participate in these alterations to the water scheduling system, but evidently during drought, they are the ones to suffer most. Especially,

the ones located at the end of secondary canals, as the water reaches them last. However, quite a few rejected land farmers benefit from natural springs, which allows them to be independent from the other farmers. Especially the ones located after the 7th canal, as they practically have their own natural spring and irrigation system. However, in times of drought, the springs can be completely dry and the rejected land farmers are forced to negotiate with the farmers from the 7th canal to be able to use water from the night storage dam on weekdays.

Management committee
The MC is not bothered by the farmers' flexible interpretation of the water scheduling system, as long as no conflicts occur. Until now, water sharing practices amongst farmers have always proceeded smoothly, but as soon as disputes arise the MC tries to solve them by either discussions or if necessary by enforcing the water scheduling rules by penalties.

Land sharing
Another "cultural" community aspect in Mauluma is the way farmers share their land. Farmers often hire people from the community to work on their land (planting, weeding and harvesting). As often farmers cannot afford to pay their laborers a salary, instead they offer them part of their crop or even part of their land. As a result, people of the community who are not official members of the scheme have the opportunity to farm on 2-4 beds. According to scheme members, they are happy to offer such opportunities, as it allows non-plot holders to provide their households with food. In addition, farmers mentioned that often they are not able to invest a lot of money in farming and therefore sometimes cannot even manage to cultivate their whole plot. By "sharing" their land with other community members, the land does not remain unused and the scheme is used optimally. Scheme members even hope that those farmers who are not active in winter, will allow other community members who are willing to farm but do not have access to land, to cultivate these plots at times when the plot owner is not active.

C. Rules-in-use
The rules-in-use regarding individual irrigation (II) and water sharing are well defined by the water scheduling system explained in paragraph 3.4.4. Furthermore, farmers usually abide by these rules, however as explained above, sometimes do "break" the rules but mostly in accordance with one another.

Actor behavior
According to interviews, most farmers are satisfied with the current water scheduling system and as a result conflicts hardly arise. However, farmers did mention that in times of drought water shortage occurs and especially when they are forced to share water with schemes downstream. At these times, farmers are less content, but cope with the situation. In severe cases, complaints are addressed and discussed in MC meetings. Furthermore, because of the "flexible interpretation" of rules by the farmers, it can occur that farmers in time of need just use water, without consulting the farmer who is allowed to irrigate on that day and thus disrespect the rules. When this happens, the farmers authorized to irrigate try to talk to this farmer first. If they cannot come to an agreement, the MC is informed and consequently the farmer can be penalized. Farmers also mentioned, that sometimes they find it hard to negotiate with others, as when neighbor farmers show them their "dying" crop in need of

water, they find it hard to refuse them, even though they themselves cannot afford to share their water for irrigation. As a result, it happens that farmers irrigate till late hours.

Closing outlets for the night storage dam
Sometimes farmers who were last to irrigate, tend to forget to close the outlets from the main canal to the secondary canals at night, meaning that the night storage dam is not filled up. Usually, farmers check up on each other, but if it happens often, this issue is discussed in MC meetings and if necessary farmers who were irrigating last, can be fined.

Rejected land farmers & night storage dam
The rejected land farmers, located next to the 7th canal have built their own pipe system connecting to the night storage dam. Therefore, in the weekends they use water from the night storage dam, if spring water is not enough. In times of drought, this pipe system also allows them to use water from the dam, but this is only done in accordance with the registered land farmers.

5.2.2 Collective scheme maintenance

As in paragraph 5.2.1, to identify the patterns of interactions within the farmer actor group regarding collective maintenance (CM) of the scheme, the three attributes mentioned in paragraph 2.2.3 are argued below. Also here, *actor behavior* (step 3, see frame 2.2) is described after the third attribute below.

A. Environmental settings
Regarding collective maintenance (CM) of the scheme according to farmers, the environmental settings do not form major issues.

Weeding
The growth of grass around and near the scheme fence and near the main canal is the main thing to be taken care of. This is done collectively, several times a year and is organized by the management committee. Excessive grass growth near the secondary canals is taken care of by the farmers themselves, as each of them keep their stretch of secondary canal clean, including the canal itself.

Night storage dam
There is a lot of grass growth in the dam itself. At the moment, this does not affect the water discharge into the 7th canal much yet. Farmers explained that the cleaning of the dam is still part of the RESIS program, which will take place soon. However, in the future, farmers said they will have to organize themselves and clean and maintain the dam collectively.

B. Attributes of community – "culture"
For the farmers, there is not much to argue about when discussing maintenance of the scheme. It is clear that on specific days, decided in MC meetings, collective maintenance of the main canal and fence takes place, in which all farmers participate. It is not accepted that farmers do not fulfill this responsibility and therefore in case of absence, either an apology must be given to the MC or replacement has to be found by the farmer him or herself. Concerning the secondary canals, all farmers keep their own stretch clean. If other farmers notice that water is not coming through, they check where the blockage comes from and if this is due to lack of

maintenance by another farmer, the issue is discussed and taken care of immediately. In serious cases of negligence, the problem can be discussed with the MC, who can use penalties as a last resort.

C. Rules-in-use
As can be concluded from above and from table 5.6, there are clear rules on collective maintenance (CM) of the scheme, concerning the main canal, the night storage dam and the fence around the scheme. For example, each farmer has his own assigned stretch of the main canal and of the fence, which he needs to clean up during collective maintenance activities. Furthermore, as mentioned previously, additional rules concerning individual maintenance of secondary canals are applied. The MC plays a rather significant role in the rule-system regarding collective scheme maintenance, as they are in charge of organizing these collective maintenance activities and make sure every farmer is participating (and give fines if necessary).

Actor behavior
According to interview results, most farmers deeply respect the rule of participating in collective maintenance (CM) activities. The only arguments that have been used to justify absence of certain farmers are age or other commitments. However, all farmers confirmed that in those cases either a substitute is found or the farmer comes back on another day to do his specific job. In any case, farmers explained that if they do not abide by the collective maintenance rules, they get fined, which they would rather avoid. Also, they emphasized that if they neglect the "clean-keeping" of the canals, they are the ones to suffer the consequences (i.e. low water flow). Farmers also mentioned that maintenance is always well organized by the MC and always takes place on time in order to avoid problems with water flow or with the fence. Nevertheless, if farmers have a complaint or notice there is a leakage or anything of the like, they discuss this with the MC and a solution if found (either they fix the problem themselves or hire a contractor).

5.2.3 Discussion on actor interaction and behavior

This paragraph discusses the interactions between actors and actor behavior presented in paragraphs 5.2.1 and 5.2.2, concerning the two action situations individual irrigation (II) and collective maintenance (CM) of the scheme.

Individual irrigation
It is clear that in Mauluma lots of interactions occur between scheme members, which are not always in accordance with the formal water scheduling rules. However, it is interesting to note that somehow these interactions are transparent and farmers consult each other before performing and action, which officially could be punished by a penalty. From the field it has been observed that the Mauluma farmers are quite pleasant and comprehensive towards one another and farmers understand each other when the one asks the other to allow him to irrigate his crop in need of water, even though it is not his turn. A major difference with other schemes, such as Thabina is that there have not been any conflicts regarding water scarcity and farmers have never had the need to secretly irrigate in order to save their crops. This is

also why the MC sees no problem in this flexible interpretation of the water scheduling sytem and individual alterations. An interesting question is how this water sharing system will be affected by ongoing training sessions of RESIS program, which in the future will surely address the water scheduling system and perhaps even suggest a new Water Management Plan (see paragraph 3.4.2). Another question concerns the irrigation methods of the farmers, as through RESIS training, farmers might decide to plant other kinds of crops, because for example of better markets. Such changes could affect their flexibility in irrigation turns. In short, it can be concluded that Mauluma is still in the process of change and maturing, so the current "interaction and behavior" of actors can still alter significantly, depending on the further development of the scheme during RESIS and after.

Collective maintenance of the scheme
As mentioned before, interactions and actor behavior regarding collective maintenance is quite clear. Scheme members respect the cleaning activities in the scheme and actively participate in these actions. Whenever somebody cannot be present, apologies are made or a substitute is found. Compared to Thabina, in Mauluma cleaning the main canal and the maintenance of the fence are collective proceedings, which scheme members see as actions they are responsible for and benefit from. This refers back to a well-developed sense of ownership in Mauluma, which does not exist in Thabina.

5.3 Three levels of rules

The last step in the IAD Framework, described in paragraph 2.2.3, is to identify the three levels of rules that play a role in the "Mauluma irrigation scheme" action arena. As the rules-in-use have been thoroughly presented in paragraphs 5.2.1 and 5.2.2 and to avoid repetition, only a short clarification is given on the existing rules in the Mauluma scheme, according to the three levels Ostrom, *et al.*, 1994 distinguish. Paragraph 5.3.1 does this for individual irrigation (II) and water sharing and paragraph 5.3.2 for collective maintenance (CM) of the scheme. Paragraph 5.3.3 discusses these rules-in-use.

5.3.1 Individual irrigation and water sharing

Below, the three levels of rules are specified for individual irrigation (II) and water sharing in Mauluma.

Operational rules

- Irrigation and water sharing should be done as prescribed in the water scheduling system, which needs to be agreed on by the MC and all members of the scheme. Alterations to the water scheduling system may take place at own risk and own responsibility to cope with the consequences.
- Violation of the water scheduling rules will be monitored and sanctioned by the MC (natural resources portfolio).
- Violation of the water scheduling rules that have gone unnoticed and/or cause conflict must be reported to the MC.
- In times of drought, the MC in accordance with all scheme members will temporarily and appropriately adapt the water scheduling system.

Collective-choice rules

All operational rules can be adapted and changed, when needed and when requested through discussions in MC meetings and in accordance with all scheme members.

Constitutional-choice rules

Every scheme member is eligible to participate in discussions on the rules-in-use (operational and collective-choice) regarding individual irrigation and water sharing. In MC meetings, changes and adaptations to these rules are agreed upon through a voting-system where majority counts. In case of a draw, the chairperson has the power to make the final decision.

5.3.2 Collective scheme maintenance

Below, the three levels of rules are specified for collective maintenance (CM) of the Mauluma scheme.

Operational rules

- Every member in the scheme is obliged to participate in collective maintenance activities for the main canal, the fence and the night storage dam.
- Collective maintenance activities take place several times a year, of which the dates the MC decides upon, in accordance with all scheme members.
- The MC (secretary) monitors attendance and in case of absence and no apology or substitute a sanction is applied.
- All secondary canals must be maintained throughout the year on individual basis.
- Negligence of secondary canals must be reported to the MC and will be penalized.

Collective-choice rules

Equal to individual irrigation and water sharing rules.

Constitutional-choice rules

Equal to individual irrigation and water sharing rules.

5.3.3 Discussion on existing rules

From paragraphs 5.3.1 and 5.3.2, it seems the existing ruling system seems well developed. However, with the disrespect of rules and problems regarding II and CM in Thabina, it is hard to believe that in Mauluma the ruling system can exist without any problems. As has been stressed repeatedly throughout this chapter, the fact that water is not scarce at this point in time in Mauluma is the major explanation for the absence of major water management and scheme maintenance conflicts. Furthermore, in Mauluma farmers do not feel they are competing against each other but acknowledge that they are all “colleagues” and working together in a scheme that belongs to all of them, contrary to Thabina, where such “team” feelings are hard to find. Nevertheless, farmers have confirmed that once in a while farmers have received penalties for not being present at CM activities or even for irrigating at inappropriate times. In general however, this does not seem to occur regularly as farmers feel responsible for their actions and prefer to maintain a good relationship with others in the scheme as well as with the MC. It will take another two years, when the RESIS program will complete the work or even a year after, before the current ruling system will actually be put to challenge. It is only then that the scheme will start functioning independently and when difficulties or setbacks will have to be endured and solved by the MC and the scheme members on their own. At that point in time, the current ruling system can be judged more appropriately as it is mostly during difficult times (e.g. drought, increase in crop surface and water demand because of more water demanding crops, etc.) when a ruling system if abided by, brings “order and organization” and can influence the management of the scheme in a positive way.

5.4 Ostrom’s eight efficiency and sustainability principles

Finally, in order to summarize results obtained from the IADF approach, which have been presented throughout this chapter and to give a clear view on the scheme’s economic and financial viability, institutional strength and overall efficiency and sustainability, Ostrom’s “8 design principles” (paragraph 2.3) for sustainable irrigation systems and institutions are reviewed below.

1. Clearly defined boundaries
The Mauluma scheme has clear boundaries, which are known to the scheme members themselves and to the village community. A well-maintained fence protects the scheme boundaries and prevents cattle from trespassing.

2. Proportional equivalence between benefit and costs
Results on the SMILE approach (chapter 4) partly address this principle. As discussed in paragraph 4.4.3, Mauluma’s annual gross margin of R 433,000 is relatively good compared Thabina (~ R 59,000). However, labor costs still need to be subtracted. In addition, at the moment the scheme does not charge farmers any water fees, but will probably be doing that in the future, in order to finance any operation and maintenance costs. These additional costs will have to be subtracted from the gross margin in the near future as well. Regarding this aspect, it is most important to answer the question on how much a farmer is actually going to

be willing to pay for water charges, which depends on the gross margin a farmer makes from farming, but also other incomes he might have. Again here, the livelihood question rises (as explained in paragraph 4.5), which will give insight on the farmers' motivation and interest to invest in farming or not. Due to all these "unknowns", it is difficult to say if a proportional equivalence between benefit and cost will be achieved in the near future.

3. Collective-choice arrangements
As explained in paragraph 5.3, the collective-choice arrangements are equally organized among scheme members. Modification of rules, due to changes in environmental and other settings, can be proposed by any scheme member and will be agreed upon in MC meetings through majority of vote.

4. Monitoring
Monitoring in Mauluma is actually ongoing in a collective way, as all farmers cooperate closely together, as explained in paragraph 5.2. Furthermore, the MC plays an important role in monitoring, through own observation or through farmers' reports and applies penalties and sanctions when rules are violated.

5. Graduated sanctions
As mentioned above and in paragraph 5.2, in Mauluma, a penalty system exists, which is enforced by the MC in cooperation and accordance with all scheme members.

6. Conflict resolution mechanisms
As explained in paragraph 5.1.2, the MC plays an important role in conflict resolution mechanisms. In specific, the MC member in charge of the human resources portfolio is the one mainly responsible for conflict resolution. In addition, the chairperson can also help in resolving conflicts in the scheme.

7. Minimal recognition of rights to organize
The MC is recognized as the official institution managing the irrigation scheme. However, there is no formal proof of recognition by government. The establishment and transformation into a legitimate Water Users Association (WUA), plays a crucial role in obtaining formal recognition by government. RESIS in cooperation with DWAF are focusing on this issue, which is explained in more detail in paragraphs 1.1 and 1.2.

8. Nested enterprises
When looking at the organization of the Mauluma scheme, the MC forms a structure with nesting layers of organization, referring to core MC members and the different portfolio members (see paragraph 5.1.2). Other than that, no other forms of organization seem to exist. However, there appears to be potential for farmers to organize themselves regarding collective input investments and also collective crop production for available markets. Nearby, the GIANTS factory is an interesting market for tomatoes, as long as the quality of the crop corresponds to the factory demands. There could be major interest in starting up some kind of joint venture between the scheme and the factory, as has been done in other schemes incorporated in the RESIS project (e.g. production of cotton and bananas). Another interesting form of organization would be for the scheme to collectively invest in tractors so

that farmers are no longer dependent on tractor owners who are scarce and expensive at the moment and substantially delay farmers in planting their crops.

Discussion and comparison with Thabina

When trying to answer the "8 design principles" with what has been found in Thabina by Veldwisch and Perret, 2004, very different conclusions are drawn compared to Mauluma. In Thabina, there are also *clear boundaries*, but Thabina does not perform as well as Mauluma on the second principle *proportional equivalence between benefits and costs*. Also the *collective-choice arrangements* are not as well organized as there is only one group of active farmers, who are mostly involved in the MC and thus no equal arrangements exist. Furthermore, no clear forms of *monitoring* or *graduated sanctions* exist. Furthermore, a lot of conflicts are ongoing between head-enders and tail-enders, but no real *conflict resolution mechanism* seems to be able to address this. As Thabina has completed rehabilitation programs, the scheme should be officially ready to establish a WUA. However, as it was one of the pilot schemes for rehabilitation and is not functioning properly yet, the scheme will most probably have to be readdressed through the RESIS program, before qualifying for any *legitimate recognition* as a WUA. Finally, regarding the organizational structure of the scheme very complex overlapping *nested layers of organization* exist (ward committees, functioning under the MC committee), but as these layers are not really functioning properly together with the main MC, such nested layers are more disadvantageous than beneficial for the scheme. Furthermore, in Thabina there is hardly any sense of ownership among the scheme members and a strong sense of competition for water among farmers, which are accompanied by feelings of being threatened by one another, other forms of organization such as joint-ventures seem very unlikely to be successful.

For Mauluma, it can be concluded that almost all eight principles of Ostrom seem to have a positive answer, or are answered by arguments, which imply relatively positive results in the future. This shows that Mauluma has a good prospective in becoming an economically viable and sustainable smallholder irrigation scheme. The question is however, if things will continue to run as smoothly or even improve after the RESIS program is completed and the scheme will have to survive on its own. In addition, the implementation of a water charging system can have a major effect on the further development of the scheme. Until now, farmers have acknowledged that when they will be independent and responsible to solve problems in the scheme, which will involve costs (e.g. technical repairs, water leakages, etc.) and hire personnel (e.g. water bailiff, secretary, etc.), water charges will have to be implemented. Until now, farmers seem to agree to pay water and operation and maintenance cost, but it remains unclear how much they would be willing to pay. Most probably this is due to the fact that farmers have no clear idea on how much they spend and make with farming and therefore can not really say how much of that income (or other incomes) they would be willing to set aside for scheme costs.

5.5 Conclusion and recommendations Mauluma

From the IADF approach results on Mauluma, presented in this chapter, knowledge is gained on individual farmer irrigation practices and strategies, on collective scheme maintenance activities and on existing regulations and institutional arrangement. This paragraph summarizes the main conclusions and recommendations resulting from analysis for the scheme itself, but also for the RESIS program.

Further development of institutional strengthening

With the current MC structure and the ongoing well-attended meetings held per week and per month, there seems to be a good institutional basis in Mauluma. However, this structure should be developed further, especially regarding the responsibilities of each portfolio member, which should become more important than they are now. Farmers did appoint these members of the MC and seem to vaguely know what their tasks are, but it was noticed that somehow it is still unclear how the responsibilities should be put into practice. This is one of the aspects RESIS is still going to work on in their program, which is crucial to the further strengthening of the institutional arrangements in the scheme and to a good and sustainable management of the scheme in the future.

New Water management plan versus current water scheduling system

At the moment the water scheduling system seems to work well and most farmers are satisfied with it. However, with possibly further developments and changes in the future such as more active farmers, different crops, etc. it might very well be that the current water scheduling system will not be as appropriate and also less flexible as it is now. In addition, most farmers want the rejected land farmers to become officially registered as they are part of the scheme, but questions regarding their integration in the official water scheduling system have not been discussed yet. For now, they are irrigating in weekends, but there might be possibilities that with the new Water Management Plan (paragraph 3.4.2), already proposed in the Water Care Program, a more efficient use of water can be implemented and therefore more farmers could benefit from irrigating during the week. Again here, RESIS plays an important role as in their program this issue needs to be addressed and farmers will have to be properly trained in following a new water scheduling system, if implemented. Hereby, it is essential to be sure of an efficient yet equitable distribution of water to which farmers agree and to guard the good relationships among and between farmers that exist at the moment, as it would be misfortunate if conflicts that were not present before arise in the scheme because of a new supposedly “efficient” Water Management Plan.

Start discussion on water charging system

In Mauluma, farmers are not paying for any charges regarding the scheme. However, in the future, such costs will most probably be implemented, as the RESIS program is the last form of “intervention” the government is subsidizing. This means that in the future the scheme will have to be able to keep the scheme functioning independently. As farmers are not used to paying any fees, it will most probably take some time to get used to this idea, even though farmers confirm that they know they will have to start paying in the future. Also here, RESIS will have to open discussion regarding this issue and help the scheme to assess their capability to account for cost recovery. Using the SMILE approach in economic viability studies is already a good start, but more data on farmers’ actual expenditures and incomes is needed to be able to get an idea of how much farmers will be able and willing to contribute to scheme costs. As recommended in paragraph 4.5, therefore *record keeping* regarding farming costs and sales and specific *livelihood analyses* are essential.

Design forms of collective organization to lower input costs
As brought forward in principle eight in paragraph 5.4, it would be most advisable for farmers to start collective organizations for buying seeds, fertilizers and pesticides as a scheme, as this would allow them to buy in bulk and thus at lower prices. Farmers indicated that such actions have been performed before, but not all farmers were involved. Furthermore, the MC member in charge of the service portfolio has recently been changed and new incentives to buy inputs in bulk have not been initiated yet. Further development of portfolio MC members with RESIS could focus on this issue. Furthermore, as there seems to be an interesting market for tomatoes with GIANTS, it should be investigated how sales to this factory can be ensured. RESIS could initiate contacts with the factory through the service portfolio MC member and start training programs for production of good quality tomatoes. Finally, as the scarcity of tractors in the scheme has frequently been mentioned by farmers in addition to their complaints about how expensive land preparation is, it seems farmers could benefit by starting some kind of collective money saving action, to be able to invest in tractors, which will belong to the scheme. Perhaps, this could be integrated with the plans on future charges for water and scheme maintenance.

Perform IADF approach again after RESIS
It is evident from what is presented and discussed in this chapter that the IADF approach has given a good idea of the various institutional arrangements in Mauluma and more specifically what is happening when considering individual irrigation and collective scheme management. However, it is stressed continuously that in fact the scheme is not really ready yet to be judged on its institutional arrangements, as it is only just learning and applying institutional improvements through the RESIS program. Such a situation makes the results of the IADF approach seem very unproblematic, which at the same time seems unrealistic. However, the IADF results give a good description of the current situation, which is probably comparable to a lot of other smallholder irrigation systems, which are now addressed through the RESIS program. It would be most interesting to do this analysis again, once the RESIS program has been completed and the scheme has been functioning independently for a certain amount of time. Those IADF results can then be compared to the current ones and conclusions could be drawn on the institutional development of the scheme.

6 CONCLUSION & DISCUSSION: APPLICATION OF METHODOLOGIES

In this chapter a final conclusion on the application of the SMILE and IADF approaches is given. Therefore, the relevance as well as the limitations of both approaches for the RESIS program and for future research are discussed in paragraphs 6.1 and 6.3. In paragraph 6.2 a short interlude is given on how the SMILE approach has been tested for RESIS on the Morgan irrigation scheme (Venda region, Limpopo Province). Finally, paragraph 6.4 ends with some general conclusions and recommendations for further use of the two approaches in the RESIS program and further research.

6.1 Application of SMILE approach and methodology

Below, the application of the SMILE approach and methodology, as described in chapter 2, is discussed. The interests and limitations are argued for both the RESIS program and for future research in paragraphs 6.1.1 and 6.1.2.

6.1.1 Interests and limitations for RESIS

As explained in chapter 1, RESIS needs to assess the economic viability of all smallholder irrigation schemes before these can be officially admitted into the revitalization program. Schemes have to be proven "economically/financially viable", before any revitalization by RESIS can take place and before any WUA can be legitimately implemented by DWAF. Therefore a suitable tool was needed to perform this evaluation for all schemes.

Relevance of SMILE
Through many discussions between RESIS and CIRAD & UP researchers over the past two years, SMILE was found to be one of the tools RESIS could use for the required economic viability studies. The SMILE approach seems very adequate, as it provides economic results and results on water requirements for irrigation at crop, farmer and scheme level (paragraph 2.1). These results are needed to determine whether a scheme is economically viable and thus conclude it the scheme is "worth" revitalizing.

Implementation of WUAs
RESIS is also helping schemes to strengthen their institutions (i.e. MC) so that they can apply for the establishment of WUAs with DWAF. Therefore, RESIS is in continuous meetings and discussions with DWAF representatives on what is required of a scheme before a WUA can be legitimized and implemented. The economic viability studies containing SMILE results, which give an indication of economic performances of the existing farming systems can help DWAF determine if the scheme is well prepared and sufficiently equipped to implement and suitably manage a legitimate WUA. In addition, the results on irrigation requirements obtained through SAPWAT can significantly help DWAF in water allocation and licensing as an estimation is obtained of the volume of irrigation water needed for the scheme to provide its crops with sufficient amounts of water.

Limitations
A major limitation when using SMILE for RESIS is “time”. As RESIS has to revitalize approximately 130 schemes in a time span of 6-9 years it is unfeasible to apply the full SMILE approach (paragraph 2.1), which takes a researcher about 3-4 months. Furthermore, all data is based on interviews with farmers, which are not always very reliable as in general most farmers do not keep any records. Consequently, all answers are based on what farmers can remember, which cannot be verified or validated with recorded data. Therefore, when analyzing SMILE results, all figures need not be interpreted as an exact reflection of reality. This goes for both economic results as results on water requirements for irrigation. At the same time RESIS needs consistent data to be able to justify economic viability of a scheme, as well as DWAF in order to implement WUAs.

6.1.2 Interests and limitations for future research

The SMILE database and platform has developed significantly over the past four years, as explained in paragraph 2.1. From a conceptual framework to numerous excel spreadsheets it has now evolved and matured into a users friendly tool and database, which is available on the Internet. For researchers this provides broad possibilities to analyze smallholder irrigation schemes from an economic point of view in relation to agriculture, irrigation and water management. In addition, through its unlimited accessibility online, information on irrigation schemes all over the world can be stored, compared and analyzed.

Practical application: RESIS
An interesting development has been the collaboration of CIRAD & UP researchers with the RESIS program. At first, SMILE was mostly used for economic and financial viability studies on irrigation schemes, performed by researchers in research projects. Since the past two years, SMILE has attracted a lot of other potential users in South Africa, such as government representatives (DWAF & LDA), consultants (i.e. Golder Associates, WOMIWU, RIENG, etc.) and more recently RESIS. This growing interest in SMILE to be used as a practical tool for government and consultancy projects has enhanced another quality of SMILE, which extends much further than only research.

Limitations
In most research projects, which have been performed lately for CIRAD at UP, the SMILE approach has been applied to full extent (e.g. Dingleydale-New Forest, Thabina, etc.). This means, that from field data averages have been calculated at crop and farmer level (see appendix 2 A). It is obvious that this is very time consuming and that it takes a long time before all the data has been prepared (i.e. conversions to comparable units, calculations of average total revenue, input cost, etc.) and is ready to be used as input for the SMILE database.

Monograph approach
As explained in appendix 2 A, the monograph approach is an alternative to the “original” more time consuming SMILE method. The monograph approach has been applied in this research on Mauluma, which made it possible to perform SMILE calculations in a much shorter time period. This approach was also used for RESIS, but was even simplified more

(see paragraph 6.2). However, the monograph approach implies a few limitations, as one farmer is chosen to represent his type as a monography. This means that all farmers within the same type are assumed to "farm" in the same way as the monograph farmer. This is evidently not the case in reality and thus some diversity is lost while applying this approach. Furthermore, only data from the chosen "representative" farmer eventually provides input for SMILE, meaning that all other information gathered on the field from other farmers is not actually being used or stored in the database itself. This data is "lost" and can only be found in the researcher's spreadsheets, which have been made prior to SMILE simulations to compare results and identify the monograph farmer.

Unreliable data

As already mentioned in paragraph 6.1.1, a major concern regarding SMILE is its need for accurate data to be able to generate reliable results. The tool itself can give very interesting and useful output information, but highly depends on precise input data. As all input data relies on field interviews with farmers, there are bound to be certain inaccuracies. This risk of working with erratic data depends from scheme to scheme, but in general this always plays a significant role. Concerning this research on Mauluma, it has to be taken into account that farmers never kept any records, meaning that when answering questions they often have to rely on their memory. In interviews it has been experienced that farmers have a real hard time remembering how much they harvested from a certain crop, how much money they gained from it, let alone how much money they invested in input costs. In addition to using "questionable" data as input for SMILE, these uncertainties make it difficult to identify the adequate monograph farmer.

Missing link with livelihood & household analysis

Even though SMILE considers economic results at crop, farmer and scheme level, it does not consider these results at livelihood or household level. This is a very important aspect, as a farmer's life does not only consist of agriculture and irrigation. The farmer has a family to sustain and each farmer's financial situation reflects the general well being of the community he/she is part of. Therefore a livelihood & household analysis (see frame 4.5 for a simplified example) would complete the SMILE approach, as hereby not only agricultural incomes and costs are considered but also all other incomes and costs a farmer is confronted with (i.e. social grants, salaries, remittances, rent, school fees, electricity bills, etc.). From such analysis, it could very well be reflected that the income generated from agriculture is more or less significant than other incomes, which will help to understand why a farmer is either active and investing a lot in agriculture or not and how much he/she is able and/or willing to pay for water charges, which will be implemented on the long-run. On the other hand, non-farming incomes may be capable of sustaining farming activities and cover some farming costs besides the household costs and help to motivate farmers to become more active in the scheme.

Future evolutions

In this research, there was no time span available for scenario testing, although this is a very important and most interesting component of the SMILE approach. However, it needs to be taken into account that scenario testing is only relevant if the farmers of the concerning scheme are interested in such simulations, meaning that they should be ready to question themselves about the future of the scheme. Such simulations will be more difficult for schemes that are only at the beginning or half way through the revitalization process, like

Mauluma, as they have not gained much experience yet with the newly revitalized scheme. Furthermore, before testing scenarios in SMILE, researchers farmers and other implicated stakeholders should agree that the SMILE results represent the "current situation" of the scheme well enough, depending on available data. Regarding future research evolutions in SMILE, scenario testing is important, as in this phase "action-research" plays a significant role, which is one of the main objectives of the SMILE database platform. Scenarios are created, requested and discussed by farmers, which inevitable makes this phase of the approach participative and actually steered by farmers. Furthermore, scenario testing can form the starting point for role-playing games, which can give all actors involved a much better idea of what the stakes are and what each actor wants or needs and how he/she will behave in order to get it. This concerns both farming strategies as water management and irrigation practices.

6.2 Interlude: Designing and testing a simplified SMILE approach

As explained in paragraph 6.1.1, there is a need for a more simplified and less time consuming approach, in order to use SMILE in the RESIS program. Therefore, in addition to this research on Mauluma, a simplified SMILE approach has been designed in collaboration with the RESIS task team on sustainability and two agricultural economists of the LDA, working for RESIS. The task team designed a new 15-day fieldwork methodology, which was performed by the two economists on the Morgan pilot scheme. This was followed by a 1-2 week data analysis period by the two economist, partly in cooperation at UP and partly independent at LDA. As this was only a first test in using the designed simplified approach, the time consumed was still quite long: approximately one month. However, once the two economists are completely familiar with the methodology and fully capacitated, the simplified approach should be feasible in two weeks time.

In paragraph 6.2.1 the fieldwork results (performed by the two LDA economists) of Morgan are presented, followed by the general SMILE results in paragraph 6.2.2, which are compared to the Mauluma scheme. In paragraph 6.2.3, the limitations of this simplified approach are discussed as well as its future in the RESIS program.

6.2.1 Morgan fieldwork results

Morgan is also located in de Venda region, but more to the east and closer to Thohoyandou, see figure 6.1. Morgan has a pipeline system until the plots, from where the water flows into furrows. There are 23 farmers, with an average plot size between 1-2 ha, except for two "commercial" farmers with 4 and 8 ha. Three farmers are not irrigating and only cultivate in summer, as they depend on rain. Even though these farmers are connected to the system, they cannot irrigate because they have not got sufficient funds to pay for water fees, charged to every irrigating farmer. The other 20 farmers irrigate and cultivate both in summer and winter. The total scheme area is approximately 75 ha of which about approximately 38 ha of the land can be potentially irrigated and 37 ha is dependent on rain (dry lands). However, only approximately 36 ha of the land is under irrigation, due to the three farmers who are connected but do not irrigate (Legodi and Dikgale, 2004).

To obtain the SMILE input data for Morgan, an appointment was made with Morgan's MC. In this meeting the list with all farmers was discussed and together with the MC a suitable farmer typology was made. Criteria were developed to facilitate the typology procedure. These criteria include plot size, production season and type of agriculture being practiced (rainfed or irrigated) (Legodi and Dikgale, 2004). The application of these criteria resulted in five farmer types, as presented in table 6.1.

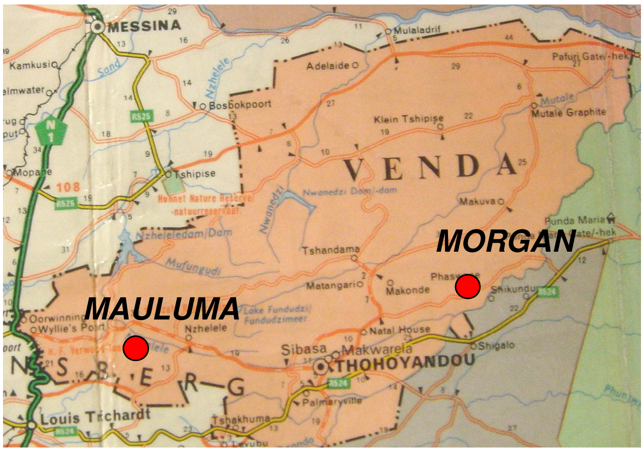


Figure 6.1 Morgan and Mauluma in the former Venda "homeland"

Table 6.1 Farmer typology and representation in Morgan

Farmer type	Number of farmers in type*	Average plot size* [ha]	Total area in scheme* [ha]	Type scheme representation** [%]
Summer *non-irrigating*	3	0.67	2.25	5
Winter & Summer *irrigating < 2 ha*	13	1.0	12.75	35
Winter & Summer *irrigating > 2 ha*	5	2.1	10.50	28
Commercial Winter & Summer *irrigating*	1	4.0	4.0	11
Commercial Winter & Summer *irrigating*	1	8.0	8.0	21
TOTAL	**23**	**-**	**37.5**	**100**

** Data calculated by SMILE, with same consequences as explained in paragraph 4.3.1. Also here as a result of SMILE's inconsistency with exact and rounded off figures, the total area a type represents in the scheme does not exactly equal: number of farmers * average plot size.*

*** The representation in the scheme is calculated by taking a total scheme area of approximately 38 ha, thus excluding the remaining dry land (approximately 37 ha).*

Hereafter, the "representative" farmer per type had to selected in order to apply the monograph approach. This was done through discussion and consultation with the MC who in the end advised which farmer would be best to represent his/her type. This implies, selecting a certain "average" farmer, who is not the best neither the worst in his type. Finally, this monograph farmer is the one to be interviewed and whose answers serve as input data for the SMILE database. Consequently, for Morgan, only five farmers were interviewed; one "representative" farmer per farmer type.

After field data was obtained, all information was prepared for the SMILE database at UP. SMILE was run and the results were analyzed (see paragraph 6.2.2). Finally, all SMILE results were presented to the farmers and validated in a report-back session.

6.2.2 Morgan general SMILE results

In order to show the final results of the application of the simplified approach on Morgan, this paragraph only gives the general SMILE results in table 6.2. A more detailed explanation of all the results at crop, farmer and scheme level can be found with RESIS and the document that will be generated by the two economists who performed the economic viability study on Morgan (Legodi and Dikgale, 2004).

Table 6.2 SMILE results at scheme level (calculated on annual basis)

GENERAL	
Number of farmers	23.00
Scheme area [ha]	75.00
Number of irigation farmers	20.00
Potentially irrigated area [ha]	35.25
ECONOMICS	
Total revenue [R]	**502,158.01**
Average total revenue per farm [R]	21,832.96
Average total revenue per cultivated ha	**12,952.17**
Gross margin [R]	**424,412.23**
Average gross margin per farm [R]	18,452.71
Average gross margin per cultivated ha	**10,946.87**
Estimated return to water [R/m3 gross margin]	**1.73**
WATER	
Crop water demand [m3]	233,467.00
Actual water consumption [m3]	**245,140.14**
Average water consumption per farm [m3]	10,609.79
Average water consumption per cultivated ha	**6,583.10**

Compared to Mauluma, Morgan's irrigated area is approximately 10 ha smaller with only 23 farmers. The limited amount of farmers is explained by the presence of two farmers with rather big plots (4 and 8 ha). However, it is interesting to note that the scheme's gross margin of approximately R 424,000 is quite comparable to Mauluma (~ 433,000), but much higher than the gross margin for Thabina (~ R 59,000). On the other hand, the average gross margins per ha are lower in Mauluma (~ R 7,000/ha) and Thabina (~ R 1,000) than in Morgan (~ R 11,000), which is most probably related to the two "big" farmers influencing the average per ha. The costs at scheme level for Morgan are only R 78,000 including labor, which is more comparable to Thabina (~ 82,000) than to Mauluma (~R 128,000, excluding labor). This could mean that in Morgan farmers are much better skilled as with the lowest cost, they are able to reach almost the same gross margin as in Mauluma. However, here also the two "big" farmers could influence these figures a lot as they might have a better access to input markets and higher farming budgets, which have a positive effect on the scheme's gross margin. This could also be the reason for Morgan to have the highest ratio between total revenue and gross margin (85 %).

Regarding water, the actual water consumption in Morgan is approximately 7,000 m^3/ha, which is relatively comparable to Mauluma (~ 10,000 m^3/ha), however the total water consumption of 245,000 m^3 at scheme level is much lower than in Mauluma (~602,000 m^3). This can be explained by the geographical location of Morgan, where the average annual rainfall is much higher (~ 796 mm) than in Mauluma (~ 391 mm) and the smaller irrigated surface of the scheme. As a result of low water consumption and the relatively high gross margin at scheme level, Morgan's water productivity is the highest, compared to Mauluma (R 0.71/m^3) and Thabina (R 0.11/m^3).

In conclusion, the Morgan scheme seems to be doing quite well, which would confirm what RESIS expected by performing this economic viability study using the simplified SMILE approach in order to provide DWAF with some figures, which could show that Morgan might very well be ready for the establishment of a WUA. However, it needs to be taken into account that the influence of the two "big" farmers on the SMILE figures could be substantial and that in comparison the "smaller" farmers might not be doing as well compared to them.

6.2.3 Future use of simplified SMILE approach in RESIS

The conducted economic viability study on the pilot scheme Morgan, was very valuable to the RESIS project, as it gave a good idea of what can be done with SMILE, what results are generated and in how much time all can be accomplished. As it was only a first test, discussions and meetings are still ongoing between the sustainability task team members, RESIS, CIRAD & UP researchers and DWAF representatives concerning the official implementation of this simplified SMILE approach in future economic viability studies. Nevertheless, it can be said that this pilot study is a very good start and RESIS is satisfied with its results, even though the figures are debatable due to questionable field data. Furthermore, two economists have been trained and capacitated and with them a new erudite team with expertise in economic viability studies on smallholder irrigations schemes using SMILE is born.

DWAF is also quite content with the results regarding water requirements for irrigation that SMILE generates by using SAPWAT data. However, it could very well be that farming practices regarding water consumption differ substantially from what SAPWAT calculates, so investigating how big the difference is between SAPWAT and what is actually happening on the field through monitoring what farmers do, could be of great use to DWAF when considering water allocation and licensing.

The results generated by the simplified SMILE approach for Morgan can be of great help to determine if the establishment of a WUA in Morgan is adequate. However, also regarding this aspect, discussions are ongoing between RESIS and DWAF to agree if this simplified SMILE approach is the best most thorough yet time saving methodology to decide on the establishment and implementation of WUAs.

6.3 Application of IADF approach and methodology

In this paragraph, the application of the IADF approach and methodology as described in chapter 2 is discussed. The interests and limitations for both the RESIS program and for future research are argued in paragraphs 6.3.1 and 6.3.2.

6.3.1 Interests and limitations for RESIS

An important aspect of the RESIS program is institutional strengthening of irrigation schemes, which mainly refers to the scheme's MC. RESIS needs MCs to be fully equipped and ready to manage a scheme independently, which means the MC is responsible for leading the scheme and deal with all issues relating to operation and maintenance, water sharing, irrigation, production and all other aspects the scheme is concerned with. All this is of crucial importance, as after a scheme has completed the full RESIS program, it should be able to continue on producing and functioning independently. Without a strong institutional basis such autonomy is bound to be difficult to accomplish. Therefore, institutional analysis is a vital and imperative aspect RESIS is obliged to address.

Pre-development surveys and institutional analysis
In the RESIS program, the first fieldwork that is completed is the "pre-development survey" presented in RESIS, 2004 (b). In this survey, as much "need based" and "people oriented" information as possible is gathered regarding the scheme or project and its people, from the people involved. This survey is slightly linked to the IADF approach for institutional analysis as, although a much broader approach is applied by consulting a wide range of actors including agricultural, technical and women & youth groups. Furthermore, broad issues are addressed such as poverty, crime, hunger, agriculture and production, water, etc. In the IADF approach, mostly water management aspects regarding irrigation and agricultural production are considered. Nevertheless, RESIS is interested to find ways in integrating the IADF approach in their program, but instead of combining it with the pre-development surveys it seems better to design a separate institutional analysis survey, which can be carried out before, after or even in combination with the economic viability studies.

Sustainability task team and Ostrom's eight sustainability principles
In discussions with the RESIS sustainability task team, the IADF approach was agreed upon to be very useful. The task team was especially immersed by the "8 design principles" of Ostrom, which could facilitate in the decision making process of determining whether a scheme is economically viable, sustainable and ready for the implementation of a WUA. Although in need for further exploration and testing, it was concluded that the eight sustainability principles could serve as a final framework to check if a scheme is bound to be "sustainable" in all aspects brought forward by Ostrom.

Limitations
Although integrating the IADF approach in the RESIS program seems valuable, consequently time has to be made available for this analysis. This is problematic, as RESIS only has a limited amount of time to spend per scheme. Furthermore, another team or the team conducting economic viability studies needs to be trained and fieldwork periods will have to be extended.

6.3.2 Interests and limitations for future research

At first CIRAD & UP researchers mainly focused on the SMILE approach, excluding any in-depth institutional analysis. Although aware of the close relation of such analysis with SMILE and the importance of it in the research work carried out, time was usually the limiting factor. The first attempts in finding a workable link between SMILE results and institutional analysis, was executed in the Thabina irrigation scheme, see Veldwisch and Perret, 2004. In Thabina the SMILE approach had already been completed before, see Perret and Touchain, 2002 and Perret, *et al.*, 2003. Therefore, an independent institutional analysis was done in Thabina in 2004. However, as a lot of focus was put on the contents of the different results of the institutional analysis, which focused on water sharing, organizational patterns and strategies in water management, no clear generally applicable methodological framework was described.

The need for a combined methodology
After conducting SMILE and institutional analysis separately from each other in different research projects, the next step was to integrate both analyses in one research project. Consequently, a combined methodology was to be implemented, which was done in this research on Mauluma. For that reason, the SMILE approach was performed simultaneously with institutional analysis. However, for the latter a clear methodology was still missing. Therefore, at first a suitable framework was sought and found through the IADF approach, which is presented in paragraph 2.2. Both approaches are complementary to each other, making it feasible for the researcher to link results and gain a much better and complete understanding of the functioning of the scheme. This refers to various issues, such as agricultural production, irrigation, water management, economics and institutions.

Limitations
The IADF approach provides a supportive methodological framework for institutional analysis of irrigation schemes and their MCs. Nevertheless, after performing it for the first time in Mauluma, it can be concluded that performing such institutional analysis is worth more when a scheme has been functioning independently for at least a minimum amount of time. In Mauluma, the RESIS program still has two more years to go and the MC is functioning but has not fulfilled all the training sessions yet. Furthermore, the scheme has recently been revitalized, so farmers are just barely experiencing the new system, as since the floods of 2000, their scheme was not operating until repairs and works were completed in 2003. Therefore, in comparison to Thabina, which has been operating independently for quite some time after having experienced rehabilitation as a pilot scheme, in Mauluma no major institutional problems were encountered (see chapter 5). Ironically, it could be said that an

irrigation scheme with significant institutional and management troubles will make the IADF approach more motivating to work on and generate results more interesting to research and institutional analysis.

6.4 General conclusion and recommendations

In conclusion, a few points can be brought forward regarding both approaches and the combined methodology presented in this research document.

SMILE approach
For RESIS, the SMILE approach promises to be a very useful tool to help conduct economic viability studies. However, the simplified SMILE approach, which has been tested for the first time in Morgan, still needs to be refined and fully adapted to the requirements of RESIS and DWAF. Furthermore, although the team conducting this work has been capacitated, more time still needs to be invested in assisting the team to maximize its skills and become fully independent in applying the approach. Furthermore, to ensure more reliable input data for the SMILE database, RESIS could play a significant role by implementing special training sessions on record keeping for farmers, concerning all their agricultural and irrigation activities in the RESIS program. This would substantially increase the consistency of SMILE input and most of all SMILE results, benefiting all stakeholders using the database.

Regarding future research, the SMILE approach has developed significantly and the online version of the database proves to be very functional, mostly as it opens up possibilities to share information with users all over the world. However, as the online version has only recently been activated, revisions and updates are still ongoing, making it difficult to work continuously. Nevertheless, these minor deficiencies should be improved shortly. Hereby, it must be emphasized again that in order to get acceptable and trustworthy results, SMILE depends on reliable input data, both coming from fieldwork and from the SAPWAT model. As many other models and databases, this is somehow a limiting factor of SMILE, as often such accurate data is simply not available and assumptions have to be made by the researcher. Furthermore, as mentioned previously, SMILE looks at crop, farmer and scheme levels, but hereby a very important level is missing: the livelihood and household level. To improve the SMILE approach, it would be of crucial importance to add this feature into an additional SMILE module or to an existing module. Finally, when considering further research in the Mauluma scheme, the "SMILE scene" is set by the first two phases of the approach (see figure 1.2). Now doors are open to start the next phase of the SMILE approach: *scenario buildup and testing* (see figure 1.2). As a lot of information and knowledge has been gained on Mauluma and its members have been cooperative and seem relatively active and involved, it would be a misfortune to end the work that has been achieved at this stage. Research or more precisely "action-research" and eventually role-playing games could take place, as long as the scheme is not left waiting for too long. This relies on both researchers and RESIS.

IADF approach
Concerning the integration of this approach in RESIS, it was concluded (in task team meetings) that a lot of information gathered from the pre-development surveys and the economic viability studies are also needed for the IADF approach. This implicates that in one

way or another an integrated approach could be designed, which needs to be run by a well-trained team. Such an integrated approach would in the end, save time and avoid repetition of comparable fieldwork and analysis.

Regarding future research, it is important to realize that he IADF approach could bring forward much more valuable insights through institutional analysis once the Mauluma scheme will have finished the RESIS program and will have been functioning on its own for some time. Then, the IADF approach could almost be used as a kind of evaluation framework or tool. At the same time, executing the IADF approach beforehand and later on performing it again after completion of the RESIS program, could be fascinating, as "before" and "after" revitalization situations could be analyzed.

Combined methodology for analysis

This research brings forward a new *combined methodology for analysis*, integrating both agronomic, economic and irrigation and water related aspects with institutional and management aspects present in an irrigation scheme. However, no clear link has been found between the established farmer typology in Mauluma and the water sharing strategies brought forward by the IADF approach, except when distinguishing between rejected land farmers who irrigate in weekends and registered ones irrigating during the week. This is mostly because farmer typologies are based on agronomic characteristics, such as planted crops, planting dates, yields etc. and it does not automatically mean that farmers in one type also behave in the same way regarding water use strategies or regarding the water scheduling system. An idea would be to create a water sharing typology, if applicable in the scheme and compare this to the SMILE farmer typology and see what conclusions can be drawn.

The *combined methodology* proves, that although both approaches can be applied independently, a lot of data needed for the one is at the same time needed for the other. Applying both approaches concurrently generates complete, all-inclusive and more comprehensive results. Consequently, the researcher or research team is well aware of all aspects, avoiding a limited vision of only one side of the coin. This benefits research but at the same time the implicated irrigation scheme and its members, as during report-back sessions, meetings or discussion analysis results can be shared and farmers can be made aware of all the different processes taking place in their scheme. This will help them to further develop their potential, address their shortcomings and move forward to a promising future and secure well being, which integrate agriculture and irrigation to "full" extent or at least in the most optimal way.

In conclusion, the combination of the SMILE and IADF approaches has resulted in a practical and functional *combined methodological approach* for studies on economic viability and institutional arrangements, which is generic enough for future use in research projects on smallholder irrigation schemes in other parts of South Africa and even other parts of the world.

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APPENDIX 2 A – SMILE USERS' GUIDE

The "6 input modules" of SMILE

From the SMILE users' guide (Perret *et al.*, 2004 available on the Internet website: www.smile-cirad.co.za) a summary of the six input modules is given below:

1. Scheme module

In this module the user is supposed to document general information of the scheme. The total scheme area [ha] is essential and must be captured in this module in order to be used throughout the session for calculation.

2. Costs module

This module refers to the *manager's cost function* (Le Gal *et al.*, 2002) and provides a framework for data capturing then calculation on the costs incurred by the scheme and its management. These costs are:

- Capital costs (provision, refurbishment or replacement of infrastructures and equipment);
- Maintenance costs;
- Fixed operation costs;
- Variable operation costs (i.e. energy costs for pumping); and
- Personnel costs (i.e. wages, fees and training costs).

This information gives and indication of how high the costs are to operate the scheme in a sustainable manner, regardless of who is going to pay for it (Perret, *et al.,* 2003).

3. Crops module

This module requires information on crops within the scheme in order to perform calculations on the existing cropping systems. Each potentially productive and water-consuming crop needs to be captured with its technical and economic features (i.e. water demand, yield, production and marketing costs, etc.). However, for existing cropping systems, it is often impossible to reflect the diversity of farmers' crop management practices in a given scheme (even for one given crop). Therefore, the user must establish a typology of cropping systems by identifying a series of typical and reasonably homogenous crop management styles that represent reality. Criteria for such a typology may include the following elements:

- Type of crop (crop name);
- Crop management style (i.e. summer/winter crop, intensive/extensive input, etc.);
- Level of yield (i.e. low, high or average yield);
- Cropping calendar; and
- Market price.

It has to be taken into account that the typology of cropping systems only represents a model of the reality and does not capture in detail the diversity of it. Therefore, the typology should be validated with farmers of the scheme and local experts. The typology of cropping systems has to be established prior to any data capturing in the *crops module*. Eventually, the module generates micro-economic output variables (i.e. gross margin/ha) that allow comparative evaluation of crops in terms of profitability and land and water productivity (Perret, *et al.,* 2003).

4. Farming systems module

This module refers to the *farmers' cost function* (Le Gal *et al.*, 2002) and requires data on farm types within the scheme, with which calculations at farm level are performed. However, within any given scheme, it is very difficult to completely reflect the diversity of farmers' strategies, farming systems and farm styles. Like in the *crops module*, it is therefore suggested to also establish a typology of farmers. Thus, grouping farmers into a series of homogenous types. Just like the typology of cropping systems, the typology of farmers needs to be validated with farmers and local experts. Criteria for the farmer typology may include the following elements:

- Farm size;
- Farming orientation (i.e. subsistence, commercial, diversification, etc.);
- Farming system (major crops and productive activities, based on the *crops module*); and
- Socio-economic traits (head gender, age, family size, etc.).

The data captured in this module should represent the "average" situation of each type. In order to respect this, the user can choose between two approaches:

A. *Create a "virtual average" farm*, from the data gathered among the different farmers within a type and through calculation of averages. If the type seems to be too heterogeneous and too many arbitrations are made, calculated averages may not reflect reality anymore. In this case, approach B (see below) is advised.
B. *Choose a typical farm within a type*, which may represent the type as a monography. This approach is much quicker and simpler to follow.

As soon as the "average" situation for each type has been established, data capturing in the *farming systems module* may begin. As a result, the module generates type-related output variables (i.e. aggregated profit per type) and scheme-related output variables (i.e. number of farmers, aggregated water demand) when combined with the *scheme module* (Perret, *et al.,* 2003).

5. Water balance module

In the previous modules, water needs have only been envisaged according to the crop water demand. In this module the following elements can be addressed:

- Losses that occur during water conveyance from bulk supply to plant watering. Here threw, the actual water consumption at farm and scheme level are taken into account; and
- Overall weekly water balance (capturing rainfall and resource related data and crop water consumptions).

The losses mentioned above are considered proportional to the crop water demand and are three folded:

- Bulk conveyance loss, occurring between the resource and the scheme itself (i.e. evaporation, leaking canals, etc.);

- Scheme conveyance loss, occurring in primary and secondary canals; and
- In-field irrigation loss, occurring at farm and plot level (efficiency of irrigation equipment).

6. Water charging system module

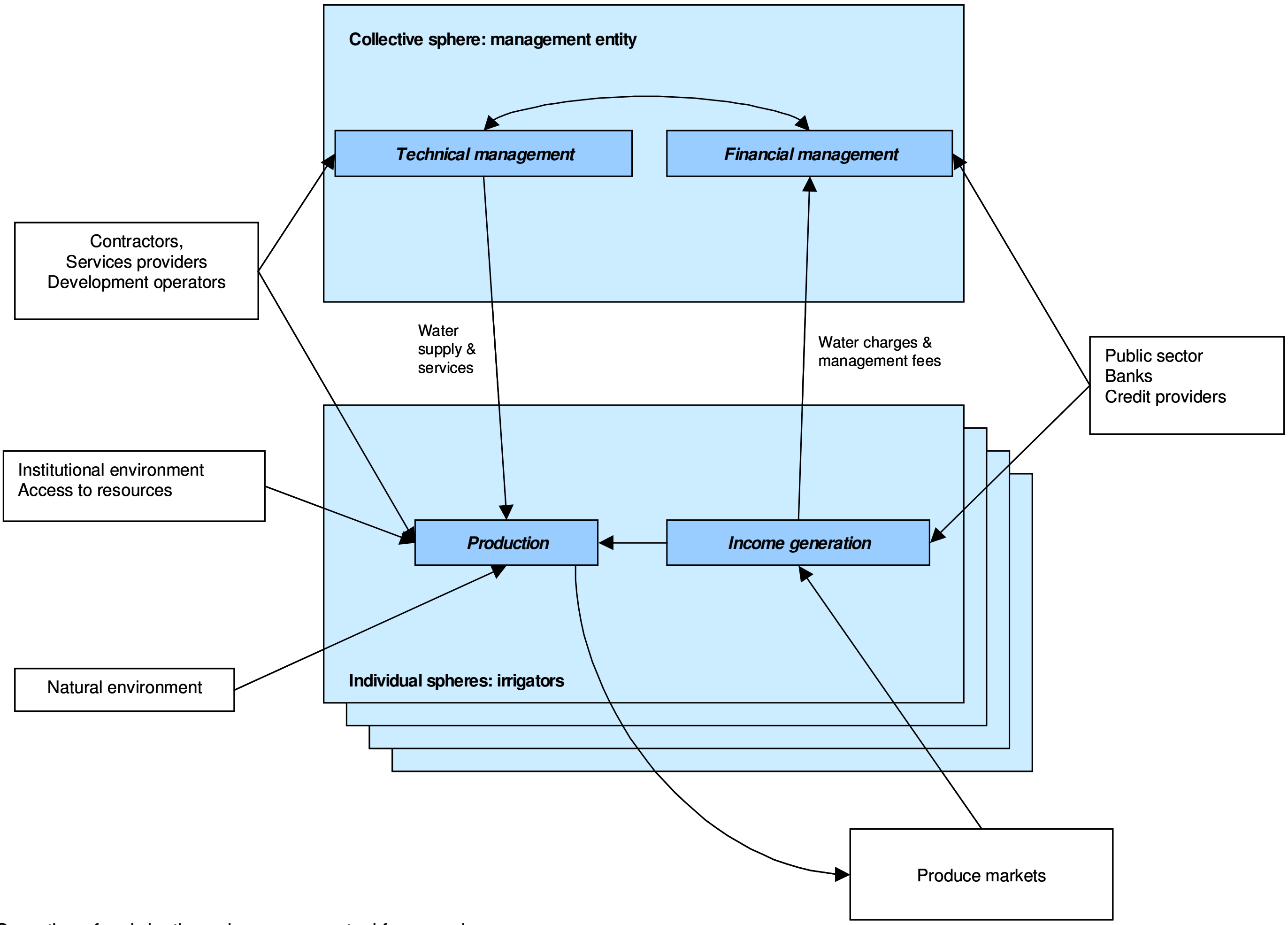
This module refers to the *water charge definition*, which combines the *manager's* and *farmers' cost functions* (Le Gal *et al.*, 2002) and aims at feeding reflections and possible negotiations on a water charging system for the scheme. Ultimately, the module can help evaluate the potential and possible options for cost recovery and financial viability of the scheme.

The farmer and cost modules are combined and used within the water charging system module, which generates output variables on water pricing, tariff, cost recovery rate, contribution per farmer type and others. This information can give an indication of who may pay for water services and how much (Perret, *et al.,* 2003).

APPENDIX 2 B – CONCEPTUAL FRAMEWORK IRRIGATION SCHEME

A framework for the operation of an irrigation scheme

This framework attempts to integrate the different dimensions, stakeholders and functions that take place in a scheme. It is as well a conceptual as an analytical framework, as it provides guidelines for multidisciplinary and comparative analysis (Perret *et al.*, 2003 quoting Le Gal, 2001).



Operation of an irrigation scheme: conceptual framework
(from Le Gal, 2001 ; Perret & Touchain, 2002)

APPENDIX 2 C – SMILE QUESTIONNAIRE

Household & farming survey – Questionnaire based on the SMILE approach
The questionnaire used to collect input data for the SMILE database is presented below.

1. General information

- Date;
- Respondent's name;
- Gender;
- Name household head;
- Secondary canal in scheme; and
- Interview reference number.

2. Household composition

Name	Gender	Age	Main occupation
1. Head			
2. Spouse			
3. Children in total			
4. Household members (adults & children)			
5. Children < 14 in household			
	Male/Female		- Full time farmer - Regular/salaried employee - Unemployed - Self employed - Retired - Student/pupil

3. Land tenure system

Type of plot	Total plot size with unit	Tenure system
1. Irrigated land		
2. Dry land		
3. Rejected irrigated land		
4. Orchard		
5. Other		
	Bed/levy/morgen, ha/m^2	- PTO/communal/tribal - Shareholding - Free holding/quitrent - Leasing agreement - Other (borrowing, springbok)

- When has your family settled in the scheme?
- Do you pay any fees for land?
- If yes, how much per ha? To whom?
- Do you pay any fees for water?
- If yes, how much per ha? To whom?
- Do you experience problems or conflicts regarding water sharing?
- Do you experience water shortages (never, sometimes, often, always)?

4. Cropping system

Crop name	Area planted	Qty harvested	Qty sold	Price	Qty consumed	Market outlet
1. 2. 3. etc.						
	Beds, scales, furrows, ha, m^2	Specify unit: tons, kg, bags, cobs, mugs, crates, bundles, etc.	Specify unit	R/unit	Specify unit	- Neighbors - Hawkers - Factory - City / town shop - Local shop - Other (specify)

 # The average of quantity harvested for the last 2/3 years

 # Market price per unit will be checked with an extension officer, local shops

- What is your favorite or main market outlet?
- Which crops are grown mainly for family consumption (thus hardly sold?)
- What is the major problem you face regarding farming?

5. Farm expenditures / production costs

FERTILIZERS

Crop name	<u>FERTILIZERS</u>	Qty purchased	Cost (R/unit)	Supplier	Input market	Marketing costs
1. 2. 3. etc.						
	- 2-3-2 - 2-3-4, ureum - kan - 3-2-1, etc.	Also, used per bed or per year	Per bed or per year	- Local shop - Cooperative - Friend or neighbor, etc	Description: distance, organization	- Transport (per year) - Packaging - Other

 # Input cost per unit will be checked with an extension officer

SEEDS

Crop name	SEEDS	Qty purchased	Cost (R/unit)	Supplier	Input market	Marketing costs
1.						
2.						
3. etc.						
		Also, used per bed or per year	Per bed or per year	- Local shop - Cooperative - Friend or neighbor, etc	Description: distance, organization	- Transport (per year) - Packaging - Other

 # Input cost per unit will be checked with an extension officer

PESTICIDES/HERBICIDES

Crop name	PESTICIDES/ HERBICIDES	Qty purchased	Cost (R/unit)	Supplier	Input market	Marketing costs
1.						
2.						
3. etc.						
	- Malathon - chloripirifos, - Cypermethrin, etc.	Also, used per bed or per year	Per bed or per year	- Local shop - Cooperative - Friend or neighbor, etc	Description: distance, organization	- Transport (per year) - Packaging - Other

 # Input cost per unit will be checked with an extension officer

LABOR

Crop name	LABOR Planting	Weeding	Harvest	Costs
1.				
2.				
3. etc.				
	How many people for how many days?	How many people for how many days?	How many people for how many days?	Rand/day or Rand/month

TILLAGE

TILLAGE	**No. of beds prepared for <u>WINTER</u> crops**	**No. of beds prepared for <u>SUMMER</u> crops**	**Total no. of beds per year**	**Costs** (per bed, per plot, per year)
1. Complete land preparation				
2. Only plowing				
3. Only discing				
4. Only furrowing				

BAKKIE RENTING

Crop name	**1.**	**2.**	**3.**	**4. etc.**
Number of loads				
Cost per load/trip				
Cost per year				

6. Crop calendar

Crop	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1.												
2.												
3. etc.												

 # Planting and harvesting

- When is food scarce in your household (month)?

	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**

7. Finances

Other sources of income in household	**How many of each source?**	**From who?** (Government, children, neighbors, etc.)	**How much per month?** (Rand)	**How much per year?** (Rand)
1. Pension (Social Grant)				
2. Child Grant Support				
3. Own salary				
4. Other salaries				
5. Own business (bakkie / tractor renting)				
6. Other business				

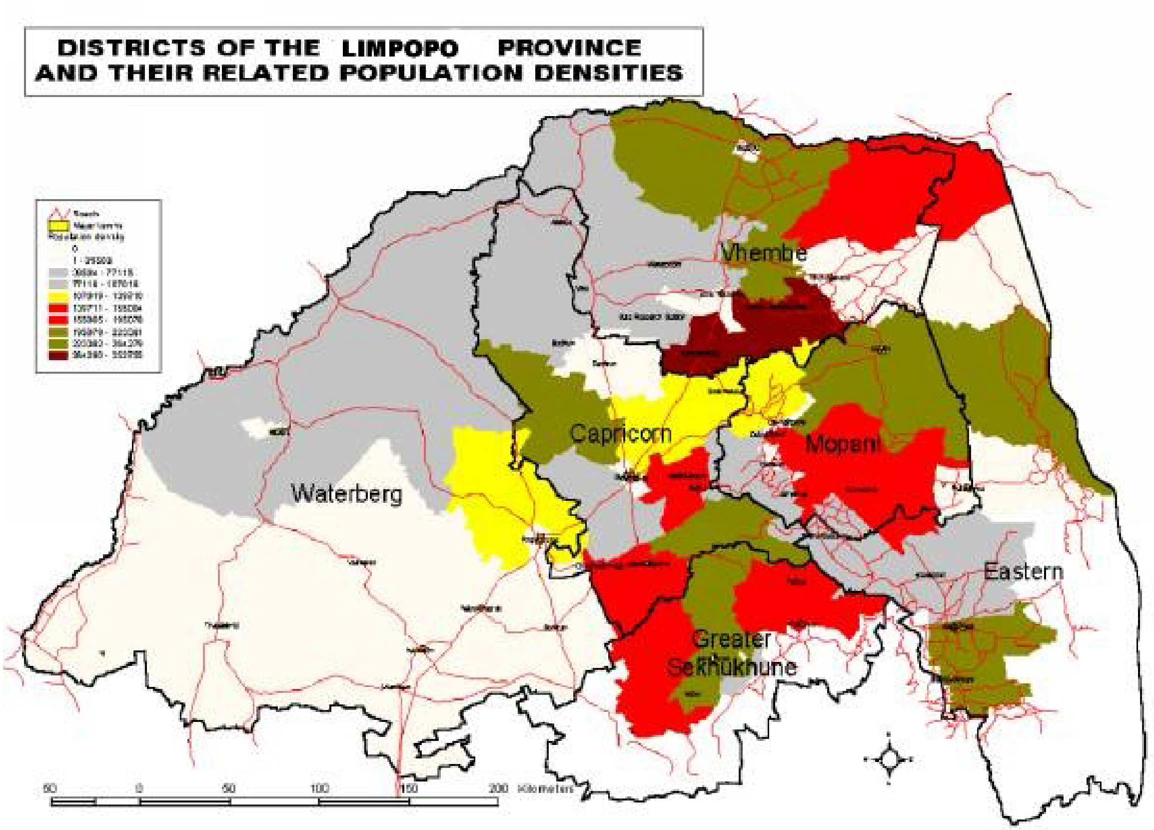
- Are you using credit facilities? What kind?
- What was it for (farming, general maintenance, household purchases, food)?
- Have you got any debts outstanding?

8. Concluding the interview

- How do you see the future as a farmer in the scheme and what are your prospects?
- As a farmer in the scheme, has your situation improved over the last 2 years? Why?
- Do you have any final general comments you would like to make?

APPENDIX 3 A – LIMPOPO PROVINCE DISTRICT MAP

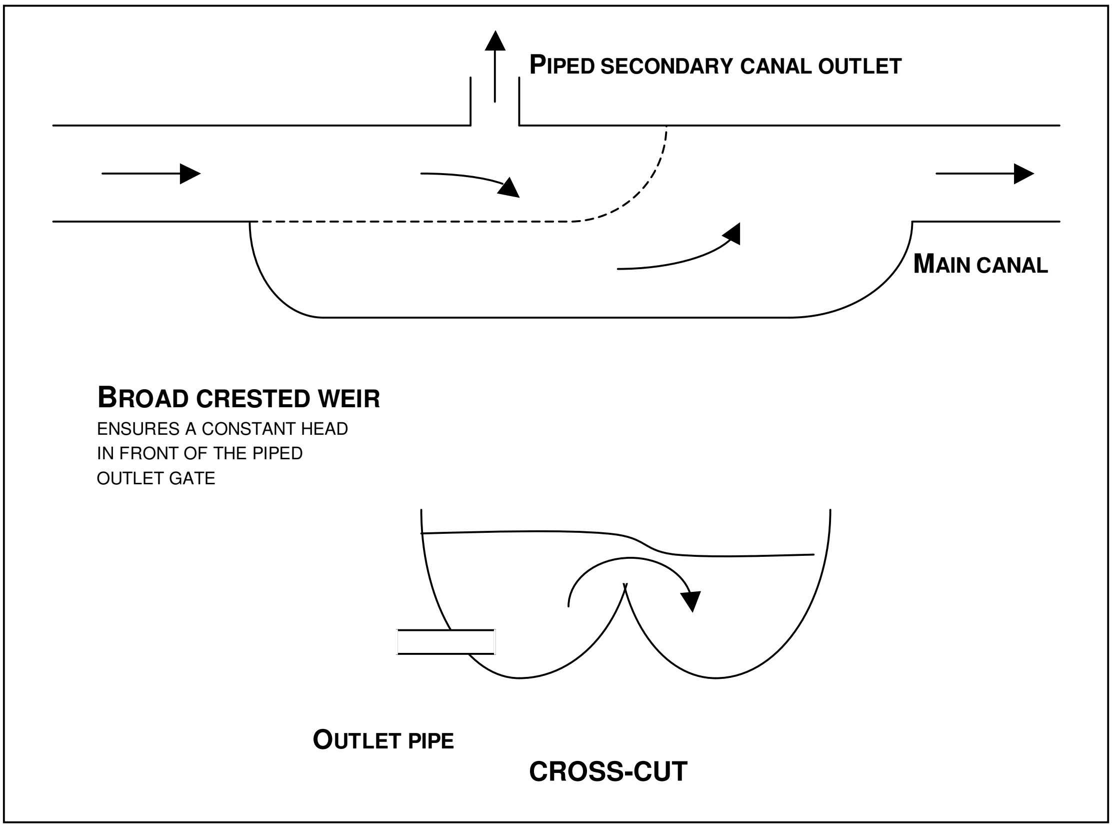
Limpopo Province district and population density map
The map shows the six districts in the Limpopo Province: Vhembe, Waterberg, Capricorn, Mopani, Greater Sekhukhune and Eastern Districts. The shaded colors from gray to yellow, to red to green to brown, give an indication of the population density in ascending order.



<u> From:</u> Limpopo Provincial Government – District and Population Density Map: (http://www.limpopo.gov.za/about_limpopo/location.htm)*

APPENDIX 3 B – IRRIGATION OUTLET STRUCTURE

Layout of the outlet structures to secondary canals in the Thabina irrigation scheme.
This scheme is located close to Tzaneen in the Limpopo Province.



<u> From:</u> Veldwisch and Perret, 2004*

APPENDIX 4 A – MAULUMA PLOT MEASUREMENTS

Famers list – Mauluma

The plots of farmers who were interviewed are marked *bold*.

BED MEASUREMENTS - MAULUMA IRRIGATION SCHEME

Average normal bed width [m]	6.63
Average double bed width [m]	12.65
Average bed length [m]	138.33
Average bed area [ha]	0.09

REGISTERED LAND PLOTS

Plot No.	Beds	Plot Area [ha]
1	**11**	**1.01**
2	13	1.19
3	**12**	**1.10**
4	**12**	**1.10**
5	**11**	**1.01**
6	9	0.83
7	**10**	**0.92**
8	**14**	**1.28**
9	**11**	**1.01**
10	**16**	**1.47**
11	**14**	**1.28**
12	**10**	**0.92**
13	**11**	**1.01**
14	**8**	**0.73**
15	13	1.19
16	**10**	**0.92**
17	**10**	**0.92**
18	**10**	**0.92**
19	13	1.19
20	14	1.28
21	8	0.73
22	**14**	**1.28**
23	14	1.28
24	8	0.73
25	**11**	**1.01**
26	11	1.01
27	9	0.83
28	**14**	**1.28**
29	13	1.19
30	12	1.10

DRY LAND PLOTS

No.	Beds	Plot Area [ha]
1	3	0.28
2	**0.5**	**0.05**
3	3	0.28
4	3.5	0.32
5	**2.5**	**0.23**
6	2	0.18
7	1	0.09
8	2	0.18
9	**0.75**	**0.07**

REJECTED LAND PLOTS

No.	Beds	Plot Area [ha]
1	2	0.18
2	5	0.46
3	2	0.18
4	5.5	0.50
5		
6	**13**	**1.19**
7	**3**	**0.28**
8	4	0.37
9	2.5	0.23
10	2	0.18
11	6	0.55
12	**6**	**0.55**
13	6	0.55
14	5	0.46
15	**7**	**0.64**
16	**6**	**0.55**
17		
18	1.5	0.14
19	9	0.83
20	**4.5**	**0.41**
21	2	0.18
22	5.5	0.50
23	2	0.18
24	**4.5**	**0.41**
25	3	0.28
26	5	0.46
27	**2**	**0.18**
28	5	0.46
29	2	0.18
30	7.5	0.69
31	5.5	0.50
32	5	0.46
33	2	0.18
34	2.5	0.23
35	2.5	0.23
36	1	0.09
37	3	0.28
38	1	0.09
39	**9**	**0.83**
40	1	0.09
41	2	0.18

APPENDIX 4 B – MAULUMA CM STYLES AND YIELD

Crop management styles for Mauluma showing yield/ha

Crop Name	No.	CM Style	No. Farmers	Planting Date	Yield [bag/bed]	Yield [bag/ha]	STDEV: Yield [bag/ha]
MAIZE	1	Spring Maize - high yield	10	01-Sep	4.92	53.63	16.56
	2	Spring Maize - low yield	9	15-Sep	2.05	22.34	6.62
	3	Summer Maize - high yield	2	15-Dec	6.86	74.73	17.61
	4	Summer Maize - low yield	7	01-Dec	2.30	25.07	7.27
	5	Winter Maize - high yield	1	15-Jul	4.00	43.59	-
	6	Winter Maize - low yield	2	15-Jul	1.65	17.98	2.31
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Planting Date**	**Yield [crate/bed]**	**Yield [crate/ha]**	**STDEV: Yield [crate/ha]**
TOMATO	1	Fall Tomato - high yield	5	15-Mar	102.00	1111.58	309.01
	2	Fall Tomato - low yield	4	15-Mar	48.75	531.27	167.74
	3	(Early) Winter Tomato - high yield	4	01-Jun	177.46	1933.98	807.49
	4	(Early) Winter Tomato - low yield	5	15-May	23.39	254.85	324.85
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Planting Date**	**Yield [bag/bed]**	**Yield [bag/ha]**	**STDEV: Yield [bag/ha]**
BEANS	1	Fall Beans - high yield	4	01-Mar	2.35	25.66	5.16
	2	Fall Beans - low yield	7	01-Mar	1.04	11.29	4.86
	3	Late Fall Beans - high yield	2	15-May	2.60	28.33	6.16
	4	Late Fall Beans - low yield	6	15-May	1.01	10.98	5.94
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Planting Date**	**Yield [bag/bed]**	**Yield [bag/ha]**	**STDEV: Yield [bag/ha]**
GROUND NUT	1	Spring GrNuts - high yield	1	15-Sep	10.00	108.98	-
	2	Spring GrNuts - low yield	4	15-Sep	3.43	37.33	7.88
	3	Summer GrNuts - high yield	2	15-Dec	5.50	59.94	7.71
	4	Summer GrNuts - low yield	1	15-Dec	2.67	29.06	-
	5	(Late) Winter GrNuts - high yield	4	15-Aug	5.92	64.48	7.49
	6	(Late) Winter GrNuts - low yield	2	01-Aug	3.00	32.69	15.41
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Planting Date**	**Yield [bucket/bed]**	**Yield [bucket/ha]**	**STDEV: Yield [bucket/ha]**
SW. POTATO	1	All Year SwPotato - high yield	1	15-Apr/01-Nov	78.00	850.03	-
	2	All Year SwPotato - low yield	5	15-Apr/01-Nov	12.85	140.04	87.60
	3	Fall SwPotato - high yield	2	15-May	18.25	198.89	26.97
	4	Fall SwPotato - low yield	2	15-Apr	12.50	136.22	38.53
	5	Winter SwPotato - high yield	1	15-Jul	50.00	544.89	-
	6	Winter SwPotato - low yield	1	15-Jul	22.00	239.75	-
Crop Name	**No.**	**CM Style**	**No. Farmers***	**Planting Date**	**Yield [bag/bed]**	**Yield [bag/ha]**	**STDEV: Yield [bag/ha]**
ONION	1	Fall Onion	7 (3)	15-Mar	80.00	871.83	0.00
	2	Late Fall Onion - high yield	1	15-May	40.50	441.36	-
	3	Late Fall Onion - low yield	2	01-May	10.00	108.98	0.00
	4	Winter Onion - high yield	2	01-Jul	100.00	1089.79	0.00
	5	Winter Onion - low yield	1	15-Jun	14.00	152.57	-
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Planting Date**	**Yield [bundle/bed]**	**Yield [bundle/ha]**	**STDEV: Yield [bundle/ha]**
MUTCHAINA	1	Early Fall Mutchaina - high yield	2	01-Mar	246.00	2680.87	832.24
	2	Early Fall Mutchaina - low yield	1	15-Mar	32.00	348.73	-
	3	Late Fall Mutchaina - high yield	2	15-May	296.00	3225.77	446.95
	4	Late Fall Mutchaina - low yield	2	15-May	70.67	770.12	318.51
	5	Winter Mutchaina	1	15-Jun	83.50	909.97	-
Crop Name	**No.**	**CM Style**	**No. Farmers***	**Planting Date**	**Yield [bundle/bed]**	**Yield [bundle/ha]**	**STDEV: Yield [bundle/ha]**
SPINACH	1	Early Fall Spinach - high yield	2	01-Mar	388.00	4228.37	2650.85
	2	Early Fall Spinach - low yield	1	15-Mar	25.00	272.45	-
	3	Late Fall Spinach	5 (2)	15-May	296.00	3225.77	446.95
	4	Winter Spinach	1	15-Jul	75.00	817.34	-
Crop Name	**No.**	**CM Style**	**No. Farmers***	**Planting Date**	**Yield [head/bed]**	**Yield [head/ha]**	**STDEV: Yield [head/ha]**
CABBAGE	1	Early Fall Cabbage	3 (1)	15-Mar	340.00	3705.27	-
	2	Late Fall Cabbage	2	01-Jun	206.00	2244.96	940.13
	3	Winter Cabbage	2 (1)	01-Jul/15-Jul	46.67	508.57	-

<u> Important:</u> figures between brackets are actual number of farmers who were able to provide data to calculate with (i.e. for CM Style "Fall Onion", only 3 of the 7 farmers were able to give figures for yield and price, thus averages are based on 3 farmers instead of 7).*

APPENDIX 4 C – MAULUMA CM STYLES AND TOTAL REVENUE

Crop management styles for Mauluma showing total revenue/ha

Crop Name	No.	CM Style	Price [R/bag]	Revenue [R/bed]	Total Revenue [R/ha]	STDEV: Total Revenue [R/ha]
MAIZE	1	Spring Maize - high yield	172.00	847.25	9233.21	2840.33
	2	Spring Maize - low yield	178.89	363.75	3964.10	1093.93
	3	Summer Maize - high yield	170.00	1154.29	12579.25	1937.50
	4	Summer Maize - low yield	180.00	414.00	4511.72	1308.29
	5	Winter Maize - high yield	180.00	720.00	7846.46	-
	6	Winter Maize - low yield	180.00	297.00	3236.67	416.12
Crop Name	No.	CM Style	Price [R/crate]	Revenue [R/bed]	Total Revenue [R/ha]	STDEV: Total Revenue [R/ha]
TOMATO	1	Fall Tomato - high yield	30.68	3087.76	33649.98	24911.70
	2	Fall Tomato - low yield	25.17	1232.48	13431.40	8280.06
	3	(Early) Winter Tomato - high yield	26.25	4478.57	48806.86	30826.89
	4	(Early) Winter Tomato - low yield	33.50	727.57	7928.97	9693.81
Crop Name	No.	CM Style	Price [R/bag]	Revenue [R/bed]	Total Revenue [R/ha]	STDEV: Total Revenue [R/ha]
BEANS	1	Fall Beans - high yield	1115.00	2563.33	27934.85	5054.96
	2	Fall Beans - low yield	735.00	713.57	7776.40	7088.81
	3	Late Fall Beans - high yield	250.00	650.00	7083.61	1541.19
	4	Late Fall Beans - low yield	1050.00	1058.26	11532.81	7463.52
Crop Name	No.	CM Style	Price [R/bag]	Revenue [R/bed]	Total Revenue [R/ha]	STDEV: Total Revenue [R/ha]
GROUND NUT	1	Spring GrNuts - high yield	200.00	2000.00	21795.73	-
	2	Spring GrNuts - low yield	200.00	685.00	7465.04	1575.49
	3	Summer GrNuts - high yield	200.00	1100.00	11987.65	1541.19
	4	Summer GrNuts - low yield	100.00	266.67	2906.10	-
	5	(Late) Winter GrNuts - high yield	195.00	1156.67	12605.19	2526.17
	6	(Late) Winter GrNuts - low yield	200.00	600.00	6538.72	3082.38
Crop Name	No.	CM Style	Price [R/bucket]	Revenue [R/bed]	Total Revenue [R/ha]	STDEV: Total Revenue [R/ha]
SW. POTATO	1	All Year SwPotato - high yield	30.00	2340.00	25501.00	-
	2	All Year SwPotato - low yield	25.40	307.75	3353.82	1624.10
	3	Fall SwPotato - high yield	27.50	497.50	5421.69	38.53
	4	Fall SwPotato - low yield	30.00	375.00	4086.70	1155.89
	5	Winter SwPotato - high yield	30.00	1500.00	16346.79	-
	6	Winter SwPotato - low yield	20.00	440.00	4795.06	-
Crop Name	No.	CM Style	Price [R/bag]	Revenue [R/bed]	Total Revenue [R/ha]	STDEV: Total Revenue [R/ha]
ONION	1	Fall Onion	12.50	1066.67	11624.39	2516.75
	2	Late Fall Onion - high yield	16.00	648.00	7061.82	-
	3	Late Fall Onion - low yield	6.00	60.00	653.87	154.12
	4	Winter Onion - high yield	8.00	800.00	8718.29	3082.38
	5	Winter Onion - low yield	14.00	196.00	2135.98	-
Crop Name	No.	CM Style	Price [R/bundle]	Revenue [R/bed]	Total Revenue [R/ha]	STDEV: Total Revenue [R/ha]
MUTCHAINA	1	Early Fall Mutchaina - high yield	3.00	738.00	8042.62	2496.73
	2	Early Fall Mutchaina - low yield	3.00	96.00	1046.19	-
	3	Late Fall Mutchaina - high yield	2.50	725.50	7906.40	1163.60
	4	Late Fall Mutchaina - low yield	2.50	187.00	2037.90	1340.84
	5	Winter Mutchaina	3.00	250.50	2729.91	-
Crop Name	No.	CM Style	Price [R/bundle]	Revenue [R/bed]	Total Revenue [R/ha]	STDEV: Total Revenue [R/ha]
SPINACH	1	Early Fall Spinach - high yield	3.00	1164.00	12685.11	7952.54
	2	Early Fall Spinach - low yield	3.00	75.00	817.34	-
	3	Late Fall Spinach	2.67	725.50	7906.40	1163.60
	4	Winter Spinach	2.00	150.00	1634.68	-
Crop Name	No.	CM Style	Price [R/head]	Revenue [R/bed]	Total Revenue [R/ha]	STDEV: Total Revenue [R/ha]
CABBAGE	1	Early Fall Cabbage	3.83	850.00	9263.18	-
	2	Late Fall Cabbage	3.25	654.25	7129.93	2261.70
	3	Winter Cabbage	3.25	186.67	2034.27	-

APPENDIX 4 D – MAULUMA MONOGRAPH APPROACH RESULTS

Economic and water related results per crop management style (monograph approach)

Crop Name	No.	CM Style	No. Farmers	Yield [bag/ha]	Total Revenue [R/ha]	Production Costs [R/ha]	Gross Margin [R/ha]	SAPWAT Water Req. [mm]
MAIZE	1	Spring Maize - high yield	10	53.63	9233.21			997.00
			(monograph 5)	39.96	7192.59	3096.99	4095.60	
			(monograph 2)	49.04	8336.87	4883.44	3453.42	
			(monograph 8)	54.49	9808.08	2454.77	7353.31	
			(monograph 10)	70.84	12750.50	1913.52	10836.98	
	2	Spring Maize - low yield	9	22.34	3964.10			990.00
			(monograph 1)	12.71	2288.55	1587.17	701.38	
			(monograph 6/7)	21.80	3923.23	1571.25	2351.98	
	3	Summer Maize - high yield	2	74.73	12579.25			760.00
			(monograph 3)	62.27	11209.23	3071.64	8137.59	
	4	Summer Maize - low yield	7	25.07	4511.72			797.00
			(monograph 9)	32.69	5884.85	2138.81	3746.04	
	5	Winter Maize - high yield	1	43.59	7846.46			1022.00
	6	Winter Maize - low yield	2	17.98	3236.67			1022.00
			(monograph 4)	16.35	2942.42	1996.09	946.34	
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Yield [crate/ha]**	**Total Revenue [R/ha]**	**Production Costs [R/ha]**	**Gross Margin [R/ha]**	**SAPWAT Water Req. [mm]**
TOMATO	1	Fall Tomato - high yield	5	1111.58	33649.98			865.00
			(monograph 10)	959.01	28770.36	2790.70	25979.65	
			(monograph 6/7)	1438.52	75522.19	3010.86	72511.33	
	2	Fall Tomato - low yield	4	531.27	13431.40			865.00
	3	(Early) Winter Tomato - high yield	4	1933.98	48806.86			1175.00
			(monograph 8)	1743.66	43591.45	2360.68	41230.77	
	4	(Early) Winter Tomato - low yield	5	254.85	7928.97			1077.00
			(monograph 9)	822.01	24660.31	3461.40	21198.91	
			(monograph 5)	228.86	8009.93	4783.71	3226.22	
			(monograph 4)	43.59	2288.55	1915.71	372.84	
			(monograph 1)	108.98	3269.36	4169.29	-899.93	
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Yield [bag/ha]**	**Total Revenue [R/ha]**	**Production Costs [R/ha]**	**Gross Margin [R/ha]**	**SAPWAT Water Req. [mm]**
BEANS	1	Fall Beans - high yield	4	25.66	27934.85			481.00
			(monograph 2)	21.80	30514.02	1239.63	29274.38	
			(monograph 8)	32.69	32693.59	2199.76	30493.83	
	2	Fall Beans - low yield	7	11.29	7776.40			481.00
			(monograph 5)	13.08	19616.15	2175.21	17440.94	
			(monograph 3)	10.90	15257.01	1089.79	14167.22	
			(monograph 10)	16.35	1634.68	871.83	762.85	
	3	Late Fall Beans - high yield	2	28.33	7083.61			447.00
			(monograph 4)	23.98	5993.82	1896.64	4097.18	
	4	Late Fall Beans - low yield	6	10.98	11532.81			447.00
			(monograph 9)	6.81	7151.72	1958.35	5193.37	
			(monograph 6/7)	2.42	2542.83	1280.64	1262.19	
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Yield [bag/ha]**	**Total Revenue [R/ha]**	**Production Costs [R/ha]**	**Gross Margin [R/ha]**	**SAPWAT Water Req. [mm]**
GROUND NUT	1	Spring GrNuts - high yield	1	108.98	21795.73			1008.00
	2	Spring GrNuts - low yield	4	37.33	7465.04			1008.00
			(monograph 1)	34.87	6974.63	871.83	6102.80	
			(monograph 5)	27.24	5448.93	1035.30	4413.63	
	3	Summer GrNuts - high yield	2	59.94	11987.65			838.00
			(monograph 8)	54.49	10897.86	1307.74	9590.12	
	4	Summer GrNuts - low yield	1	29.06	2906.10			838.00
			(monograph 3)	29.06	2906.10	726.52	2179.57	
	5	(Late) Winter GrNuts - high yield	4	64.48	12605.19			1084.00
			(monograph 4)	65.39	13077.44	871.83	12205.61	
			(monograph 10)	54.49	10897.86	871.83	10026.03	
			(monograph 6/7)	65.39	10461.95	871.83	9590.12	
	6	(Late) Winter GrNuts - low yield	2	32.69	6538.72			1084.00

** Important: For each crop management style, before the values per monograph type are shown, for comparison's sake the average value for yield and total revenue (as found in appendices 4 A and B) as well as the total number of farmers belonging to each crop management style are given in the first row.*

Continuation results per crop management style (monograph approach)

Crop Name	No.	CM Style	No. Farmers	Yield [bucket/ha]	Total Revenue [R/ha]	Production Costs [R/ha]	Gross Margin [R/ha]	SAPWAT Water Req. [mm]
SW. POTATO	1	All Year SwPotato - high yield	1	850.03	25501.00			591.00 or 692.00
	2	All Year SwPotato - low yield	5	140.04	3353.82			591.00 or 692.00
			(monograph 1)	59.94	1798.15	871.83	926.32	
			(monograph 10)	130.77	3923.23	871.83	3051.40	
			(monograph 3)	98.08	1961.62	1089.79	871.83	
	3	Fall SwPotato - high yield	2	198.89	5394.44			675.00
			(monograph 4)	179.81	5394.44	871.83	4522.61	
	4	Fall SwPotato - low yield	2	136.22	4086.70			591.00
			(monograph 5)	163.47	4904.04	1035.30	3868.74	
			(monograph 6/7)	108.98	3269.36	871.83	2397.53	
	5	Winter SwPotato - high yield	1	544.89	16346.79			570.00
			(monograph 2)	544.89	16346.79	871.83	15474.97	
	6	Winter SwPotato - low yield	1	239.75	4795.06			570.00
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Yield [bag/ha]**	**Total Revenue [R/ha]**	**Production Costs [R/ha]**	**Gross Margin [R/ha]**	**SAPWAT Water Req. [mm]**
ONION	1	Fall Onion	7	871.83	11624.39			901.00
	2	Late Fall Onion - high yield	1	441.36	7061.82			548.00
			(monograph 9)	441.36	7061.82	2143.56	4918.25	
	3	Late Fall Onion - low yield	2	108.98	653.87			
	4	Winter Onion - high yield	2	1089.79	8718.29			901.00
			(monograph 8)	1089.79	10897.86	3095.63	7802.23	
	5	Winter Onion - low yield	1	152.57	2135.98			598.00
			(monograph 1)	152.57	2135.98	2304.34	-168.35	
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Yield [bundle/ha]**	**Total Revenue [R/ha]**	**Production Costs [R/ha]**	**Gross Margin [R/ha]**	**SAPWAT Water Req. [mm]**
MUTCHAINA	1	Early Fall Mutchaina - high yield	2	2680.87	8042.62			1548.00
			(monograph 5)	2092.39	6277.17	3379.70	2897.47	
	2	Early Fall Mutchaina - low yield	1	348.73	1046.19			1220.00
	3	Late Fall Mutchaina - high yield	2	3225.77	7906.40			1808.00
			(monograph 8)	3541.81	7083.61	2818.64	4264.97	
	4	Late Fall Mutchaina - low yield	2	770.12	2037.90			1808.00
			(monograph 6/7)	995.34	2986.01	1274.83	1711.18	
	5	Winter Mutchaina	1	909.97	2729.91			1869.00
			(monograph 1)	909.97	2729.91	1380.80	1349.12	
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Yield [bundle/ha]**	**Total Revenue [R/ha]**	**Production Costs [R/ha]**	**Gross Margin [R/ha]**	**SAPWAT Water Req. [mm]**
SPINACH	1	Early Fall Spinach - high yield	2	4228.37	12685.11			971.00
			(monograph 5)	2353.94	7061.82	3379.70	3682.12	
	2	Early Fall Spinach - low yield	1	272.45	817.34			
	3	Late Fall Spinach	5	3225.77	7906.40			1286.00
			(monograph 8)	3541.81	7083.61	2818.64	4264.97	
	4	Winter Spinach	1	817.34	1634.68			1388.00
Crop Name	**No.**	**CM Style**	**No. Farmers**	**Yield [head/ha]**	**Total Revenue [R/ha]**	**Production Costs [R/ha]**	**Gross Margin [R/ha]**	**SAPWAT Water Req. [mm]**
CABBAGE	1	Early Fall Cabbage	3	3705.27	9263.18			472.00
	2	Late Fall Cabbage	2	2244.96	7129.93			503.00
			(monograph 9)	1580.19	5530.67	4641.35	889.31	
	3	Winter Cabbage	2	508.57	2034.27			619.00 or 677.00
			(monograph 4)	508.57	2034.27	2447.89	-413.62	

APPENDIX 4 E – MAULUMA SAPWAT RESULTS

SAPWAT results per crop management style

Crop Name	No.	CM Style	Planting Date	SAPWAT Water Req. [mm]	SAPWAT Date	SAPWAT Crop Option
MAIZE	1	Spring Maize - high yield	01-Sep	997.00		Mealies
	2	Spring Maize - low yield	15-Sep	990.00		Mealies
	3	Summer Maize - high yield	15-Dec	760.00		Mealies
	4	Summer Maize - low yield	01-Dec	797.00		Mealies
	5	Winter Maize - high yield	15-Jul	1022.00	01-Aug	Mealies
	6	Winter Maize - low yield	15-Jul	1022.00	01-Aug	Mealies

Crop Name	No.	CM Style	Planting Date	SAPWAT Water Req. [mm]	SAPWAT Date	SAPWAT Crop Option
TOMATO	1	Fall Tomato - high yield	15-Mar	865.00		Tomato (table)
	2	Fall Tomato - low yield	15-Mar	865.00		Tomato (table)
	3	(Early) Winter Tomato - high yield	01-Jun	1175.00		Tomato (table)
	4	(Early) Winter Tomato - low yield	15-May	1077.00		Tomato (table)

Crop Name	No.	CM Style	Planting Date	SAPWAT Water Req. [mm]	SAPWAT Date	SAPWAT Crop Option
BEANS	1	Fall Beans - high yield	01-Mar	481.00		Beans (runners)
	2	Fall Beans - low yield	01-Mar	481.00		Beans (runners)
	3	Late Fall Beans - high yield	15-May	447.00		Beans (runners)
	4	Late Fall Beans - low yield	15-May	447.00		Beans (runners)

Crop Name	No.	CM Style	Planting Date	SAPWAT Water Req. [mm]	SAPWAT Date	SAPWAT Crop Option
GROUND NUT	1	Spring GrNuts - high yield	15-Sep	1008.00	01-Oct	Ground Nut
	2	Spring GrNuts - low yield	15-Sep	1008.00	01-Oct	Ground Nut
	3	Summer GrNuts - high yield	15-Dec	838.00		Ground Nut
	4	Summer GrNuts - low yield	15-Dec	838.00		Ground Nut
	5	(Late) Winter GrNuts - high yield	15-Aug	1084.00	01-Sep	Ground Nut-Middelveld
	6	(Late) Winter GrNuts - low yield	01-Aug	1084.00	01-Sep	Ground Nut-Middelveld

Crop Name	No.	CM Style	Planting Date	SAPWAT Water Req. [mm]	SAPWAT Date	SAPWAT Crop Option
SW. POTATO	1	All Year SwPotato - high yield	15-Apr/01-Nov	591.00 or 692.00		Patats
	2	All Year SwPotato - low yield	15-Apr/01-Nov	591.00 or 692.00		Patats
	3	Fall SwPotato - high yield	15-May	675.00		Patats
	4	Fall SwPotato - low yield	15-Apr	591.00		Patats
	5	Winter SwPotato - high yield	15-Jul	570.00	30-May	Patats
	6	Winter SwPotato - low yield	15-Jul	570.00	30-May	Patats

Crop Name	No.	CM Style	Planting Date	SAPWAT Water Req. [mm]	SAPWAT Date	SAPWAT Crop Option
ONION	1	Fall Onion	15-Mar	901.00		Onion (seeded)
	2	Late Fall Onion - high yield	15-May	548.00		Onion (transplant autumn)
	3	Late Fall Onion - low yield	01-May	-		-
	4	Winter Onion - high yield	01-Jul	901.00	01-Aug	Onion (transplant spring)-Middelveld
	5	Winter Onion - low yield	15-Jun	598.00	30-May	Onion (transplant autumn)

Crop Name	No.	CM Style	Planting Date	SAPWAT Water Req. [mm]	SAPWAT Date	SAPWAT Crop Option
MUTCHAINA	1	Early Fall Mutchaina - high yield	01-Mar	1548.00		Swiss Chard
	2	Early Fall Mutchaina - low yield	15-Mar	1220.00		Swiss Chard
	3	Late Fall Mutchaina - high yield	15-May	1808.00		Swiss Chard
	4	Late Fall Mutchaina - low yield	15-May	1808.00		Swiss Chard
	5	Winter Mutchaina	15-Jun	1869.00	30-May	Swiss Chard

Crop Name	No.	CM Style	Planting Date	SAPWAT Water Req. [mm]	SAPWAT Date	SAPWAT Crop Option
SPINACH	1	Early Fall Spinach - high yield	01-Mar	971.00		Spinach
	2	Early Fall Spinach - low yield	15-Mar	-		-
	3	Late Fall Spinach	15-May	1286.00		Spinach
	4	Winter Spinach	15-Jul	1388.00		Spinach

Crop Name	No.	CM Style	Planting Date	SAPWAT Water Req. [mm]	SAPWAT Date	SAPWAT Crop Option
CABBAGE	1	Early Fall Cabbage	15-Mar	472.00		Cabbage (early) - Autumn plant
	2	Late Fall Cabbage	01-Jun	503.00		Cabbage (early) - Winter plant
	3	Winter Cabbage	01-Jul/15-Jul	619.00 or 677.00		Cabbage (early) - Winter plant

** Important: For late fall onion – low yield and early fall spinach – low yield, no SAPWAT results were obtained, as none of the chosen monograph farmer types is performing these crop management styles.*

APPENDIX 5 A – IADF QUESTIONNAIRE: II AND CM ACTION SITUATIONS

A. Individual irrigation – Questionnaire based on IADF approach

The questionnaire used for the survey on *individual irrigation* (II) at plot level is presented below.

1. General information

- Date;
- Respondent's name;
- Gender;
- Name household head; and
- Interview reference number.

2. Action situations

- *Participant & position*
  - Are you a MC or SC member (function) or only a farmer (official member, official dry land member, rejected land, other)?
  - What is your position/function and responsibility (regarding Individual Irrigation)?
  - Do you see irrigation as important?
  - Is it good for your crops to have a lot of water? The more the better?
  - What can you tell me about water and crops?
- *Actions*
  - What do you do exactly when you are irrigating your plot(s)?
  - How many hours do you spend on your plot(s) per day?
  - When do you decide to irrigate your plot(s)? How often do you irrigate per week?
  - Do you think it is enough for your crops? How often should they be irrigated ideally?
  - Is the time you spend irrigating different during drought?
  - What would be the minimum irrigation required for your crop to survive (frequency)?
- *Potential outcomes*
  - What is the impact/effect of irrigation on your crops?
  - And what is the effect on your crops if you do not irrigate?
  - What makes you decide not to irrigate?

3. Patterns of interaction and actor behavior

- *Individual preferences*
  - Do you follow the current water sharing/distribution rules (scheduling) and are you satisfied with it?
  - Do you have any other preferences (scheduling system) and how do you make sure your preferences will be addressed?
  - What do you do when other farmers do not respect the water scheduling system?
  - What do the MC and other participants do?
  - Do you ever have difficulties to irrigate according to water scheduling system? When do you choose not to follow it?
  - What is the reaction of other farmers when you don't follow the water scheduling rules?
- *Individual information-processing capabilities and selection criteria*
  - What do your neighbor farmers or other members of the scheme do in case of drought or water shortage?
  - What would your reaction be to that?
  - What do you do in time of drought or water shortage?
  - How do other farmers react to that?
- *Individual resources*
  - Do you pay for water or any other water services?
  - What happens if you don't pay?
  - Does irrigating your plot involve high costs or consume a lot of time?
  - Are these constraints limiting factors and do they prevent you from irrigating or anything else you want to do on the field?

* Do you have any other comments you would like to make?

B. Collective scheme management – Questionnaire based on IADF approach

The questionnaire used for the survey on *collective management* (CM) at scheme level is presented below.

9. General information

- Date;
- Respondent's name;
- Gender;
- Name household head; and
- Interview reference number.

10. Action situations

- *Participant & position*
  - Are you a MC or SC member (function) or only a farmer (official member, official dry land member, rejected land, other)?
  - What is your position/function and responsibility (regarding Collective Maintenance)?

- Do you see maintenance of the system as important?
- What is the effect of maintenance on the secondary canal you are connected to? Does the flow increase? And main canal?

- *Actions*
  - Do you participate in any general maintenance jobs (cleaning main canal/night storage dam)? What do you do and where?
  - How often do you do this and how long does it keep you busy?
  - When do you decide to clean the secondary canal you are connected to (main canal)? How often & how long does it take?
  - Do you ever do maintenance jobs together with others?
  - With whom and how many are you usually?
  - What do you do with others and when (how often)? (main weir, canals, crested weirs, storage dams, silt traps, etc.)
- *Potential outcomes*
  - What impact does maintenance (cleaning of canals, etc.) have on water availability for irrigation and on your crops?
  - Does it affect you when maintenance is not carried out?
  - Why do you think it is not being done? What do you think are the reasons?

11. Patterns of interaction and actor behavior

- *Individual preferences*
  - Are you satisfied with the way maintenance works are organized among the farmers of the scheme?
  - Does it work well? How would you rate maintenance of the scheme at the moment (very good/excellent, good/satisfactory, average, bad/non-sufficient, very bad/never done)?
  - Do you have any other preferences regarding the organization and how do you make sure your preferences will be addressed?
  - What do you do when other farmers do not respect and perform maintenance on the system or attend the works?
  - Does it happen that you sometimes don't participate? What is the reaction of other farmers when you don't participate?
- *Individual information-processing capabilities and selection criteria*
  - What do your neighbor farmers do to maintain the canals? How often?
  - Does it happen that your neighbors do not maintain the canal? Would it affect you and what would your reaction be?
- *Individual resources*
  - Does cleaning the canals or other infrastructures involve high costs or consume a lot of time?
  - Are these constraints limiting and do they prevent you from participating in maintenance jobs or cleaning your canals?

* Do you have any other comments you would like to make?