Best management practices for small-scale subsistence farming on selected irrigation schemes and surrounding areas through participatory adaptive research in Limpopo Province

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Dr AJ Sanewe (Chair 2004-07)	WRC
Dr SS Mkhize (Chair 2003-04)	WRC
Dr GR Backeberg	WRC
Prof MC Laker	Retired professor – University of Pretoria
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Mr FB Reinders	ARC – Institute for Agricultural Engineering
Prof ATP Bennie	University of the Free State
Prof GCG Fraser	University of Fort Hare
Prof A Lourens (2003-06)	TUT
Prof A Kok (2006-07)	TUT

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Substantial parts of this report are based on the work of post-graduate students who participated in the project and their work is acknowledged. Where applicable

reference is made to the dissertations they have produced. These manuscripts have been made available to the Water Research Commission in electronic format and can be requested from this organisation. Hard copies can be obtained by approaching the Library of the TUT using an inter-library loan request.

The specific contributions by post-graduate students to the content of this report are as follows:

Chapter 2: The characterisation of the soils at Dzindi and the soil maps was the work of Mr B Adriaens.

Chapter 4: The analysis of livelihood and farming of plot holders at Dzindi is largely based on the theses of Dr SS Mohamed.

Chapter 5: The institutional and organisational analysis of water sharing, maintenance of infrastructure and collective action in relation to markets at Dzindi is the work of Mr SS Letsoalo.

Chapter 6: The analysis of relationships between Dzindi and its surrounds is based on field work conducted by Mr MM Netshithomboni.

Chapter 7: The investigation of the potential to integrate crop and animal production was the work of Mr KE Ralivhesa supervised by Prof FK Siebrits of the Department of Animal Sciences at TUT.

Chapter 8: Characterisation of the nutrient response of Chinese cabbage and Nightshade is contained in the Master's dissertations of Ms TE Tshikalange and Ms KA Juma, respectively, and the experiments that investigated the effects of planting date and irrigation strategy on the yield of Chinese cabbage were done by Mr C Netshithuthuni.

Chapter 9: The research aimed at improving green maize production at Dzindi was done by Mr TB Khosa.

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PREFACE

This report consists of 11 chapters which can be grouped into four parts. The first part is made up of Chapter 1 and provides the background to the project. In this chapter the meaning of the important concepts that are contained in the title of the project is explained. The chapter also provides a brief history of smallholder farming and small-scale irrigation in South Africa and explains the objectives of the project and the approach that was used during implementation.

The second part presents the results of an analysis of the situation at selected smallholder canal irrigation schemes in Limpopo Province and is subdivided into five chapters. Chapter 2 provides a general overview of the situation at the three schemes that feature in this report. In chapter 3 the important commodity systems found at these schemes are analysed. Chapter 4 investigates livelihood and farming of plot holders on smallholder irrigation schemes and chapter 5 analyses the social and institutional dimensions of smallholder irrigation. Chapter 6 deals with relationships between irrigation communities and their surrounds.

The third part of the report is concerned with improvements to existing production systems and responds to the core theme of the project, namely the development of best management practices for smallholders on irrigation schemes through participatory adaptive research. Chapter 7 reports on the introduction of broiler production at Dzindi using on-farm processing of grains as a way to integrate crop and animal production systems. Chapter 8 reports on experimental research aimed at improving the production of two African leafy vegetables, namely Chinese cabbage and nightshade. Chapter 9 reports on experimental research that was aimed at improving green maize production.

The last part of the report brings the study to its conclusion. In chapter 10 the impact of the project on the participating smallholders is evaluated and chapter 11 contains the most important conclusions and recommendations that were derived from the different research activities. Appendix A reports on capacity building in the project and Appendix B lists all the research products.

EXECUTIVE SUMMARY

BACKGROUND TO THE PROJECT

In this report on WRC Project K5/1464/4, entitled *Best management practices for small-scale subsistence farming on selected irrigation schemes and surrounding areas through participatory adaptive research in Limpopo Province*, the findings of the research and development activities that occurred over a four-year period from April 2003 until March 2007, are presented.

The project was conducted in the form of a case study using Dzindi Irrigation Scheme (23°01'S; 30°26'E) as the case. Additional fieldwork was conducted at Khumbe Irrigation Scheme (23°03'S; 30°21'E) and Rabali Irrigation Scheme (22°53'S; 30°07'E) to find out to what extent the findings at Dzindi had wider application. All three schemes were similar in size and used canal irrigation. They also shared a similar general production pattern that featured maize in summer and vegetables in winter.

Research activities aimed at identifying best management practices occurred in three domains, namely the domain of the individual plot holder household and farm enterprise, the domain of the irrigation scheme and the domain of the world outside the scheme. Two types of research and development activities were done, namely activities aimed at understanding existing management practices and activities aimed at improving management practices. Nearly all of these activities were done at Dzindi. Methods used in data collection at Dzindi included the use of Rapid Rural Appraisal (RRA) techniques, surveys involving probability sampling and structured interview schedules, experiments in the green house, on-station and on-farm field experiments and qualitative methods. Methods of data collection at Khumbe and Rabali were largely limited to the use of RRA techniques.

To encourage active participation of plot holders in the project at Dzindi, the 'merging of communities of practice' approach was adopted. The application of this approach yielded a priority list of goals for the project, which were translated into research and development activities, taking into account the limitations imposed by the availability of financial and human resources.

RESULTS OF THE ANALYSIS OF EXISTING MANAGEMENT PRACTICES ON SELECTED SMALLHOLDER CANAL IRRIGATION SCHEMES IN LIMPOPO PROVINCE

The domain of the individual plot holder

It is well known that management practices at the level of the individual farm enterprise are guided by the objectives of the farmer. Generally, farmers on the three irrigation schemes that featured in this study matched the description of 'the smallholder farmer – lower risk, diversified farming' development trajectory proposed by Denision and Monona (2007). The key question was whether plot holders on these schemes can be regarded as a homogeneous group who share the same farming objectives. To answer this question, livelihood and farming of plot holder households were analysed on these schemes. The most detailed investigation was done at Dzindi and the results presented here only refer to that scheme. The studies conducted at the other two schemes produced results that did not contradict the findings at Dzindi.

Using principal source of income (cash and kind), which was defined as the source of income that contributed at least 50% to total household income, to categorise livelihood among plot holder households at Dzindi, **nine livelihood types** were identified. These were:

(i) One-generation pensioner households;
(ii) Two-generation pensioner households;
(iii) Three-generation pensioner households;
(iv) Wage-earner households reliant on skilled formal employed;
(v) Wage-earner households reliant on unskilled formal employment;
(vi) Market oriented farming households;
(vii) Subsistence farming households;
(viii) Households active in the informal sector; and
(ix) Diversified-income households.

Among households in the different livelihood types, total household income was subject to considerable variability. Skilled wage-earner households had the highest mean total household income, followed by unskilled wage-earner households. Subsistence farmer households were the poorest. Households with a large number of economically active adults did not necessarily obtain high levels of income. This was particularly evident among subsistence farmer households and three-generation pensioner households. Market-oriented farmers had the highest mean gross farm income and the mean gross margin of their plot enterprises was also the highest, suggesting that households in this livelihood type had a different approach to farming than households in the other livelihood types.

The analysis of diversity of farming at Dzindi resulted in the identification of **four farming styles**. Farming style is an integrating concept that portrays a particular way of practising agriculture. The four farming styles identified at Dzindi were:

(i) Profit makers;
(ii) Employers;
(iii) Food farmers (type 1); and
(iv) Food farmers (type 2)

Profit makers farmed mainly for market purposes (>50% of the total annual value of their production was sold). Important commodities were white cabbages and green maize. Compared to other farming styles, profit makers were least adverse to risk. Typically they made use of inputs and services of high quality in their production systems and were prepared to pay a premium for these. Profit makers sourced most of their labour from within their homesteads, hiring temporary labour only at times of peak demand. Finding markets for their produce was their most important concern.

Characteristic of employers was that they hired one or more full-time workers to provide the labour on their farms. This contributed considerably to the total variable costs of production usually resulting in negative gross margins.

Food farmers farmed mainly for home consumption (>50% of the total annual value of their production was consumed at home). The food farmers (type 1) style corresponded most closely with the concept of the subsistence farmer, which has the general characteristics of:

i. operating a farm that is limited in scale and output;
ii. having household food security through own production as the primary objective and not the generation of income through cash sales of produce;
iii. making limited use of purchased inputs;
iv. being risk adverse; and
v. having cash sales of farm produce as a minor source of total homestead income.

During summer, food farmers (type 1) produced maize for grain, which was stored at home or delivered to the commercial mill in return for credit notes. Producing and storing sufficient maize grain to supply the homestead for a full year or even longer was a key objective of these farmers. Winter production was mainly limited to traditional vegetables on small parts of the plot, partly for sale and partly for consumption at home. The main concerns of these farmers were to limit expenditure and to avoid risk.

The food farmers (type 2) had characteristics that were similar to those of food farmers (type 1). They also farmed mostly for home consumption and produced the same type of crops but on a small scale they were also prepared to take risk by producing green maize or white cabbage. The identifying characteristic of this farming style was that they achieved high returns from expenditure on variable costs of production (>R2 for every R1 invested).

Livelihood types and farming styles were shown to be related, providing evidence that irrigated farming by plot holder households needs to be understood in the context of their overall livelihood strategy. The longitudinal study of livelihood and farming of a selection of households at Dzindi showed that both were dynamic and subject to interaction.

The domain of the irrigation scheme

The social and institutional dimensions of irrigated farming were found to be of great importance in the domain of the irrigation scheme. The social arenas that were investigated included (i) the sharing of water among smallholders; (ii) the maintenance of infrastructure; (iii) accessing markets; (iv) land tenure and exchange; and (v) land preparation.

Management of irrigation water: At Dzindi, the rules governing the sharing of water among farmers were imposed when the scheme was commissioned and they have largely survived for more than 50 years. Reduced influence of the state brought about relaxation of the rules by creating room for farmers to negotiate among each other. Whereas this increased the flexibility of the rule system, it also opened the door for abuse and conflict.

Maintenance of irrigation infrastructure: At the establishment of Dzindi, an institutional system of collective action was imposed, monitored and enforced by the state to ensure that routine maintenance was taken care of. Over time, the routine maintenance institution was internalised by the group and when external monitoring and enforcement was removed, the institution persisted.

Natural change in the composition of the group and change in the structure of the livelihoods of plot holders provided the context for the institution to be challenged, initially by norm entrepreneurs and later on by the majority of plot holders. This forced the group to fundamentally modify the routine maintenance institution from a system that relied on plot holders to voluntarily supply their labour to a system that demanded plot holders to make financial contributions to pay for labour.

The new institution showed its weaknesses almost immediately and for the practical purpose of ensuring that the conveyance system is maintained, it has already collapsed, threatening the sustainability of irrigation at the Scheme. The 2007 initiative of plot holders in Block 2 to revert to the old system of collective action to get their section of the canal cleaned up suggested that the Dzindi community will find a solution to the crisis.

The current group of plot holders at Dzindi lacked understanding of the relationship between routine maintenance, flow rate in the canals, and stream size at plot edge. Educating plot holders about this relationship is considered a critical element to the internal debate that is necessary to craft a new and effective routine maintenance institution.

Access to input and output markets: At Dzindi, voluntary co-operation among farmers for improved access to markets has been limited to input markets. No evidence of voluntary cooperation was found in relation to output markets and this also applied to Khumbe and Rabali. The farmers' association was the original form in which farmers at Dzindi sought to improve access to input markets. The concept was introduced by the state but farmers were given the opportunity to reflect on what the role of the farmers' association should be, how it should be structured and managed and what its functions should be. The institutional arrangements plot holders arrived at were based on the value of mutual aid in line with traditional forms of collectivism. Structurally, power and authority in the organisation was held by the collective of plot holders and its elected leadership. The management practices of the organisation were based on volunteerism and mutual trust. Despite the absence of any bookkeeping procedures there were no complaints of misappropriation of funds during the long history of the Dzindi Farmers' Association.

The state, probably influenced by the expert system that informed it, felt it necessary to intervene and insisted that the small holder farmers' associations be converted into registered co-operatives. It imposed the co-operative model that applied to the white commercial farming sector seemingly with complete disregard for the differences between that sector and the African smallholder sector. The outcome was not successful because the imposed model did not suit smallholder communities.

Access to land: Trust tenure applied to all three irrigation schemes that were included in this study. The issue of new permission to occupy (PTO) certificates by the authorities to register transfer of ownership of plots continues, even though from a legal perspective these issues are no longer valid.

Historically plot holders have experienced Trust tenure as highly insecure, especially at Dzindi but enforcement of PTO conditions by the state is largely a thing of the past, even though some conditions remain in force. In terms of holding rights, plots remain indivisible, but subdivision of the user rights is being allowed. The authorities maintain control over the transfer of the rights over a plot following the death of a plot holder or when a plot is vacated, but the composition of what constituted the authorities differed among the schemes.

The contemporary irrigator communities at the three schemes each interpreted the Trust tenure system differently and enforced selected elements of the historical PTO conditions that applied, whilst ignoring others. This phenomenon had important implications for land exchange at the three schemes. At Dzindi, exchanges of land have been discouraged completely by the community and its leadership until very recently, seemingly because of the history of evictions for non-compliance with PTO conditions at that scheme. At Khumbe, land exchanges were allowed by means of sharecropping arrangements involving members of the Khumbe community only. Strictly forbidden at Khumbe were the renting out of land against payment and exchanges of land involving 'outsiders', with severe fines being imposed on transgressors. At Rabali, both sharecropping and renting out of land were common practice and both members of the irrigation community and 'outsiders' were allowed to engage in these types of land exchanges. Poverty was the main motivation among plot holders at Rabali to engage in exchanges of land.

Land preparation: The withdrawal of the subsidized public land preparation service from smallholder irrigation schemes in Limpopo Province resulted in a substantial increase in the cost of cultivation to farmers. Five different strategies developed by farmers to cope with the high cost of land preparation were identified. They included establishing a collective cultivation service that offered discounts, leaving part of the plot fallow, share cropping, converting to animal draught and resorting to manual labour. The different strategies enabled farmers to continue producing crops, which was particularly important for the attainment of food security at the level of their households. For the poor the withdrawal of the subsidized public land preparation service has made life more difficult than before.

The domain of the world outside the scheme

The external world influences farming in many ways. Markets are one of the important ways in which the external world affects farming. Access to markets tends to be a spatial factor, particularly in smallholder agriculture. Smallholder access to markets improves with proximity to urban areas.

Commodity prices, policy, security, the cost of doing business and input costs are other important external-world factors that affect the functioning of irrigation schemes. For example, policy measures in the form of subsidised assets (land, equipment, water), or services (advisory, marketing, finance) can improve the financial viability of farming. Low commodity prices, high input costs and security concerns are examples of factors that reduce the financial viability of farming.

The availability of livelihood options other than farming is an important indirect effect of the external world on farming as it affects the availability of labour on the farm.

Research into the domain of the world outside the scheme conducted under the auspices of this project was limited to an investigation of the relationship between Dzindi Irrigation Scheme and the settlements that surround it with special reference to the issues of land and water.

Dzindi is located in a zone of rapid urbanization and in the settlements surrounding the Scheme access to land for farming was extremely limited. Functionally, the livelihood of households residing in these settlements was urban, but the rural heritage of people still had a strong influence on their lifestyles and outlooks. Dzindi was essentially the only potential source of arable land in the area. Residents of settlements surrounding Dzindi identified purchase or renting of unused land as suitable options to obtain access to land for crop production at Dzindi but were not interested in share cropping. No evidence was found that people in the settlements surrounding Dzindi entertained the idea of challenging ownership of land at Dzindi. Instead, a general acceptance that plot holders were the legitimate owners of their plots prevailed among those that participated in the study even though the demand for land, especially arable land, in the surrounds was high. This was evident from the widespread use of residential sites for agricultural purposes and the cultivation of roadsides and land alongside the irrigation canal.

Access to water in the settlements surrounding Dzindi was generally adequate. Households obtained water from different sources for various uses, including domestic and agricultural. Extraction of water from the canal by residents in these settlements was limited and probably did not materially affect water availability at the Scheme. A degree of tension between plot holders and members of surrounding communities who planted crops along the canal and used water from the canal to irrigate these crops was identified, even though the amounts of water extracted for this purpose were negligible on the whole.

Above the weir that supplies Dzindi, extraction of water from the river occurred at several sites, by means of pumps and river diversions. These extractions undoubtedly had a reducing effect on the amount of water reaching the weir during periods of base flow but the overall impact was limited.

About one in every four households residing in the settlements surrounding Dzindi declared that they benefited from the presence of Dzindi Irrigation Scheme. The main benefit was in the form of access to cheap and fresh food, sometimes obtained in the form of gifts. Employment on the scheme was another benefit that was identified but its impact was more modest.

ANALYSIS OF IMPORTANT COMMODITY SYSTEMS ON SELECTED IRRIGATION SCHEMES IN LIMPOPO PROVINCE

Maize

The results of the study of the maize commodity chain at Dzindi showed that maize simultaneously served as a high-value cash crop and as a food crop. The close proximity of Thohoyandou ensured the availability of a sizeable market for green maize cobs. Growing maize for the purpose of green maize sales enabled smallholders to obtain much higher gross margins from maize than growing the crop for grain but hawkers, to whom most green maize was sold, applied quality control measures that limited the proportion of cobs being sold by farmers. Plants with cobs that did not make their quality standards were left in the field for farmers to harvest as grain at maturity.

The importance Dzindi farmers attached to the role of maize grain in the food security of their households was re-enforced by the availability of two storage and transformation systems, which enabled farmers to process their grain into maize meal for consumption. The proximity to Dzindi of an industrial mill where grain could be exchanged for meal using a system of credits, which permitted long-term storage of grain for emergencies, was coincidental. The supply of maize by Dzindi farmers to the industrial mill, which sources its grain mainly from producers in the maize triangle, was of no consequence to the turn-over of the mill. The presence of two small-scale, privately-owned grain mills at Itsani, of which Dzindi is part, was not coincidental because these small mills appeared to generate sufficient business from irrigated maize production at the Scheme and dryland production in the surrounds.

Technically, maize production practices at Dzindi appeared to address the key growth requirements of the crop, using both modern and traditional technology, but the relatively low yields, equivalent to about 2.5 tons grain ha^{-1} on average, suggested room for improvement.

The study showed that many farmers at Dzindi associated household food security with the availability of maize grain in their stores. This association was strengthened further by the availability of the necessary infrastructure to transform the grain into the desired products for consumption. For this reason, attempts to replace maize with other crops on smallholder irrigation schemes where circumstances are similar to Dzindi are likely to meet with resistance from farmers.

Vegetables

At all three smallholder irrigation schemes that featured in this study, production during the winter season mainly involved vegetables. The types of vegetables that were grown differed among the three schemes. At Rabali, tomatoes were the principal winter crop, whilst cabbages, Chinese cabbage and nightshade featured most prominently at Dzindi. Among the three schemes, Khumbe displayed the widest diversity in vegetable production, Vegetable species grown at Khumbe included fruity types, such as tomatoes, tuberous and bulbous vegetable species, such as sweet potatoes and onions and also a wide range of leafy vegetables.

A detailed study of the smallholder vegetable commodity chain was conducted at Dzindi and focused on two African leafy vegetables, namely, Chinese cabbage (*Brassica rapa* subsp. *chinensis*) and nightshade (*Solanum retroflexum* Dun.) and two exogenous vegetables, namely, Swiss chard (*Beta vulgaris* L.) and white cabbage (*Brassica oleracea* L. var. *capitata*).

For each of the four vegetables, farmers had developed, adapted or adopted comprehensive production systems. Farmers were most confident in the production of the two African leafy vegetables but the Chinese cabbage enterprise provided farmers with the lowest gross margin followed by the nightshade enterprise. The production of cabbage was the most lucrative but managerially farmers considered it to be the most demanding of the four vegetables that were investigated.

From a technical perspective the high and on occasion excessive use of fertilisers, which accounted for about 40% of the total variable costs of production of the two African leafy vegetables, was identified as an opportunity for improving the gross margins of production. Development of fertiliser guidelines for these two vegetables was selected as a suitable topic for research and development aimed at improved management of these two crops.

Integrating crop and livestock production systems on smallholder irrigation schemes in Limpopo Province

All three smallholder irrigation schemes had the virtual absence of animal production in common. Integrating crop and animal production holds potential advantages in smallholder irrigation. These include the creation of additional produce markets in the form of crops to be used as animal feed and animal products and the local supply of animal manures for use in the management of nutrient availability in cropped land. Following a feasibility study of different types of poultry production, the research team developed the idea to introduce broiler production as a first step in the direction of developing integrated farming systems on smallholder irrigation schemes.

BEST MANAGEMENT PRACTICES FOR SMALLHOLDER IRRIGATION SCHEMES IN LIMPOPO PROVINCE: GENERAL RECOMMENDATIONS

The domain of the individual plot holder

The implication of the observed diversity at the level of the individual farm enterprises found on smallholder irrigation schemes was that best management practices should be tailored to suit the specific objectives of farming households. Consequently, a 'one size fits all' approach is unlikely to be successful when developing and disseminating best management guidelines for use at the farm enterprise level. Categorising households in livelihood types and farming styles was shown to be a suitable approach to make sense of the diversity among them. The results of this study showed that households contained in the same farming style category tended to share the same farming objectives. Categorising plot holders according to their farming styles is, therefore, a suitable way to identify extension domains for the development and dissemination of technical management information.

The domain of the irrigation scheme

The domain of the irrigation scheme, more specifically the group of people who make use of this asset, is probably the most important and also the most ignored domain in the management of smallholder irrigation schemes in Limpopo and possibly also elsewhere in South Africa. It is this domain of management that determines access to irrigation water and land by individual farmers. Management in this domain can also improve access to markets and services, such as land preparation.

The **management of water and irrigation infrastructure** is of particular importance in smallholder canal irrigation. The findings of this study indicate that a system of simple rules that govern the sharing of water among farmers and the routine maintenance of the canal system can form the appropriate basis for sustainable water management by plot holders. However, the study also identified the need for an external agency to form part of the overall management system. The principal roles of this agency should be to participate in regular monitoring and evaluation of the management activities and to intermediate, and if necessary intervene, in conflict situations. Considering that the Limpopo Department of Agriculture is the legal owner of many if not all of the smallholder canal irrigation schemes in the Province, it is appropriate that this Department serves as the proposed external agency. Critical outcomes of a sustainable water and irrigation infrastructure management system for canal irrigation schemes are that water is being shared equitably among farmers and that canals are clean and in good condition.

An important weakness identified at all three schemes was the absence of adequate expertise to manage water flow in the canal system. As a result, gates and valves were not used to best effect, causing water losses and inequitable distribution of the water to the different parts of the scheme. Invariably, the extension staff assigned to the three schemes that featured in this study had never been trained in the regulation of water in canal irrigation systems. Considering the abundance of smallholder canal irrigation schemes in South Africa, particularly in Limpopo Province, the need to develop an appropriate training programme for extension staff working on this type of schemes was identified.

The results of this study showed that voluntary co-operation among farmers can improve **access to markets**. The results also suggested that institutional arrangements that are based on the value of mutual aid, in line with traditional forms of collectivism, are probably best suited when developing collective action among plot holders for improved market access. Intervention by the state should aim to support the initiatives of farmers and not to regulate voluntary collective action. When regulation does become prudent, it should be introduced in ways that allow smallholders sufficient time to internalise the new concepts and to adapt them to suit their own circumstances.

The results of this study show that *de facto* Trust tenure continues to apply on many canal irrigation schemes in Limpopo Province. Whereas most plot holders on these schemes do not cultivate their entire allotment at all times, there are others, primarily those that run farm enterprises with a strong market focus, who are in desperate need of additional land. **Land exchanges** among plot holders are the most obvious way for those in need to access more land. Opening the market for land exchanges on these schemes is expected to be assisted by the development of a simple rule system to govern exchanges, the development of a register of plot holders (usually in place), the demarcation of the individual plots in the field, and the appointment of an external agency to intervene when conflicts arise. As in the case of water management, the Limpopo Department of Agriculture is the most appropriate body to serve as the external agent. Lastly, there is also a need for mobilisation to encourage plot holders to consider land exchange as a way of deriving benefit from their plots.

Affordability and access to mechanised **land preparation** limit overall production on smallholder irrigation schemes. Poor households who are involved in subsistence farming are most affected by this constraint. The option of re-introducing animal draught on smallholder irrigation schemes as a way to reduce variable costs and possibly limiting the problem of soil compaction associated with the use of tractors warrants investigation. It is probably not practical for each plot holder to own the wherewithal to cultivate land using animal draught but there are no obvious reasons why selected households could not provide land preparation services to others on a commercial basis using animal draught equipment.

The domain of the world outside the scheme

Limiting recommendations for best management practices to aspects that were investigated empirically, the study identified two opportunities to distribute more widely the benefits associated with smallholder irrigation schemes.

One opportunity was to broaden access to irrigation land. Land is available at these schemes, particularly during winter, suggesting room for others to join production. However, at this stage plot holders tend to be reluctant to enter land exchanges involving outsiders.

Another opportunity to enable more people to benefit from the presence of a canal irrigation scheme was to allow outsiders to extract water from the canal, particularly during the night and storing this water in tanks. This opportunity would benefit people living within close vicinity of the canal by enabling them to access irrigation water for home gardening purposes. However, at Dzindi, existing extraction by outsiders, which mostly involved small quantities of water, already stirred up emotions among plot holders, suggesting that considerable negotiations would be needed before plot holders would allow for this to happen.

SELECTED BEST MANAGEMENT PRACTICES FOR IMPORTANT COMMODITY SYSTEMS FOUND ON SMALLHOLDER IRRIGATION SCHEMES IN LIMPOPO PROVINCE

Improving green maize production

Several opportunities exist to improve green maize production on smallholder irrigation schemes in Vhembe. To maximise the number of marketable cobs per unit area, cultivar selection is important and ETZ 200 and SC 701 were identified as superior cultivars in terms of cob length and other important attributes. For September plantings at Dzindi, the optimum planting density for green maize production using the cultivar SC 701 was about 4.0 plants m^{-2}, but planting density has to be reduced to about 3.0 plants m^{-2} when using the PAN 93 cultivar.

Improving the production of selected African leafy vegetables

Optimising soil nitrogen availability was the most critical nutrient management concern in the production of Chinese cabbage and nightshade. Sufficient nitrogen needs to be available in the soil for the two crops to achieve optimum growth, but adding too much nitrogen adversely affects biomass production. Considering that smallholders produce these two vegetables under irrigation, which increases the likelihood of nitrogen losses due to leaching, maintaining optimum availability of N in field soils throughout the growing season is expected to be difficult to achieve. The use of split application of N, which is common practice among smallholders at present, is likely to be the appropriate strategy to achieve optimum availability of N but this needs to be investigated.

Production of Chinese cabbage and nightshade is also dependent on the adequate availability of phosphorus and potassium, but the adverse effects caused by applying these two nutrients in excess of the rate at which biomass production peaked were less distinct than for nitrogen.

Growers stand to benefit financially from optimizing fertiliser application rates in the production of Chinese cabbage and nightshade, but field experiments are needed to identify these rates.

The yield of Chinese cabbage peaks when the crop is planted during the period 25 May until 2 July. Postponing the planting date beyond the 2nd of July rapidly reduces yield and bringing planting forward to dates earlier than 25 May also reduces yield, but in a less extreme way. Consequently, the option of spreading the planting date of Chinese cabbage more widely, to avoid the period of excess supply on the local market, is seriously compromised by the important effect of planting date on the yield of this crop.

Full irrigation produces the highest yield in Chinese cabbage but this requires farmers to irrigate the crop at least twice per week. Considering that plot holders on canal schemes are only allocated water once per week, farmers can only implement full irrigation by practising night-irrigation or by negotiating access to additional water with other plot holders using the same supply furrow. Use of a deficit irrigation approach when producing this vegetable has limitations because compared to full irrigation, deficit irrigation reduces yield substantially.

Integrating crop and animal production systems

Assessment of the performance of a single-phase broiler diet obtained by on-farm processing of yellow maize grain and soya beans using a commercially available three-phase diet as the benchmark for comparison showed that birds fed of the commercial diet (C) grew faster and were ready for marketing one week earlier than birds fed on the on-farm diet (OF). From an economic perspective, the performance of the enterprises based on the use of the two diets was not very different. The experimental enterprise that used the three-phase commercial diet (C) provided a higher gross margin (R6.79 $bird^{-1}$) than the enterprise that used the on-farm single-phase diet (OF) (R5.38 $bird^{-1}$), a difference of R1.32 $bird^{-1}$. The main advantage of using the on-farm diet was that it provided the opportunity to integrate crop and animal production and to locate a larger part of the value chain within the local agrarian economy. The results obtained so far warrant further research.

References

DENISON, J. & MANONA, S. 2007. *Principles, approaches and guidelines for the participatory revitalisation of smallholder irrigation schemes: Volume 1: a rough guide for irrigation development practitioners*. WRC Report No. TT 309/07. Gezina (Pretoria): Water Research Commission.

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SYMBOLS AND ABBREVIATIONS

AD	Anno Domini
BEE	Black Economic Empowerment
CFT	Charged Farmer Treatment
COSA	Centre for Organic and Smallholder Agriculture
DFA	Dzindi Farmers' Association
DFAC	Dzindi Farmers' Association Committee
DFC	Dzindi Farmers' Co-operative
DFCC	Dzindi Farmers' Co-operative Committee
DFFT	Double Frequency Farmer Treatment
EO	Extension Officer
FA	Farmers' Association
FI	Full Irrigation
FT	Farmer treatment
g	Gram
GEAR	Growth, Employment and Redistribution
ha	Hectare
IMT	Irrigation Management Transfer
IPARP	Intercepted Photo-synthetically Active Radiation per Plant
IPAR %	Proportion of incident PAR intercepted by the canopy
I_o	Incident PAR above the canopy
I_t	Incident PAR below the canopy
K	Potassium
kg	Kilogram
KNE	Kernel Number per Ear
LSD	Least Significant Difference
MI	Minimal Irrigation
N	Nitrogen
O & M	Operation and Maintenance
p	Probability
P	Phosphorus
PAR	Photo-synthetically Active Radiation
PD	Planting Date
PTO	Permission To Occupy
R	Rand (South African currency)
RDP	Reconstruction and Development Programme
RESIS	Revitalisation of Smallholder Irrigation Schemes
SMC	Scheme Management Committee
TUT	Tshwane University of Technology
WRC	Water Research Commission
WWII	Second World War
£	Pound Sterling (British currency)

1 INTRODUCTION

The Water Research Commission (WRC) solicited WRC research project K5/1464/4 presented in this report and provided the general terms of reference and the title. The title of the project, '*Best management practices for small-scale subsistence farming on selected irrigation schemes and surrounding areas through participatory adaptive research in Limpopo Province' c*ontains several important concepts. In the first part of this introductory chapter these concepts are explored and the implications of the findings of this exploration for the current study, which is concerned with smallholder canal irrigation schemes in Limpopo Province, are highlighted. In the second part, the history of smallholder farming and smallholder irrigation development in South Africa are reviewed. This review is followed by a presentation of the generic objectives of the project and how these were interpreted by the project team. The chapter is concluded by an introduction to the three study sites and a brief description of the overall approach that was followed during the conduct of this project.

1.1 Important concepts

1.1.1 Smallholder farming in South Africa

In South Africa, the terms 'small-scale farmer' and 'smallholder' are commonly used when referring to African farmers, because the majority of African farmers in this country operate enterprises that are small in size relative to those of White farmers (Machete and Mollel, 2000). Farming on smallholdings in South Africa is not exclusive to African people. There are White people who hold small farms, often referred to as plots, particularly around cities, such as Pretoria and East London. Conversely, there are also African people who hold large farms (Laker, 2004) and their number is likely to increase in future as a result of natural economic processes of land acquisition and investment in agriculture by African people.

1.1.2 Subsistence farming

Spedding (1979) defined subsistence farming as the production of sufficient food and fibre to satisfy the needs of the farming family. He pointed out that in the past, particularly in the tropics, subsistence farming was quite common with large numbers of farmers producing only what they required, collecting fuel and building materials from their surrounds and playing little part in the cash economy. Spedding (1979) indicated that producing nothing for sale at all had become a rare phenomenon among subsistence farmers even though many of them still fell short of adopting a commercial attitude to agriculture. The subsistence farmer practice of selling some produce was confirmed by Makeham and Malcolm (1986) who identified the production of sufficient food to feed the farming family as the primary objective of subsistence farming, but indicated that earning some cash income and accumulate some savings were also important. Makeham and Malcolm (1986) pointed out several elements that were characteristic to subsistence farming systems. These were:

i. Farming occurs on holdings that are small, both in terms of size and output.
ii. Farming does not rely much on purchased inputs.
iii. Generally, food acquisition activities that form part of subsistence farming systems, including crop and animal production, hunting and the collection of food

plants from the wild, are aimed at supplying the basic nutrient needs of the farming household and, where possible, a surplus for barter or sale. The traditional methods of achieving these two goals are typically the result of a long process of farmer experimentation and are often ingenious.

iv. Subsistence farmers are reluctant to try out new practices that increase risk, even when these practices hold the promise of more food, better food or increased cash income. The main reason for this reluctance is that failure of the innovations can have a disastrous impact on household food security.

v. Subsistence farmers prefer to invest their savings in liquid assets and not in long-term fixed-capital investments, such as buildings, land improvements or even long-term monetary investment instruments. Even traditional farming systems carry risk and in times of adversity long-term fixed-capital investments cannot easily be converted into cash. To safeguard household food security subsistence farmers tend to invest in liquid assets, such as livestock.

vi. Proportionally, cash sales of farm produce make a small contribution to the total gross household income in cash and kind of subsistence farmers. Typically this income has four components, namely the market value of farm products consumed by the household, cash income from the sale of farm produce, cash income from off-farm employment and payments in kind, often food, for services rendered to others.

vii. Labour is the main category of direct farm inputs in subsistence farming systems and cash expenditure on direct farm inputs is small.

viii. In addition to payment for direct farm inputs, such as fertilisers, plant protectants, tools and contract services, subsistence farmers use cash for overhead and personal expenses, such as schooling, clothing and possibly savings and investments. The other type of expenditure incurred by many subsistence farmers involves the payment in kind, whereby farm produce is exchanged for services rendered or as tribute to traditional leaders.

1.1.3 Irrigated smallholder schemes in South Africa

South Africa has about 1.3 million ha under irrigation of which about 0.1 million ha is in the hands of African smallholders (Backeberg, 2006). Smallholder irrigators have been categorised into four groups (De Lange, 1994; Crosby *et al*., 2000; Du Plessis *et al*., 2002), namely,

(i) farmers on irrigation schemes;
(ii) (ii) independent irrigation farmers;
(iii) (iii) community gardeners; and
(iv) (iv) home gardeners.

Backeberg (2006) estimated the total number of smallholder irrigators contained in these four groups combined to range between 200 000 and 250 000, but pointed out that the majority were irrigating very small plots, primarily to provide food for home consumption.

This report is concerned with one group of small-scale irrigators only, namely those operating on irrigation schemes. Smallholder irrigation schemes in South Africa can be defined as multi-farmer irrigation projects larger than 5 ha in size that were established by black people or agencies assisting their development in the former homelands or in resource-poor areas. Using this definition, Denison and Manona (2007b) counted 317 smallholder irrigation schemes in South Africa in 2003. Estimates of the combined command area covered by this type of irrigation schemes range between 46 000 ha and 49 500 ha (Bembridge, 2000; Backeberg, 2003; Denison and Manona, 2007b). This represents about 47% of the total smallholder irrigation area in this country and 3.6% of the 1.3 million ha under irrigation at the national level (Backeberg, 2006). Denison and Manona (2007b) estimated that the land on smallholder irrigation schemes was held by about 31 000 plot holders. By comparison, the 1.2 million ha of irrigated land in South Africa, which is referred to as large-scale commercial, is held by about 28 350 land holders (Backeberg, 2006). Dividing the total irrigated area by the number of plot holders, the average size of irrigated plots on South African smallholder irrigation schemes is about 1.5 ha and that of irrigated holdings in the large-scale commercial irrigation sector about 42 ha.

1.1.4 Management

1.1.4.1 General definition: Hodgetts (1981:3) defined management as 'the process of getting things done through people'. Kreitner (1995:4) provided additional detail when he defined management as 'the process of working with and through others to achieve organisational objectives in a changing environment'. In their definition of management, Jones, George and Hill (2000:5) elaborated the meaning of management as a process. They defined this process as the planning, organising, leading and controlling of resources to achieve organisational goals effectively and efficiently. In their definition resources included people, machinery, raw materials, information skills and financial capital. They defined organisations as 'collections of people who work together and coordinate their actions to achieve a wide variety of goals'. They defined a goal as 'a desired future outcome that an organisation strives to achieve'.

1.1.4.2 Management of family farm enterprises: Boehlje and Eidman (1984) pointed out that the management of a farm enterprise essentially consists of three functions, namely planning, implementation and control. Planning involves the selection of a strategy or course of action to pursue the goal(s) of the farm enterprise. It comprises of the making of decisions on what should be done, on how and when each task should be done and who should do it. Implementation involves the execution of the plan. It entails the acquisition of the required resources, the organisation of the work and the direction and supervision of the different tasks. Control involves the measurement and analysis of performance and decisions on corrective actions when necessary. It involves the comparing of the actual outcomes with the expected outcomes contained in the plan and implies the keeping of records in some or other form. The three functions of farm management need to be applied in three main domains, namely, production, marketing and finance.

Conceptual specificity arises when the general meaning of farm management is applied to a particular context. In this research project the primary focus is on the individual enterprises that are found on smallholder irrigation schemes. On most of these schemes the plots are held by individuals who form part of a family or household. The small size of the irrigation plots enables the plot holder and his family to provide most of the labour. This is not always the case, as will become evident from the results of this research project, but for practical purposes the majority of farm enterprises on smallholder irrigation schemes can be regarded as family farm enterprises.

Exploring various interpretations of the concept of the family farm enterprises, Gasson and Errington (1993) identified six elements that characterise this concept. These were:

i. The business principals are related by kinship or marriage.
ii. Family members, including the business principals, provide capital to the business.
iii. Family members, including the business principals, do farm work.
iv. Business ownership and managerial control are transferred between the generations with the passage of time.
v. The family lives on the farm.

Gasson and Errington (1993) pointed out that the six elements characterising the concept of the family farm enterprise do not necessarily allow for the operationalisation of this concept because there are farms that can be regarded as family farm enterprises even though they do not feature all six of these elements.

When studying family farm enterprises, the concept of household is a useful unit of analysis. Gasson and Errington (1993:30) defined household as ‘a group of people who live under one roof and share meals’. They pointed out that the household represents the arena of everyday life for most of the world’s population and referred to it as the cushion between the individual and the uncertainty of the external world. According to Gasson and Errington (1993:32), the household is associated with an identifiable place and serves as the locus of the economic and social activities of its members. In the context of the family farm enterprise they considered the household to encompass both the material resources of the domestic group, such as land, labour, machinery and livestock, and the people brought into association through the use of these resources. For this reason, the household can be regarded as the organisation that constitutes the family farm enterprise. The household concept is revisited in Chapter 4 of this report where the operational definitions of concepts and the methods that were used to collect and analyse data on livelihood and farming are explained.
Family labour, one of the important resources on family farms, varies in relation to the family cycle (Gasson and Errington, 1993). In general terms, three phases occur in this cycle, namely,

i. The early phase, during which all children are younger than 15 years old.
ii. The middle phase, during which some of the children are of working age and live and work on or off the farm.
iii. The late phase during which all children have left home.

Boehlje and Eidman (1984) linked the three phases in the family cycle to three stages in the family farm enterprise. The first phase coincides with the establishment stage of the farm enterprise. During this stage the prospective farmer evaluates opportunities in farming relative to opportunities in other economic sectors and decides to farm for a living or not. Those deciding to enter farming progressively acquire the wherewithal to start and run a farm enterprise. The second phase in the family cycle coincides with the growth and survival stage of the farm enterprise. During this stage the farmer seeks to expand the farm enterprise. This is pursued by extensification (scale enlargement) or intensification (increased productivity per unit land). The third phase coincides with the exit or disinvestment stage of the farm enterprise, which is characterised by two processes, namely retirement and intergenerational transfer of the farm business. Each of the three stages of the family farm enterprise represents particular management challenges.

One of the important advantages of using family labour is flexibility. Peaks in labour demand can be managed by mobilising the full complement of family members, whilst during times of low demand part of the family may engage in other activities. Motivating family members to work on the farm is a critical management factor. Individual family members face the choice between working on the farm and engaging in other economic activities, which may be more rewarding financially. Three types of psychological contracts that keep family labour motivated are recognised, namely coercive, calculative and collaborative (Gasson and Errington, 1993). In the case of coercive contracts family members are forced to provide labour without being offered any specific benefit reward or promise of a reward except perhaps their part in the consumption of the enterprise returns. In the case of calculative contracts the immediate reward for labour inputs may be limited but there is a promise of a sizeable reward in future, such as inheriting the farm. In the case of collaborative contracts family members provide labour because they feel that they form part of the productive and consumptive group and place the needs of the group before their own.

In business economics, the maximisation of profit or return is usually considered as the goal of an enterprise. However, in the case of family farms this is not necessarily the case (Boehlje and Eidman, 1984; Gasson and Errington, 1993). Among the different farmer goals that have been identified were:

i. ***Maximizing profit or return***: Broadly this particular goal involves the maximisation of annual net farm income, which considers both monetary and in-kind sources of income. Instead of trying to maximise net farm income, many farmers (and other business people too) aim at obtaining at least a minimum income level, a goal referred to as 'satisfying behaviour'.
ii. ***Increasing net worth***: This goal not only affects the investment and productive behaviour of farmers but also their consumptive behaviour. When pursuing this goal, farmers and their families often have to sacrifice luxuries to reinvest surplus income in the farm enterprise to increase its productivity and net worth.
iii. ***Controlling a larger business***: Farmers pursuing this goal seek to enlarge their enterprises, be it in terms of farm size (acreage), livestock numbers or some other unit of scale, regardless of the profitability of the larger operation. Prestige is an important motivating factor for them.
iv. ***Avoiding low returns or losses***: Farmers pursuing this goal have the desire to reduce risk, to have a stable income and to remain in the farming profession. They favour business decisions that may not maximise income but may reduce possible risk. These include diversification, the maintaining of financial reserves and hedging.
v. ***Reducing borrowing needs***: Past experiences with the vagaries of economic cycles makes particularly older farmers wary of debt. They tend to pay off loans more rapidly than is necessary, even when from a purely economic perspective this behaviour is not rational.

vi. ***Improving family living***: Farmers pursuing this goal sacrifice future increased income from the family farm as a result of reinvestment in favour of using income for consumption purposes to raise the quality of life of the farming family.
vii. ***Increasing leisure time***: This particular goal is another component of the consumption function of the farm enterprise. Farmers rarely identify this as a primary goal but the behaviour of both young and older farmers underlines its importance as a motivating factor.
viii. ***Having a neat and well-kept farmstead***: Keeping a neat farmstead may require resources that could be used in income-generating activities but farm appearance is an important social indicator of a prosperous farm and a respected farmer.
ix. ***Providing community services***: Many farmers are involved in affairs of the community seeking to make it a better place to live, even when through these activities they sacrifice income. From an enterprise perspective this appears to be irrational behaviour but it makes obvious sense from a social perspective.

Sufficient evidence has been compiled on family farms in different parts of the world, including South Africa (Backeberg, 1989) to accept that:
i. The utility function of farmers is multi-dimensional;
ii. Different farmers have different, often multiple objectives; and
iii. Diversity in objectives among farmers is expressed in diversity of management styles.

Social scientists have provided improved insight into the different management styles of farmers, usually by means of a typological approach, which is concerned with ‘ideal types’. Selected examples of management styles that have been identified in different contexts are the entrepreneur, the accumulator, the extensifier, the intensifier, the cautious strategist, the sufficer and the lifestyler (Gasson and Errington, 1993).

1.1.4.3 Management of smallholder canal irrigation schemes: To function properly canal irrigation schemes require management systems that ensure that water is shared equitably among scheme farmers and that the scheme infrastructure is maintained effectively.

One of the problems in canal irrigation is the front-ender and tail-ender phenomenon. Farmers at the front end of the canal have first access to the water in the canal and when they take more than their share, farmers at the tail end get less than their share. This has obvious adverse consequences for the performance of tail-ender enterprises and is one of the most common causes of conflict among farmers on canal irrigation schemes.

Cleaning and repairing of canals is necessary to maintain optimum flow rate and to avoid distribution losses. When the distribution system is not adequately maintained, the total amount of water available to the collective of farmers per unit time is reduced, but this again affects tail-enders more than front-enders.

In the past, responsibility for the management (and sometimes even the implementation) of the two important functions of sharing of water and maintaining the canals on South African smallholder irrigation schemes was often the responsibility of the state. The review of smallholder irrigation policy following the democratization of South Africa in 1994 resulted in this responsibility being transferred to farmer communities through the adoption of irrigation management transfer (IMT) (Perret, 2002). Successful co-operation among smallholders in the management of their canal schemes depends on functional institutions and organisations to guide collective action. In the sphere of water sharing successful co-operation minimizes conflict among plot holders over water allocations. Scheme designs that restrict water availability and supply sources that are subject to seasonal fluctuations, as is the case where water is diverted from a river and the amount of water entering the scheme depends on the flow rate in that river, are circumstances that are conducive for the development of conflicts among farmers on a scheme. In the sphere of scheme maintenance, successful collaboration among farmers ensures that cleaning and repairs are done over the full length of the primary and subordinate canals in a timely and effective manner.

1.1.5 Participatory research

When soliciting this research project the premise of the WRC was that a participatory approach would benefit the development of a successful framework for smallholder agriculture research. The core component of participation is decision making (Van Vlaenderen, 2003). People participate to the extent that they choose cognitively, affectively and physically to engage in planning, establishing, implementing and evaluating activities that surround them. As such participation can be regarded as a decision making process occurring at the individual and social level (Van Vlaenderen, 2003).

For people to make decisions they need to be empowered to do so. Empowerment refers to the phenomenological development of a certain state of mind (feeling self reliant, competent, worthy of esteem, self confident). This implies less dependence on external inputs and wisdom and greater pride in the significance and validity of personal and collective knowledge and experience. Empowerment equally refers to the modification of structural conditions in order to re-allocate power (e.g. modifying the decision making structure in an organisation). In other words, empowerment refers to a subjective experience and the objective reality and is both a process and a goal (Van Vlaenderen, 2003). People need to have the capacity and the power to make decisions but at the same time they need opportunities to participate in decision making in order to build capacity and to empower themselves. True empowerment needs to be facilitated rather than imposed on people. This involves building individual and group capacity in people, so that they can empower themselves to fully participate in decision-making processes that influence their lives (Van Vlaenderen, 2003). One of the critical concerns about participation is the lack of congruence that often exists between the theory and the practice of participation.

1.1.6 Adaptive research

Adaptive research is aimed at generating knowledge for application in practice. Adaptive research interprets fundamental knowledge of bio-physical, social and economic phenomena in function of a particular context and seeks to find solutions to problems as they are experienced by a specific group of people. In this research project the specific group of people are smallholders operating on canal irrigation schemes in Limpopo Province.

1.1.7 Implications for the current study

Existing knowledge of the management of family farm enterprises emphasises the importance of farmers' goals (see section 1.1.4.2). Consequently, to be effective, research aimed at developing 'best management practices' for farmers needed to determine the goals of farmers and take these into account.

When the WRC solicited this research project it expected that the majority of plot holders on smallholder irrigation schemes in Limpopo Province would practise subsistence farming, which is known to:

i. be limited in scale and output;
ii. have household food security through own production as its primary objective and not the generation of income through cash sales of produce;
iii. make limited use of purchased inputs;
iv. be risk adverse;
v. have cash sales of farm produce as a minor source of total homestead income.

Considering these five general characteristics of subsistence farming, it was expected that of the three domains in which management had to be applied, i.e. production, marketing and finance, production would be the most important. The principal commodities on subsistence farms were expected to be those that farming families used as food. Ensuring sufficiency for own consumption was expected to be the paramount production objective and not the production of surplus. As a result, the management domain of marketing was expected to be of secondary importance. Financial management was also not expected to be very important because subsistence farmers typically farm on a small scale and make limited use of purchased inputs.

The validity of the WRC's assumption that smallholders on irrigation schemes are subsistence farmers needed to be investigated. Farmer populations tend to display diversity in terms of the goals they pursue. Invariably, diversity in farming objectives is associated with diversity in management styles. This meant that if the current study unearthed evidence of diversity in objectives and management styles among farmers on smallholder irrigation schemes, the idea of a single set of best management practices for use by all small-scale irrigators would no longer apply. Instead there would be a need for different sets of management practices that were congruent in each case with the goals of the different types of farmers that were identified. In addition, the accommodation of diversity among farm enterprises would then become a critical component of best management practices at scheme level.

Since irrigated African smallholdings are essentially family farms, which are characterised by the use of family labour, the farming family or household was the logical unit of data collection and analysis for this study. Of importance for the study was the extent to which the labour available in the household was engaged in farm work or in other economic or livelihood activities. Another important issue was the relationships between the phases of the family cycle, the stages of farm development, the farm objectives and the farm management styles.

The prescription by the WRC that research in this project had to be participatory and adaptive meant that farmers had to play a leading role in the setting of the research agenda and that facilitation aimed at empowering farmers to make decisions had to form part of the overall approach.

1.2 Historical development of smallholder farming in South Africa

1.2.1 General trends

Many leading South African agricultural economists view contemporary South African agriculture as being dualistic or dichotomous (Vink and Kirsten, 2003; Fényes and Meyer, 2003, Ortmann and Machete, 2003). They describe the sector as consisting of a developed, large-scale, market-oriented part and a developing, small-scale, subsistence part. From a political perspective the concern is that the market-oriented part is dominated by White farmers and the subsistence part by African farmers. It is also generally accepted that this divide is a legacy of racially discriminatory policies of the past, which stunted natural agricultural development processes among African people (Lahiff, 2000; Ortmann and Machete, 2003).

During pre-colonial times, homesteads of the different African tribes in South Africa had livelihoods that were almost exclusively land-based. They used hand tools to cultivate land, which limited the area that was planted to crops to garden-sized plots (Bundy, 1988). For food, homesteads relied heavily on the milk produced by their cattle herds, particularly among the Nguni-speaking tribes, which settled along the eastern seaboard. The introduction of iron hoes and the animal drawn plough following colonisation enabled homesteads to expand the area under cultivation (Bundy, 1988). For African homesteads increasing crop production became a necessity to maintain food security because of the loss of land to the colonisers and the spread of new diseases among the cattle herds. However, the area African homesteads cultivated after adopting the plough remained limited in size and from a contemporary perspective it was still small-scale.

The Land Act of 1913 divided South Africa into areas where land was held by Whites and others where the land was held by African people. The parts that were allocated to African people were called 'Native Areas'. Combined they covered about 7% of South Africa. At that time, traditional land tenure still largely prevailed in the Native Areas. Characteristic of that tenure system was that homesteads were allocated land by the tribal leadership in accordance with their needs (Cokwana, 1988). The technology that was available at that time limited the scale of farm operations and as a result, land allocations tended to be small. From about 1910 onwards, when the White farming sector was increasingly being commercialised, but particularly after 1960, when tractors replaced animal draught, White farmers expanded the cultivated area on their farms. This particular development did not occur in the Native Areas, because when tractors were made available to African farmers, most of the available arable land had already been distributed among the growing population. In this way the small scale of African farms persisted and remains prevalent at present.

Historical factors also affected the orientation of African farming in South Africa. Following colonialisation of the country during the 19th century, there was a brief era of peasantisation among African people. During this era, which lasted from about 1860 until about 1910, selected African homesteads increasingly engaged in commodity production, such as wool and wheat, competing effectively with their white counterparts (Bundy 1988). Politically, this development was encouraged because the integration of Africans in the broad social and economic networks of colonial society was adopted as a strategy to pacify the African tribes (Bundy, 1988). African peasantisation developed along two trajectories. In the Eastern Cape and KwaZulu-Natal, African peasants farmed their own land, which in some cases was held by individual title. In the Free State and the Western Transvaal (North West Province), African peasants were involved in various share cropping arrangements with White farmers. Van Onselen (1996) presents a detailed account of the life of one of these sharecroppers who farmed in the area around Bloemhof, Wolmaranstad and Schweizer-Reneke.

During the first decades of the 20th century, change in policy curtailed the emerging African peasantry. By that time, the African tribes no longer posed a serious military threat and economically there was more need for the labour of African people than for their agricultural produce. Rapid mining development and the commercialisation of the White farming sector created demand for cheap labour and the African population was viewed as a suitable source of supply. Various policies, including territorial segregation based on race, prohibiting African people from accessing White-owned land through tenancy arrangements, restricting the size of farms held by Africans and raising taxes were introduced to make it difficult for African homesteads to maintain their agrarian livelihood (Bundy, 1988). However, unlike in other parts of the world, the natural processes of proletarisation and urban migration of the rural population were not allowed to occur in South Africa. Instead policies and practices were implemented to access rural labour without bringing about its permanent displacement. This approach gave rise to the male migrant worker system, which characterised South Africa for most of the 20th century. This system involved the employment of African men during their prime years, whilst their spouses, children and parents remained behind in the rural areas. In the case of the mines, workers were housed in male-only hostels and provided with meals that kept them fit for the heavy work they had to do. When their most productive years were over, their contracts were no longer renewed, leaving them with few options other than to retire to their rural homesteads. During their years of employment, migrant workers invested in their rural homesteads. They built up cattle herds in preparation for their retirement (Ferguson, 1991) and also supported the annual production of crops, not only financially by remitting money to pay for inputs but often also physically by taking leave during the time of ploughing and planting. Smallholder farming became increasingly subsistence oriented, responding to the new way in which African homesteads constructed their livelihood. In the case of crop production, the emphasis was on meeting the food requirements of the homestead during the absence of the male head.

During the period between 1910 and WWII, indicators of quality of life, such as life expectancy, child mortality and the absence of diseases associated with severe malnutrition, such as pellagra and kwashiorkor, showed that the social and economic status of the Native Areas was deteriorating (Bundy, 1988). At the same time, agricultural production in these areas was declining. For example, during the period 1921-30, the average annual production of maize in the Native Areas was 290 000 tons. This dropped to an average of 220 000 tons during the subsequent decade

(Bundy, 1988). There was also alarming evidence of rapid degradation of the natural resources in the form of denudation of the landscape and soil erosion (Bundy, 1988). To release pressure on the land, the state intervened by increasing the size of the Native Areas through the promulgation of the Land and Trust Act of 1936. On newly released land, also called Trust land, Betterment was implemented to protect the natural resources. One of the elements of Betterment was to subdivide the land into residential, arable and grazing. Land conservation measures included the subdivision of fenced camps on the rangeland to enable rotational grazing, imposition of restrictions on livestock densities and the construction of contour banks and contour ploughing to check soil erosion on arable land (Beinart, 2001). These new measures did not reverse the overall decline in agricultural production in the Native Areas mainly because structurally the function of these areas was to serve as labour reserves for the mining, industrial and White commercial farming sectors and not to act as centres of agrarian production. This was abundantly clear from the results of the census conducted in 1936, which revealed that 54% of the adult male population in the Native Areas was absent from their rural homes (Bundy, 1988).

The policies of the National Party, which came to power in 1948, stood out by their preoccupation with racial segregation and the separation of South African society. For the Native Areas, which were now called Bantu Areas, policy was aimed at establishing self government for each of the different African tribes. The Bantu Authorities Act of 1951 and the Bantu Self Government Act of 1959 were all legislative expressions of the intent of the National Party to implement separate development. For this policy to succeed, it was important to improve the economic and social conditions in the Bantu Areas. The Tomlinson Commission was established to develop an overall master plan for the economic development of the Bantu Areas. The Commission proposed the establishment of a class of peasants farming on farm units that were economically viable, but the relocation of large numbers of rural homesteads, which the implementation of this proposal demanded, was unacceptable to the government. Instead, implementation of Betterment was extended to land held under traditional tenure. In practice this meant that disperse settlements were consolidated into villages bringing about the spatial separation of homesteads from their different land resources, particularly their arable land. Several scholars have argued that this reorganisation of the rural space further reduced African smallholder production (Yawitch, 1981; McAllister, 1988; De Wet, 1989).

From about 1955 to about 1980, the South African economy grew rapidly. Besides substantial industrial development, mining, particularly gold mining, also expanded. During the period 1955 and 1970, gold production doubled to reach an annual production that exceeded 1 million kg. Earnings by the gold mines were boosted further when in 1968 the price of gold, which had been fixed 35 US$ per ounce after WWII, was freed. The price of this metal rose to US$150 in 1973 and briefly reached a peak of US$800 in 1980 (Beinart, 2001). White commercial farming became mechanised, reducing the demand for African labour. Surplus labour were moved from the farms and settled in the Bantu Areas. Combined with natural population growth, which was as high as 3% during this period, the influx of surplus people into the Bantu Areas, renamed homeland, caused their population to grow from 4.2 million in 1960 to 11 million in 1980. The push towards the establishment of self-government in the different homelands continued and Transkei became the first homeland to accept self government in 1963. This political process was continued resulting in the declaration of independence of four homelands during the period 1976 to 1981, namely Transkei, Bophuthatswana, Venda and Ciskei. Overcrowding in the homelands and the outflow of Africans from White farms fuelled African urbanisation. During the 1960's, the government made a serious attempt to curb this process by means of influx control legislation, but later on the process was managed by allowing the development of dense African settlements outside major urban centres. Where possible, these settlements were incorporated into homelands. Examples are Mdantsane near East London which was incorporated in Ciskei and Winterveld near Pretoria, which was made part of Bophuthatswana. Beinart (2001) points out that these areas were urban in respect of population density and lack of agricultural opportunities, but rural in relation to facilities and services. To work, the residents of these settlements had to travel long distances on trains or buses to the cities where they were employed.

Developments inside the homelands also had an impact on the structure of livelihood of residents. Employment in the civil service of the homelands, particularly in the education and health sectors, provided new opportunities to people to earn a living locally. Industrial decentralisation policies supported by means of subsidies resulted in the establishment of light industry in the homelands, creating additional local non-agrarian livelihood options for people in some of the homelands. Examples are Fort Jackson and Dimbaza in Ciskei and Butterworth in Transkei. The different homeland administrations also invested in agricultural development. Public tractor services, which were initiated by the Bantu Development Trust during the 1950's to assist homesteads that lacked the wherewithal to cultivate their field, were expanded by the homeland administration. Attempts were also made to commercialise homeland agriculture through the development of new projects, including irrigation schemes, usually through the agency of a public agricultural development corporation. These projects were mostly centrally managed, made use of farm workers and were aimed at supplying national and sometimes international produce markets as in the case of the Magwa Tea Estate in Transkei. Whereas production on these projects was often satisfactory, financially they were not viable. The financial burden of the recurrent cost to sustain these projects resulted in a policy revision during the late 1980's, which proposed the transfer of these projects to farmers. However, the privatisation process was mostly unsuccessful and when the homelands were re-incorporated into South Africa in 1994, the different agricultural parastatals that operated in the homelands were closed down. This, in turn, resulted in the collapse of many of the prestigious agricultural projects that were established during the homeland era (Lahiff, 2000; Du Toit, 2005).

Towards the end of the homeland era, the public tractor services operated by the homeland administrations were also withdrawn for reasons of low efficiency and high cost. This contributed further to the trend of abandoning field crop production among rural homesteads, which had started in earnest after 1960 (Hebinck and Van Averbeke, 2007). In response to the lack of resources in the form of draught power and labour arising from the predominantly off-farm orientation of their livelihood, many homesteads reduced their crop production activities to the cultivation of their home gardens.

This brief history of African smallholder farming explains, albeit in very general terms, how the current state of smallholder farming in South Africa came about. The central theme was that the importance of farming in the livelihood of rural African homesteads declined during the 20th century as a result of a combination of political, economic and social factors. At the beginning of the 21st century, small-scale farming activities were still widespread among rural African homesteads but in the livelihood portfolios of most of them farming had become a complementary activity.

The limited overall importance of farming in the livelihood of rural African homesteads was amply demonstrated by Orkin and Jobe (2000). Using 1996 census data and 1997 Rural Survey data they counted 1 449 000 homesteads in the former homelands that held arable land (about 50% had less than 1 ha). Among them about 823 000 (57%) were engaged in some form of farming activity but only 27 400 (3.3%) reported farming to be their main source of homestead income.

1.2.2 Smallholder farming in Venda: variations on a theme

The study sites that feature in this report all form part of the former Venda homeland, which is situated in the extreme north of South Africa. Venda shares much of its history with the other former homelands but it also has some unique features. For a comprehensive overview of the history of the Venda region, with special reference to land and agriculture, the reader is referred to Lahiff (2000).

Among the different African tribes in South Africa, the Venda tribe was the last to be subjugated by White colonisers. This occurred during the period 1898-1902. Yet, the settlement of Whites in the area had a long history. The first party to arrive from the Ciskei part of the Cape was the group led by Coenraad De Buys around 1820. Subsequent groups of Afrikaners under the leadership of Louis Trichardt, Andries Hendrik Potgieter and Johannes Van Rensburg entered the territory of the Venda in 1836. Potgieter and his followers established the first substantial White settlement in Venda in 1847. Initially this settlement was called Zoutpansberg but later it was renamed Schoemansdal. It served primarily as a hunting and trading centre with ivory as the principal commodity. Irritated by the demands and behaviour of the Zoutpansberg community, the Venda under Chief Makhado attacked and defeated the White settlers and destroyed the Zoutpansberg settlement in 1867. Chief Makhado died in 1895 and was succeeded by his son Chief Mphephu. Conflict arose between Mphephu and other Venda chiefs, who one by one submitted to the Transvaal authorities, leaving Mphephu and his followers as the only group of Venda to resist White authority. In 1898, Mphephu and his people were defeated by a commando of Afrikaners and in 1902, the Venda nation was disarmed by the British administration following the end of the Anglo-Boer War (Lahiff 2000).

In 1902, the territory of the Venda was subdivided into three Native Commissioner's areas, namely, Sibasa, Louis Trichardt and Spelonken. The southern and western parts of this territory were made available for white settlement, reducing the part held by the Venda people to a fraction of its original size (Lahiff, 2000).

Following additions of land, in line with the 1936 Trust and Land Act, the total area held by the Venda people amounted to about 525 500 ha. The size of the Venda territory was increased to 680 700 ha during the homeland era, which lasted from 1971 to 1994. This era consisted of an initial period of self-governance (1971-79) and a subsequent period of independence (1979-94).

The 1991 census showed the human population of Venda to be 558 797 people (Lahiff, 2000). This meant that towards the end of the homeland era, the population density in Venda was 82 people km^2. At that time Venda counted 103 481 households with an average size of 5.4 persons per household. Dividing the total area of Venda by the number of households, the average area of land available per household was 6.58 ha. Of the total land area, only 11% was considered arable, which when divided equally over all households would provide an arable land allocation of 0.72 ha per household.

Lahiff (2000) provides evidence that the Venda people largely sustained their agrarian livelihoods, as subsistence farmers on their own land, or as labour tenants on White farms, until about 1930 and that urban migration of Venda men only started in earnest after WWI. They did not feature in the major recruitment waves by the mines during the late 19^{th} and early 20^{th} century, partially because legislation prohibited the mines from recruiting directly in the Bantu Areas of the Transvaal. The majority of Venda men found employment in the cities as household servants, drivers and general workers.

The population density of Venda was greatly increased as a result of forced removals of African families from White farms, which occurred from about 1966 onwards (Lahiff, 2000). Simultaneously, Betterment planning was implemented resulting in the creation of large villages, where before settlement patterns had been considerably more disperse. By 1972, 78% of Venda had been subjected to Betterment planning and landlessness had become a common feature (Lahiff, 2000). It was estimated that about 35 000 homesteads in Venda hold arable land, leaving about two out of three households landless. In most cases the arable holdings were less than 1 ha in size (Lahiff, 2000).

Dryland crop production in Venda is characterised by the intercropping of a cereal (predominantly maize) with pulses (ground nuts, dry beans and bambara ground nuts) and cucurbits (pumpkins and melons). Irrigated cropping occurs on irrigation schemes and in small home gardens. Irrigation enables double cropping with vegetables featuring prominently during the winter.

During the period of self government and particularly during the era of independence, the Venda homeland administration through its agricultural parastatal Agriven, initiated a wide range of commercial agricultural development projects. However the majority of these projects collapsed when Agriven was closed down following the reincorporation of Venda into South Africa (Du Toit, 2005).

As in other former homelands, the role of farming in the livelihood of Venda people also declined during the 20^{th} century but visitors to the area usually comment on the intensity with which the available land is being cultivated. Fruit trees, particularly mangoes and bananas, also feature more prominently in the Venda cultural landscape than in that of other former homelands. Another distinguishing feature of the Venda region is the presence of large numbers of informal enterprises, which provide a range of goods and services to local people. This suggests a relatively highly developed spirit of entrepreneurship, which is often lacking in other rural parts of South Africa.

1.3 Smallholder irrigation scheme development in South Africa: history and current status

1.3.1 Historical development eras

Bruwer and Van Heerden (1995) and Backeberg and Groenewald (1995) have documented the history of irrigation development in South Africa at large, identifying several eras, which Backeberg and Groenewald (1995) linked to the economic development of this country. The different eras that were identified were characterised by specific irrigation policy objectives and irrigation technology. Similarly, several eras can be identified in South African smallholder irrigation development. Particular to this history was the influence of racial segregation policies, which characterised 20th century South Africa.

1.3.1.1 The peasant and mission diversion scheme era: There is evidence of cultural exchanges during the first millennium AD between the Bantu-speaking people who settled Sub-Saharan Africa and Cushitic-speaking people from the south of Ethiopia who had knowledge of irrigation (Lamphear and Falola, 1995). However, little if any evidence of the use of irrigation during pre-colonial times by the different Bantu-speaking groups that settled in South Africa has been discovered so far.

Historians concur that early smallholder irrigation development, which occurred during the 19th century in the Cape Colony, was the result of technology transfer from colonists to the local people. This early development can be referred to as the peasant and mission diversion scheme era, because it was associated with mission activity and the emergence of African peasantry in the Eastern Cape (Bundy, 1988; Crais, 1992; Bruwer and Van Heerden, 1995). Situated within the broad history of irrigation development in South Africa, this era coincided with the early part of the individual diversion scheme era identified by Backeberg and Groenewald (1995). Smallholder irrigation developments were also private initiatives and the technology used (river diversion) was similar. In terms of area brought under irrigation, the peasant and mission diversion scheme era was not very important and much of what was developed had ceased to function by the end of the 19th century.

1.3.1.2 The smallholder canal scheme era: Renewed smallholder irrigation development occurred many decades later in the form of canal irrigation schemes. Broadly speaking, this second era lasted from about 1930 until about 1960 and can be referred to as the smallholder canal scheme era. It coincided with the era of public storage schemes in the history of national irrigation development described by Backeberg and Groenewald (1995), and more specifically the second phase of this era, which Bruwer and Van Heerden (1995) named the 'Great Depression and the Second World War'.

Most of the smallholder schemes that were established during this era were constructed after the Second World War. They were primarily aimed at providing African families residing in the 'Native or Bantu Areas' with a full livelihood based on farming (The Commission for the Socio-Economic Development of the Bantu Areas within the Union of South Africa, 1955, hereafter referred to as The Commission, 1955). The Commission (1955) identified '*smallholdings on irrigation schemes in the north of South Africa that were supervised by Europeans*' as the most successful smallholder farm enterprises in the Bantu Areas. Surveys established that in 1952-53 on this type of schemes the mean farm income derived from plots of 1.5 morgen (1.28 ha) and a livestock holding of 5.2 animal units was £110. On average, 55% of this income was obtained in the form of own consumption and 45% from the sale of produce. By contrast, The Commission (1955) found that nationwide the mean annual income among rural families with livelihoods that were completely land based was only £57. Consequently, The Commission (1995) recommended that smallholder irrigation development be used as one of the strategies to provide full land-based livelihoods to black families in the 'Bantu Areas'. In 1952, The Commission (1955) counted 122 smallholder schemes, existing or under construction, covering a total area of 11 406 ha involving a total of 7 538 plot holders in these areas. The Commission (1955) identified a total area of 54 051 ha that had the potential for irrigation development in these territories. It estimated that exploitation of this potential could enable the settlement of 36 000 farmer families, representing approximately 216 000 people. Using data supplied by Denison and Manona (2007b), at least 18 200 ha (37%) of the existing smallholder irrigation area was developed during the smallholder canal scheme era (Table 1.1).

TABLE 1.1: Categorisation of existing smallholder irrigation scheme development using data supplied by Denison and Manona (2007b)

Era	No of schemes	Area (ha)	Mean area per scheme (ha)	Main irrigation technology used
Smallholder canal scheme (1930-1969)	74	18226	246	Gravity-fed surface irrigation
Independent homeland (1970-1990)	62	12994	210	Different forms of overhead irrigation
IMT and revitalisation (1990-present)	64	2383	37	Pump and sprinklers or micro-irrigation
Year of establishment uncertain	117	15897	136	Mostly overhead irrigation
Total	**317**	**49505**	**156**	

Typically, the irrigation schemes that were established during this era obtained their water from a river by means of a concrete weir diversion but schemes using storage dams were also built. Water for irrigation was brought to field edge by means of a concrete canal conveyance system. The size of the plots on these schemes typically ranged between 1.5 and 2 morgen (1.28 to 1.71 ha), but both schemes with larger and smaller plots were also established (Bembridge, 1997). The plot size on these schemes was considerably smaller than the 8 ha to 20 ha plots that were allocated to White settler farmers on irrigation schemes developed during the Great Depression and WWII. Settler schemes for White people were established for the same purpose as the smallholder canal schemes, namely to provide poor families with full land-based livelihoods (Bruwer and Van Heerden, 1995; Backeberg and Groenewald, 1995). The difference between the plot size allocated to White and African farmers suggests that irrigation planning proceeded under the assumption that African families required less land (and income) to attain a full livelihood than White families.

On most smallholder canal schemes the land was detribalised and ownership was transferred to the state. Betterment planning formed an integral part of scheme development and Trust tenure was imposed. As a result, farmers on these schemes held their plots by means of Permission to Occupy (PTO). Trust tenure provided the state with the necessary powers to prescribe land use and to expel and replace farmers whose practices did not comply with these prescriptions. In selected cases the state effectively used these powers to enforce the overall objectives of the schemes by evicting poorly performing families. A similar authoritarian and paternalistic approach by the state prevailed on White settler schemes established during the great depression and WWII period (Backeberg and Groenewald, 1995).

1.3.1.3 The homeland era: The third period of smallholder irrigation development can be referred to as the homeland era. This era in smallholder irrigation development lasted from about 1960 until about 1990 and was an integral part of the economic development of the homelands, which were all islands of underdevelopment and poverty (Beinart, 2001). New irrigation schemes were established with funding from South Africa. Considering that the resource base of these territories had remained essentially rural, agriculture was regarded as the main internal development opportunity for the homelands (Van Rooyen and Nene, 1996; Lahiff, 2000).

Data collected by Denison and Manona (2007b) indicated that at least 64 of the existing smallholder irrigation schemes, covering a total of about 13000 ha, were established during this era (Table 1.1). The number of existing schemes that date back to this period is probably higher, because much of the 15 896 ha of existing irrigation land in Table 1.1 that could not be dated was probably developed during this era.

Irrigation development during the homeland era was characterised by modernisation, functional diversification and centralisation of scheme management. Technologically, this era coincided with the third phase of the public storage scheme era in South African irrigation development identified by Backeberg and Groenewald (1995), which Bruwer and Van Heerden (1995) referred to as the recent development phase. Typical examples of large schemes (>500 ha) developed during this era were found mainly in the Eastern Cape and included the schemes at Qamata, Keiskammahoek, Tyefu and particularly Ncora (Van Averbeke *et al*., 1998). With the exception of Qamata, which used canals, the irrigation and farming technology that was implemented on these large schemes was often amongst the most modern that was available at the time. Even on the smaller schemes established during this era, pressurized overhead irrigation systems were used instead of surface irrigation.

On the large schemes, economic viability was pursued by means of a strategy of functional diversification. Typically included were a commercial function in the form of a central unit, which was farmed as an estate, a commercial smallholder function in the form of medium sized plots, also called mini-farms, of 5 to 12 ha in size, and a subsistence function in the form of food plots, ranging from 0.1 ha to 0.25 ha in size (Van Averbeke *et al*., 1998). It can be argued that functional diversification was a way of catering for rural livelihood diversity, although this concern was not necessarily stated explicitly in the plans. In practice, however, functional diversity provided rural homesteads with different options to benefit from irrigated agriculture, depending on the structure of their existing livelihood. For example, the mini farms catered specifically for homesteads that sought full land-based livelihoods. The food plots provided homesteads that derived their livelihood from external sources, such as male-migration or old-age pensions, with an opportunity to enhance these livelihoods by producing food for home consumption. The estate component offered opportunities to members of rural homesteads who were searching for employment and monetary income close to home. Management of these large schemes was centralised in the hands of specialised parastatals (Van Rooyen and Nene, 1996; Van Averbeke *et al*., 1998; Lahiff, 2000).

The large schemes established during the independent homeland era were socially and economically very complex and proved costly to maintain. Social unrest and conflict during the late 1980's and early 1990's further affected their sustainability. Following the democratisation of South Africa in 1994, the provincial governments decided to dismantle the agricultural homeland parastatals they had inherited. This decision particularly affected the large schemes, because they were the most complex and had been centrally managed from inception, resulting in exceptionally high levels of dependency among farmers (Van Averbeke *et al*., 1998). Partial or total collapse of production followed this decision almost immediately (Bembridge, 2000; Laker, 2004).

1.3.1.4 The irrigation management transfer (IMT) and revitalisation era: The most recent era in South African smallholder irrigation development can be referred to as the irrigation management transfer and revitalisation era. This era more or less commenced in 1990, when political change in the country became inevitable. Irrigation development during this era was influenced by change in developmental thinking and policy.

Privatisation and the establishment on a smallholder farmer class was one of the development paradigms that played a role early on during this era. The privatisation paradigm was developed by the Development Bank of Southern Africa and was implemented by means of the Farmer Support Programme. The Zanyokwe Irrigation Scheme in the former Ciskei was an example of a centrally managed irrigation scheme that was transferred to individual smallholders.

Following the political transformation of South Africa, the ideals of democracy and a better life for all featured prominently in the political thinking and this also had an influence on smallholder irrigation development. The Reconstruction and Development Programme (RDP) provided the overall political framework to eradicate poverty and improve the quality of life among poor African people in rural areas and informal urban settlements. Irrigation development focused on improving food security at community or group level, favouring the establishment of small schemes. Data provided by Denison and Manona (2007b) indicate that at least 62 new irrigation schemes were established during this era, adding about 2400 ha to the total smallholder irrigation scheme area (Table 1.1). These projects typically used mechanical pump and sprinkler technology to extract and apply irrigation water. During the period of political transition, from 1990 to 1994, the Independent Development Trust played an important role in funding these types of projects (Van Averbeke and Mei, 1998). Later on, organs of the state, particularly the Provincial Departments of Agriculture, Health and Public Works, took over this funding role.

When GEAR (Growth, Employment and Redistribution) superseded the RDP as the overall development policy of South Africa, the strategy to eradicate poverty shifted from funding community-based projects to pursuing economic growth through private sector development. Existing irrigation schemes were identified as important resources for the economic development of the rural areas, but they required revitalisation first. Revitalisation was linked to IMT (Irrigation Management Transfer). IMT refers to the transfer of the responsibility of managing, operating and maintaining irrigation schemes from the state to farmers. Elsewhere in the world IMT had been implemented as a strategy to improve scheme management performance, to increase the profitability of irrigated agriculture and to reduce recurrent public spending on operation and maintenance of the schemes (Vermillion, 1997; Shah *et al*., 2002). Adoption of the policy of IMT was aligned with GEAR, because it promised to improve the lives of poor people by means of a process that empowered them to take control over their own resources and destiny.

Among the different IMT initiatives in South Africa, the Revitalisation of Smallholder Irrigation Schemes (RESIS) of the Limpopo Province stood out for its comprehensiveness. The RESIS programme evolved from the WaterCare programme, which was launched in 1998 and ran for five years (Denison and Manaona, 2007b). The WaterCare programme was aimed at revitalizing selected smallholder irrigation schemes in the Province, not only infrastructurally, but also in terms of leadership, management and productivity. Using a participatory approach, WaterCare involved smallholder communities in planning and decision making and provided training to enable these communities to take full management responsibility over their schemes (Denison and Manona, 2007b). In 2000, the Limpopo Province was ravaged by a severe storm, which resulted in widespread floods and damage to roads, bridges and also to the weirs that provided water to many of the smallholder canal schemes. Declared a disaster area, the Province was allocated special funding to repair the damage to its infrastructure, providing impetus to the WaterCare programme.

In 2002, the Limpopo Province broadened the scope of its irrigation scheme rehabilitation intervention by launching a comprehensive revitalisation programme, called RESIS (REvitalisation of Smallholder Irrigation Schemes). RESIS adopted the participatory approach of the WaterCare programme, but planned to revitalise all smallholder schemes in the Province (Limpopo Department of Agriculture, 2002). As was the case in the WaterCare programme, RESIS combined the reconstruction of smallholder irrigation infrastructure with IMT. In support of IMT, the programme dedicated one-third of the revitalisation budget to capacity building among farmers. RESIS also sought to enhance commercialisation of the smallholder farming systems on the schemes, in order to improve the livelihood of plot holder homesteads (Limpopo Department of Agriculture, 2002).

During the WaterCare programme and the first phase of RESIS (1998-2005), the emphasis was primarily on the rehabilitation of the existing scheme infrastructure and on sustainable IMT, and less on commercialisation. Canal schemes that were revitalised during this phase remained canal schemes. In 2005, commercialisation became the principal development objective of RESIS. The shift in emphasis was probably influenced by the Black Economic Empowerment (BEE) strategy that was introduced in South Africa, first in the mining sector and later on also in other sectors of the economy, including agriculture (Department of Agriculture, 2006). Nationally, the

BEE strategy was aimed at increasing the share of black people in the economy and it emphasized entrepreneurship.

From 2005 onwards, the Limpopo Department of Agriculture increasingly equated canal irrigation with subsistence farming and inefficient water use. It discouraged revitalisation of canal infrastructure favouring the transformation of canal schemes to schemes that used modern irrigation technology, such as micro-irrigation and floppy sprinkler systems. Similar concerns have characterised the transformation of smallholder irrigation in other countries, such as Turkey (Ünlü *et al*., 2006).

1.3.2 The status and future of smallholder irrigation schemes in South Africa

For many decades smallholder irrigation schemes have generated public interest because their establishment and revitalisation were made possible through public investment and because they were considered to have the potential to generate economic development in poor and under-developed rural areas. To what extent smallholder irrigation schemes have been successful development initiatives remains the subject of debate.

In the past, production and economic considerations with a focus on whole-project performance dominated the assessment of smallholder irrigation schemes. The comprehensive assessment of agriculture in the 'Bantu Areas' conducted during the early 1950's was highly complementary of the economic performance of smallholder irrigation projects, particularly those established in the north of South Africa (The Commission, 1955). More recent assessments have been less complementary. Most of these concluded that the success of smallholder irrigation had been limited (Bembridge, 2000; Crosby *et al*., 2000). Factors that contributed to their modest performance in terms of production and economic impact were poor infrastructure, limited knowledge of crop production among smallholders, limited farmer participation in the management of water, ineffective extension and mechanisation services and lack of reliable markets and effective credit services (Bembridge, 2000; Crosby *et al*., 2000). Another factor that contributed to the limited economic impact of smallholder irrigation was the predominance of subsistence-oriented farming on these schemes. Backeberg *et al*. (1996) reported that only 37% of farmers on smallholder irrigation schemes were commercially oriented, whilst the remaining 63% were mainly engaged in subsistence production. The results of the survey by Denison and Manona (2007b) paint a similar picture. It needs pointing out that economic success through market-oriented production was not necessarily the objective of these projects (Van Averbeke *et al*., 1998), nor should the measuring of success ignore the importance of improving food security through own production. As Perret (2002) points out, 'Food security remains the major objective for many plot holders and subsistence-oriented crop production patterns have never been changed'. For this reason it is important to also assess the success of smallholder irrigation from the perspective of plot holders and their livelihood.

When viewed from a livelihood perspective, smallholder irrigation schemes represent assets or resources. They enable farmers to improve and diversify plant production, which can result in improved livelihood outcomes, either directly in the form of food or income for plot holders, or indirectly by providing full or partial livelihoods to people who provide goods and services in support of irrigated agriculture on these schemes.

Determining the value of the irrigation plot as an asset and the importance of irrigated agriculture as a livelihood activity has not received much attention from South African researchers. The current study intended to address this knowledge gap.

The perspective used to look at smallholder irrigation schemes does not only influence the way these projects are assessed and valued. It also shapes ideas on how these projects should be revitalised and what the objectives of the revitalisation should be. Examples of different objectives put forward by various participants involved in revitalisation are employment creation, poverty alleviation, improved food security, increased production, economic viability, commercialisation, establishment of an African peasant class[1] and Black Economic Empowerment (BEE).

Denison and Manona (2007a) pointed out that successful revitalisation of smallholder schemes is highly dependent on a clear and unambiguous statement of the objectives of revitalisation. They warned that the objectives that have guided revitalisation efforts in South Africa were sometimes contradictory, making it impossible for revitalisation to achieve all its stated objectives. Moreover, there are scheme-specific factors, which preordain the objectives that can be achieved in any particular case. For that reason, Denison and Manona (2007a) outlined four principal development pathways or trajectories for smallholder irrigation schemes, which they refer to as farming styles[2]. Each of these different trajectories is congruent with selected revitalisation objectives. The four principal smallholder irrigation scheme trajectories were:

1. ***The 'business farmer' – commercial production on consolidated farms*** developmental pathway involves the establishment of farm enterprises held by individuals who produce commodities on relatively large farms ranging between 5 ha and 40 ha, depending on the commodity being produced. Business farmers are expected to have the required technical and managerial capacity and financial resources to deal with the risk associated with commercial farming and to sustain the use of moderately to highly sophisticated irrigation technology. Under certain circumstances, particularly in relation to produce markets, business farmers may also act as out-growers producing one commodity only, as in the case of the cane growing sector. Revitalisation objectives congruent with this trajectory are increased production, economic viability, commercialisation, establishment of an African peasant or commercial farmer class and Black Economic Empowerment (BEE). It must be noted that for many smallholder schemes selecting this particular developmental trajectory would demand the consolidation of existing plots into larger units, which socially may not be easy to achieve.

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[1] The term 'peasant' is no longer used in South Africa but it would appear that the concept of 'emerging farmer' used in contemporary South Africa has a similar meaning.

[2] The concept of 'farming style' used by Denison and Manona (2007a) differs from that used in this report. Denison and Manona (2007a) use the concept to refer to the general approach to farming at scheme level, such as the production of food for own consumption, commercial agriculture by individual enterprises, out-growers or equity partnerships involving the employment of farm workers, and the peasant approach characterized by diverse objectives among participants. In this report the concept is used to capture the diversity among individual farm enterprises within the context of a particular scheme. For this reason the farming style concept of Denison and Manona (2007a) has been replaced by developmental pathways or trajectories in this report.

2. ***The' smallholder farmer' – diversified farming and reduced risk*** development trajectory accommodates livelihood diversity among plot holders with particular reference to the role farming plays in their livelihood. Denison and Manona (2007a) point out that this trajectory is unlikely to be a financially feasible proposition on schemes where the cost of the O&M of irrigation are high and suggest that this trajectory is best suited for low-cost canal schemes. Interestingly, it is very difficult to identify specific revitalisation objectives that are congruent with this trajectory, because it allows individual plot holders to determine their own farming objectives. One of the important contributions of the current study contained in this report is that it provides detail on how such schemes work. Hopefully, this will contribute to an increased sense of appreciation for the smallholder development trajectory.

3. ***The 'equity –labourer – plot holders in large-scale commercial partnerships*** development trajectory where the cost of O&M of irrigation and production call for commercial partner investment. This trajectory is probably best suited for large and complex schemes that are remote, such as the Ncora Irrigation Scheme in western Transkei. Denison and Manona (2007a) point out that this trajectory largely transfers control over the assets and the mode of production to the commercial partner in return for jobs, probably at the minimum wage level and the opportunity to earn some dividend. Job creation is the main revitalisation objective that is congruent with this trajectory.

4. ***The food producer –irrigated food plots and home gardens*** development trajectory aims to provide homesteads with the opportunity to enhance their access to food through own production on small irrigated plots of 0.25 ha or less. Poverty alleviation and enhanced homestead food security are the revitalisation objectives that are congruent with this trajectory.

Denison and Manona (2007a) indicate that revitalisation of a particular scheme could involve the adoption of more than one development trajectory. For example, the business farmer trajectory may be combined with the food producer trajectory by subdividing the scheme into parts, each with its own specific revitalisation objectives.

1.4 Objectives of the study

In the terms of reference of WRC Project K5/1464//4, the WRC stated '*the development and implementation of technologies and knowledge useful for farmers in order to improve rural livelihoods*' as the general objective of this project. The WRC also stated 10 specific objectives, namely,

1. *Engage and obtain community and other stakeholder endorsement for the research project;*
2. *Engage and obtain stakeholder participation;*
3. *Analyse the institutional framework;*
4. *Analyse the local social organization;*
5. *Analyse the infrastructure, natural resources, markets and finance (situational analysis);*

6. *Identify existing livelihoods and farming systems;*
7. *Identify opportunities for innovation and technological change;*
8. *Identify, introduce and/or adapt appropriate technologies in participation with the farmers;*
9. *Promote and enable individual decision making at farmer level;*
10. *Improve the flexibility of farming;*
11. *Improve application of technologies; and*
12. *Test, monitor and evaluate impact of change.*

For the purpose of the conduct of the proposed project, the research team formulated the specific objectives as follows:

Stakeholder negotiations

1. Establishing a community of practice as the end result of the negotiation process among stakeholders on endorsement and participation in the project.

Initial analysis

2. To conduct an analysis of generic issues affecting smallholder irrigation in South Africa
3. To conduct a detailed situation analysis of a particular smallholder irrigation project in Limpopo Province and its surrounding community, which is to serve as the primary study site.
4. To conduct a basic situation analysis of one or more additional smallholder irrigation projects in Limpopo Province which are similar in make-up as the primary study site in order to determine which issues are generic and which are locality specific.

Participatory technology development processes

5. To establish a mutual understanding between the three main stakeholders in the project, namely farmers, extension and research, about the project, its objectives, and its *modus operandi*.
6. To engage in participatory technology development processes aimed at solving particular constraints affecting local agriculture or at exploring identified opportunities for agricultural development.

Monitoring and evaluation

7. To assess the impact of project activities on farmers and their households, the irrigation scheme community and on other important stakeholders, particularly public extension and research students.

Lessons learnt

8. To document and contextualize the theoretical lessons learnt from the implementation of the project.
9. To document and contextualize the technological lessons learnt from the implementation of the project.
10. To document the methodological lessons learnt during the conduct of the project.
11. To interpret the different lessons learnt in terms of best management practice recommendations.

1.5 Selection of the study sites

1.5.1 Smallholder irrigation schemes in Limpopo Province: a brief overview

Among the nine provinces in South Africa, Limpopo Province is the most important in terms of smallholder irrigation development. According to Denison and Manona (2007b), Limpopo Province counts 183 smallholder irrigation schemes, which is more than half (57.7%) of the total number (317) of these schemes in the country. Combined the smallholder irrigation schemes in Limpopo Province cover a total command area of 28 283 ha. This is also more that half (57.1%) of the national smallholder scheme command area, which, according to Denison and Manona (2007b), amounts to about 49 504 ha.

Already at the stage of proposal preparation the team had made the decision to work on gravity-fed canal irrigation schemes. To the team gravity-fed canal irrigation schemes were particularly attractive because they do not require pumping to supply water to the plots. In the Eastern Cape, Van Averbeke *et al*. (1998) identified the cost of O&M of pressurised irrigation systems as a critical factor in smallholder irrigation and expressed doubts that smallholders could afford the full cost of O&M of these systems. Considering that the initiation of the current project coincided with the process of irrigation management and transfer (IMT) of schemes to plot holders in Limpopo as part of the RESIS programme (Denison and Manona, 2007b) the team considered it prudent to focus on gravity-fed canal irrigation schemes, avoiding the risk of a collapse of irrigation activities due to the inability of farmers to pay for the O&M of their irrigation system.

Among the 183 smallholder irrigation schemes in Limpopo Province, Mohamed (2006) counted 78 canal irrigation schemes covering a total command area of 14 388 ha. The command area of individual smallholder canal schemes in Limpopo Province varied considerably (Figure 1.1). Categorising smallholder canal irrigation scheme size into very small (<100 ha), small (101-200 ha), medium (201-500 ha) and large (>500 ha), 41 of the 78 smallholder canal schemes in Limpopo Province were very small, 21 were small, 10 were medium and 6 were large. In terms of scheme size, Figure 1.1 indicates that the majority (60%) of smallholder canal irrigation schemes in Limpopo Province fell in the range of 50 to 200 ha. The average command area of a smallholder canal irrigation scheme in Limpopo Province was 182 ha, the average number of farmers per scheme was 136 and the average plot size 1.31 ha (Mohamed, 2006).

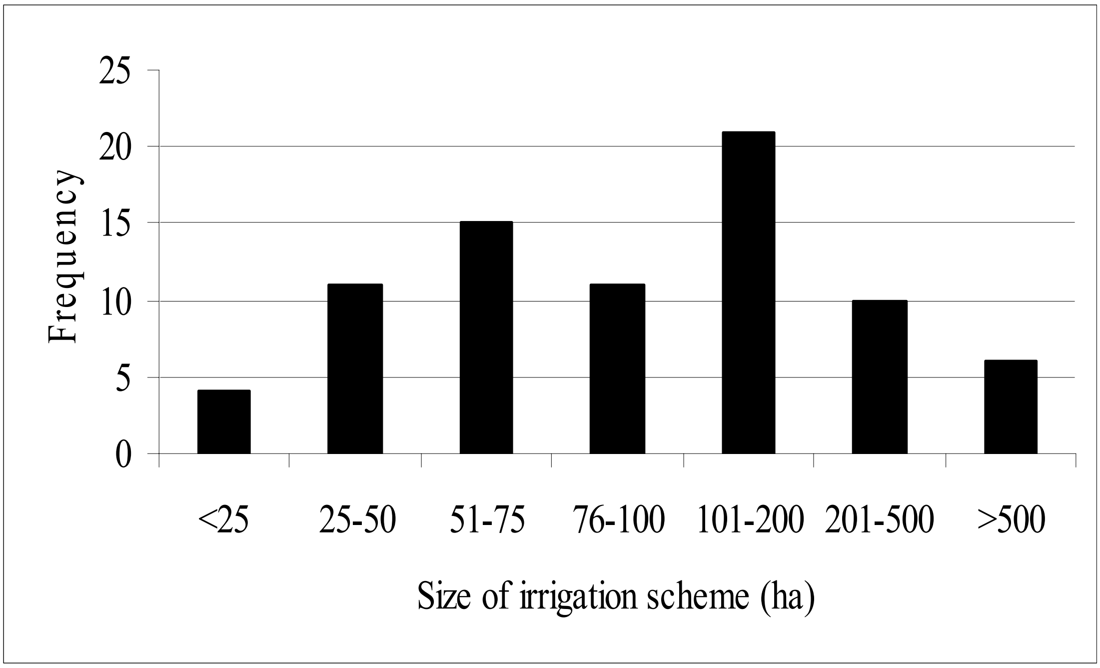

FIGURE 1.1: Frequency distribution of scheme size among smallholder canal irrigation schemes in Limpopo Province

1.5.2 Site selection

When engaging in participatory research, frequent and intensive interaction between the research team and the community of plot holders is implied. Practically, this limits the number of study sites at which research can be conducted effectively. Degree of representation is an important criterion in site selection. Irrigation system, scheme size, number of plot holders and plot size are the variables that are commonly used to categorise diversity among irrigation schemes (Denison and Manona, 2007b). However, the extent to which these criteria are meaningful in terms of explaining how well or poorly particular schemes function is questionable. A multitude of factors co-determine the functioning of an irrigation scheme and the results of this study show that among schemes with more or less the same design characteristics there are not only important similarities but also important differences. The implication is that each individual scheme is to an extent unique.

During proposal preparation the decision was made to select Dzindi Irrigation Scheme as the principal research site (Figure 1.2). The main reason for selecting Dzindi as the primary study site was that that research team had developed a good working relationship with the community and the extension officer at that scheme whilst conducting research on the use of organic manures in crop production in Limpopo Province. Dzindi also offered important practical advantages for the conduct of research. These included the availability of a dwelling to house research students and relative easy access to various amenities that are important for research and day-to-day life for the researchers on site. Moreover, relative to many other smallholder irrigation schemes in Limpopo Province and elsewhere in South Africa Dzindi had had limited state intervention in terms of management and had not yet been revitalised.

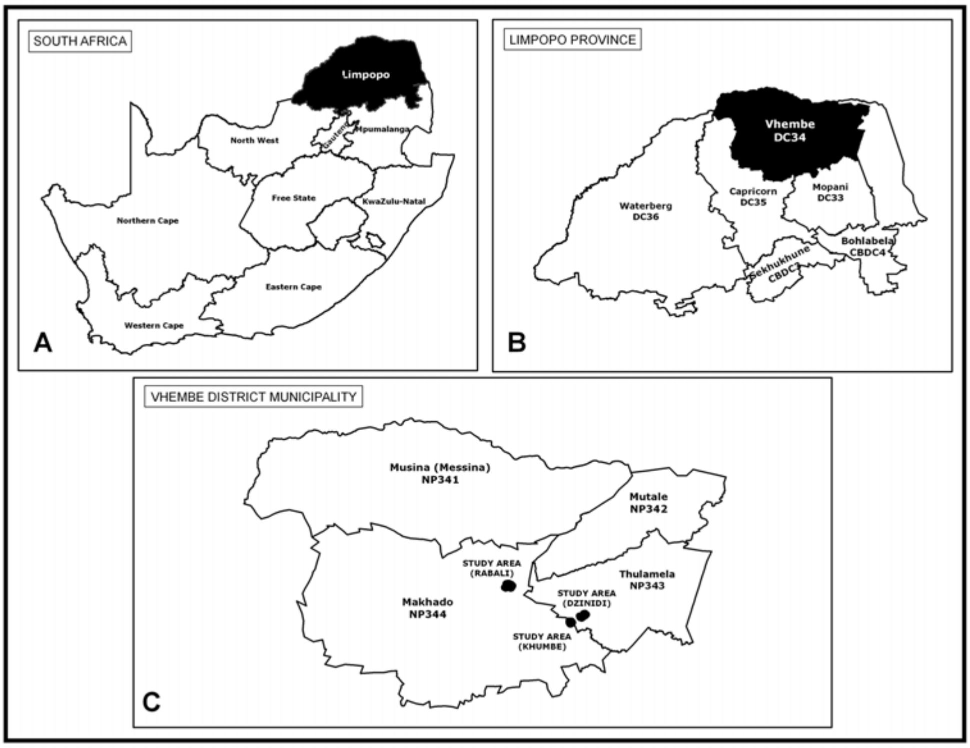

FIGURE 1.2: Location of the Dzindi, Khumbe and Rabali Irrigation Schemes that were selected for study

The team also conducted limited work at two other schemes, namely Khumbe and Rabali (Figure 1.2). These two schemes were selected because they were similar in size and design to Dzindi. Work at Khumbe and Rabali was primarily aimed at verifying the extent to which selected findings at Dzindi had wider application.

1.5.3 Brief description of the study sites

1.5.3.1 Dzindi Irrigation Scheme: Dzindi (23^{o} 01'S; 30^{o}26'E) was constructed shortly after WWII and is located in the Limpopo Province of South Africa (Figure 1.2). Dzindi is found about 6 km southwest of the town of Thohoyandou, in the Thulamela Local Municipality of the Vhembe District Municipality (Figure 1.2). It forms part of the settlement called Itsani, which counted a total of 1 080 households in 2001 (Statistics South Africa, 2001). Dzindi started operating in 1954 and occupies a total command area of 135.6 ha, which is subdivided into 106 plots of 1.28 ha each, held by a total of 102 plot holders. One of the plots is set aside for research and demonstration and this plot was used for the conduct of experimental research. At Dzindi, water is supplied by a diversion of the Dzindi River by means of a concrete weir. Dzindi has more or less the characteristics of the "average" smallholder canal irrigation scheme in Limpopo Province. Particular about Dzindi is its proximity to a fairly large urban centre (Thohoyandou-Sibasa), which is not the case for many other schemes in the Province. The peri-urban location of Dzindi provides farmers with relatively easy access to markets. Winter crops consist mainly of vegetables and maize is the principal summer crop.

1.5.3.2 Khumbe Irrigation Scheme: Khumbe (23°03'S; 30°21'E) was established in 1952 and like Dzindi is situated in the Thulamela Municipality. The Scheme is found along road R524, which links Makhado with Thohoyandou, about 20 km from Thohoyandou and 60 km from Makhado. At establishment Khumbe had a total command area of 145 ha and was subdivided into 224 plots of 0.65 ha (0.75 morgen) each, grouped into four irrigation blocks. In 2005 only 132 plots, covering an area of about 86 ha, were functional. The scheme obtains its water from the perennial Dzondo River by means of a weir, which is situated at a considerable distance from the Scheme. As a result, the main canal that conveys the water to the Scheme is very long (approximately 10 km), but within the boundaries of the Scheme its length is limited (about 4 km). There are two night storage dams at Khumbe, but these are only used when the flow in the canal has to be interrupted. Reliable transport services that use the R524 road are available in close proximity of the Scheme and along this road there is also a large covered facility where farmers can sell their produce to hawkers who market fruit and vegetables to road users. As in the case of Dzindi, farmers mainly grow vegetables during winter and maize during summer.

1.5.3.3 Rabali Irrigation Scheme: Rabali (22°53'S; 30°07'E) was established in 1952 and is located in the Makhado Municipality along road R523, which links Makhado with Sibasa, and it is about 50 km away from either of these towns. At establishment the Scheme had a total command area of 87 ha and was subdivided into 68 spatially consolidated plots of 1.28 ha each. Rabali forms part of a complex of 16 smallholder irrigation schemes, which draw their water from the Ndzhelele River. At Rabali the weir is situated close to the Scheme and the total length of the main canal is fairly short, about 5 km. In February 2000, floods caused by torrential rains hit the Limpopo Province and the raging Ndzhelele River destroyed the Rabali weir and cut away the bottom western part of the irrigated land. The weir and the conveyance system were completely refurbished shortly there after as part of a disaster relief programme. Rabali is far removed from urban centres, but the settlement forms part of a densely populated area. The cropping pattern at Rabali is similar to that at Dzindi and Khumbe, but tomatoes feature more prominently at Rabali than at the other two schemes.

1.6 Approach used in the conduct of the project

1.6.1 Theoretical background to the approach

To assist the team with the development of a participatory approach to the project, an independent consultant, Dr HRM Van Vlaenderen, was contracted. She proposed the use of 'merging of communities of practice' for the implementation of the participatory approach of the project. Her argument was that in order to understand the nature of the interaction between people one needs to focus on the joint activity in which they are involved. She pointed out that activities are socially situated, take place in relation to other activities and are linked to institutional practices and the actions of others. A community of practice provides goals, structure, meaning and values/rules, significance and tools for those engaging in the activity. In this way the research project should be understood as a meeting of two or more different communities of practice in a joint activity. The community of practice of the researchers, whose activities are embedded in certain goals, rules, tools and values, interacts with the focal community whose activities are embedded in its own goals, tools, rules and values. The simplest framework including only two communities of practice is captured in Figure 1.3.

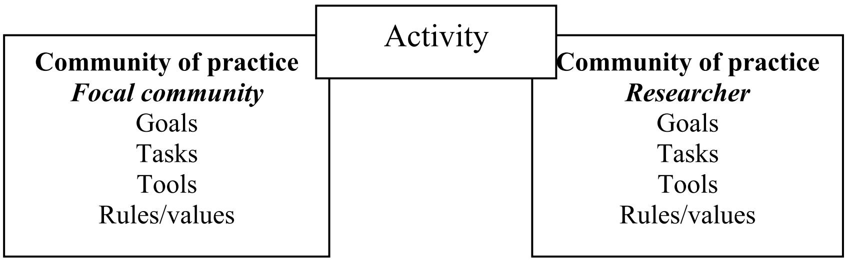

FIGURE 1.3: The research process as a meeting of communities of practice

In a participatory approach opportunities need to be provided for both communities of practice to make their rules, goals and tools explicit and there is a continued negotiation of these goals, tools and rules resulting into new emergent goals, tasks, tools and rules rooted in the research context. This approach allows for a more equitable, mutually constructed understanding of the issues and problems and provides a basis for joint decision making with regards to planning, researching/executing and evaluating interventions (Figure 1.4).

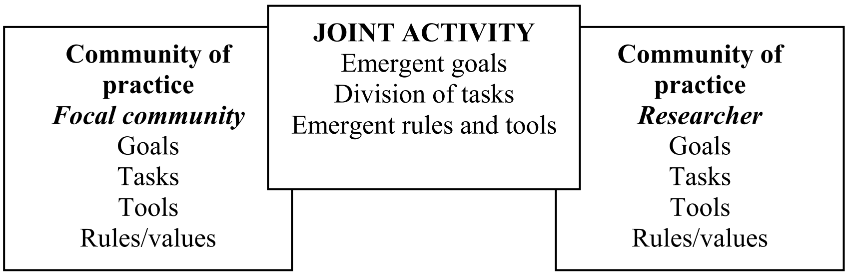

FIGURE 1.4: Merging communities of practice

For the research project at Dzindi to be conducted in a participatory way, research issues needed to be defined jointly by all stakeholders, leading to common goals, which incorporated the values and needs of all the stakeholders. The subsequent methods and strategies developed to attain these emergent goals needed to be negotiated, leading to a joint methodology (tasks and tools). The participatory approach proposed for the project aimed to empower all its stakeholders to make decisions about the research (plan, execute, evaluate) through a process of acknowledging and articulating the different communities of practice and the facilitation of a merging of the different communities.

Initial implementation of the approach was facilitated by Dr Van Vlaenderen during May 2003 and had the specific aim of creating a framework for the development of a shared community of practice. It aimed at providing the different potential stakeholders in the Dzindi Project with the opportunity to voice their needs and perceptions with regards to the research project and to initiate a process of negotiating their different goals, values and tools. Initial implementation involved three steps, which are discussed, namely a stakeholder analysis, the negotiation of a framework for joint action and the initiation of an action and evaluation strategy, all of which have been documented in detail by Van Vlaenderen (2003).

1.6.2 Initiating the approach

1.6.2.1 Stakeholder analysis: The stakeholder analysis aimed at providing all potential stakeholders with the opportunity to voice their needs and perceptions with regards to the nature and goals of the project and to identify the different stakeholders and their potential roles and tasks in the project. Preliminary identification of stakeholders, for the purpose of starting the intervention process, was based on information provided by TUT. Workshops were held with the Scheme Management Committee (SMC), staff and students of the Tshwane University of Technology (TUT), farmers from the four blocks that make up the Dzindi Irrigation Scheme (hereafter called the farmers) and the Extension Officer (EO)

With each of the groups separate workshops were held to gather the opinions of all possible stakeholders in the Project. In each workshop the group was asked to identify the goals they envisaged for the project. Goals were brainstormed and subsequently visualised by the facilitator, using drawings. The different goals were then prioritised by ranking the drawings in order of importance to the group. This prioritising exercise encouraged further definition and analysis of the particular goals. The groups were also asked whom they envisaged to be the stakeholders in the Project, what they considered to be their respective roles and tasks and how they would benefit from the project. The conclusions that were drawn from the results were:

i. There was a reasonable congruence between the different stakeholder groups with regards to the prioritised goals for the project. The goals for the Project related predominantly to physical improvement of the irrigation scheme and farming techniques, the development of additional farming activities and the improvement of the organisation between the farmers involved in the irrigation scheme.
ii. The goals identified by the TUT were formulated in more abstract, holistic and process oriented terms than those of the other stakeholders. The TUT emphasised improving the overall livelihood of the farmers and focused on the interactions necessary between the stakeholders to reach that goal.
iii. The goals identified by the other stakeholders were more concrete goals, which could be regarded as operationalisations and prioritisations of the abstract goals stated by TUT. This reflected the differences between the communities of practice. Whereas the farmers were more concerned with everyday practical, locally contextualised issues (use of concrete goals such as a tractor), the academic institution focused on disembedded systems and processes (stakeholder interactions). It is important that both approaches are accommodated in the Dzindi Project.

The core stakeholders identified by all groups were the farmers and TUT. This may be partially an artefact of the research process, since the workshops were introduced as having been initiated by TUT. The farmers regarded themselves predominantly as identifiers of needs and beneficiaries of services and the TUT as the providers. Only after facilitated discussion did some of the farmers allocate additional tasks to themselves, such as providing local knowledge and evaluating the project. This polarised perception of beneficiaries versus providers was described as a historically typical presentation of the interaction between these two communities of practice. In order to facilitate a participatory framework for the project it was important that decision making processes were regarded as a shared responsibility.

The farmers identified the government as a stakeholder but they did not specifically identify the EO as a stakeholder. The government was regarded as a provider of goods and services to the farmers who were the beneficiaries. No clear perception of the task of the EO was obtained from the farmers.

The SMC allocated itself a very important task with regards to the facilitation of communication between the different stakeholders in the project. However, none of the other stakeholder groups identified the SMC as having this particular role.

TUT regarded itself as the specialists in research and training and the farmers as beneficiaries of these services. However, they perceived the farmers to be more involved with the running of the project (identifying priorities, providing knowledge, evaluating) than the farmers did themselves. TUT regarded the EO as a partner in the running of the project, which was congruent with the perception of the EO of himself.

With regards to perceived benefits for the different stakeholders, there was a congruent perception that farmers' livelihoods would be improved by the project and that the EO and TUT would be doing the tasks and jobs they were expected to do and as such would be seen as successful.

The stake holder analysis created an opportunity for the different groups to voice and analyse their ideas about the goals of the project and their involvement in the project, without interference of the other (perceived as more powerful) stakeholders. The separate workshops with each of the groups enabled the facilitator to use appropriate methods for each of the groups (i.e. the pictorial presentations). It provided the facilitator with an insight into the different communities of practice, which enabled the preparation of the next step in the intervention process. It provided the different groups with a stake in the project and with an impetus to further develop their ideas and perceptions with regards to the project, more specifically to analyse their own role and position in the project.

1.6.2.2 Negotiating a framework for the development of a community of practice: Integrating the results of the stakeholder analysis: The second phase in the intervention involved a joint workshop of representatives of all the stakeholder groups. The aim of the workshop was to provide a platform for the discussion and integration of the perceptions and ideas of the different stakeholders, elicited during the previous phase, as such initiating a framework for participatory co-operation. In order to create a basis for discussing and determining the goals for the project a (pictorial) prioritised list was provided to the workshop. This prioritising was done by the facilitator and was based on the frequency with which a particular goal had been mentioned by the different stakeholder groups in the previous phase. For instance the improvement of the irrigation system, developing a poultry project and acquiring a tractor had been mentioned by five groups. They were therefore placed at the highest level on the priority list. The establishment of a piggery project was only mentioned by one group and was therefore at the bottom of the list. The prioritised list of goals is shown in Table 1.2

TABLE 1.2: Priority list of project goals identified by stakeholders in the project

Priority level	Project goal
1	Improve the irrigation system. Establish a poultry project. Resurrect the dairy project.
2	Acquire another tractor Resurrect the co-op Acquire title deeds to the plots Improve knowledge of the soil
3	Develop a nursery Improve indigenous crop production Replace the irrigation scheme fence
4	Establish a piggery project Develop new marketing strategies

In response to the list of priorities compiled by the workshop, TUT representatives explained that their goal for the project was of a different nature from those identified by the other stakeholders. Although they accepted the prioritised list, their main goal was to conduct research guided by farmers' needs and to assist farmers with solving their problems, as well as to train students in research. They further explained that the pursuit of any of the project goals within the overall project was dependent on the availability of human resources in the form of students and that this would have an impact on the prioritised list. They argued that the goals of 'acquiring another tractor'; 'fencing the irrigation scheme'; and 'improving the irrigation system' could be clustered because they all concerned capitalisation and needed major financial input. They explained that the budget that was made available by the WRC did not allow for the type of financial contributions that were called for and to pursue these goals another agency would need to join the project. They undertook to help identifying such an agency since these goals were highly prioritised. The TUT further pointed out that there were only sufficient students available to:

i. Develop and establish a poultry project and resurrect the dairy project;
ii. Resurrect the co-op; assist farmers with acquiring title deeds and to improve knowledge of the soil;
iii. Improve indigenous crop production; and
iv. Develop new marketing strategies

Since TUT did not have students available to establish the nursery and the piggery project the TUT representatives recommended that these two projects be removed from the priority list, which was accepted by all stakeholders.

In order to provide a basis for the participants to discuss the roles and tasks of the different stakeholders in the Project, the facilitator provided tables (based on information provided by the stakeholders in Phase 1) for each of the stakeholders, indicating what the stakeholder perceived to be its own roles and what the other stakeholders perceived to be the role of that particular stakeholder. After presentation of each of these tables a discussion ensued to reach consensus about the stakeholders' tasks. It was acknowledged that there was a great congruence between the tasks allocated to self and those assigned by others. Although only the farmers themselves indicated that farming was their main role in the Project, the other stakeholders accepted this as an evident and important activity of the farmers.

The farmers accepted their involvement in setting the agenda for the project, although they had initially not considered this as part of their responsibility. They argued that in the past they had not been asked to contribute to such decision making processes with regards to projects.

The SMC had assigned itself several executive tasks in the project, whereas none of the other stakeholders had identified the SMC as a separate stakeholder with specifically allocated tasks. Although the 'self allocated' tasks were not challenged by the other stakeholders, there was no real positive ratification either. The role of the SMC remained ambiguous.

The EO's self-allocated tasks were similar to those allocated by the others. It was ratified that starting projects and deciding on priorities, although mentioned by the other stakeholders were regarded as legitimate tasks for the EO. He also accepted taking part in the evaluation of the research and the Project.

It was acknowledged that the tasks allocated by TUT to itself and those allocated by others largely overlapped. However it seemed that the other stakeholders emphasised TUT's task in leading and facilitating the overall Project. TUT representatives indicated that they were happy to contribute to the leadership and facilitating roles, but that they did not regard themselves solely responsible for them. They wanted to share those tasks. This was accepted by other the stakeholders after discussion. TUT explained that it was not a funding organisation but that it would make available funding received from the WRC and NRF for clearly specified purposes such as the initiation of new projects. This funding would be aimed at eliminating the financial risks associated with the implementation of innovations. Reflection on the various ratified roles and tasks illuminated the joint responsibility of planning, facilitating communication and evaluation between all stakeholders.

1.6.2.3 Initiating an action and evaluation framework: During this phase the priority list was operationalised by developing an action plan for the first six months of the project. Three of the identified goals would be pursued during this period, namely the resurrection of the co-op, the capitalisation of the scheme (fencing, tractor and improving the irrigation infrastructure) and the establishment of the poultry project.

1.6.2.4 Analysis of the outcomes and reflection on the process: The consultant was of the opinion that the intervention had been successful in identifying the different stakeholders, providing them with an opportunity to voice their ideas and needs. It also enabled the different stakeholders to bring their ideas together in a forum where these could be discussed in a democratic manner.

The consultant pointed out that the intervention had not yet succeeded in merging the different communities of practice into one community with a unified goal, values and tools. Taking into account the major differences in background between the stakeholders, she predicted that the merging process would be a very slow and delicate process that could easily be damaged. Another observation was that although the different stakeholders had identified, discussed and ratified their own roles and tasks and those of others, this was done in a rather abstract manner and their acceptance of the notion of joint decision making, including planning, organising and evaluating was not yet fully understood in practical terms.

The consultant also warned that although all stakeholders had the opportunity to voice their ideas, not all groups and individuals were equally vocal during the workshops and that efforts needed to be made to ensure full participation of the farmers, especially female farmers.

The consultant identified several issues that needed to be addressed in order to further facilitate the development of a participatory framework. These included:

i. The specific role of the SMC in the project needed to be clarified, especially vis-à-vis the body of farmers as a whole.
ii. Operationalisation of the identified projects required attention, in particular with respect to the tasks of planning and organising. Care needed to be taken that the organising and planning does not become the sole task of one stakeholder (i.e. TUT), thereby undoing the resolution of joint decision making processes.
iii. There was a need for a thorough briefing of all the members of the different stakeholder groups in order to develop a coherent understanding of the project and its intended participatory framework.
iv. There was a need for regular meetings of all the stakeholders to enable a gradual strengthening of the joint community of practice, to celebrate achievements and to address problems timely should they arise. These meetings should ideally be facilitated by an independent facilitator. The representatives at the joint stakeholder meeting should be accepted as representatives of their groups and should report back adequately to their groups.

1.6.3 Subsequent developments

During the three-year duration of the project, participation remained an overall aim, but this aim was not really achieved at the project level for several reasons. From the perspective of the author these reasons included:

i. Many of the goals of farmers demanded the use of an action-research approach. The students who were responsible for the implementation of the different sub-projects expected to use their work to compile a master's dissertation or a doctoral thesis. In South Africa there is not really a tradition of dissertations and thesis that are based on action research, particularly in the field of agriculture. As the supervisor of these students the author also lacked the experience and confidence to lead them along this path. Instead, the author chose for a more classical approach to research, involving the use of established methods such as surveys and experiments even though he knew that these methods were not particularly well suited for the purpose of stakeholder participation.

ii. When preparing the proposal for submission to the WRC, the author was of the firm belief that this project had the potential to develop a better understanding of what constitutes smallholder irrigation in South Africa. At that time, he was of the belief that existing knowledge was deficient and that the lack of understanding lead to bias in the perceptions of decision makers. Consequently, several of the project activities were essentially knowledge generating in nature and purpose and of no real direct benefit to the community participating in the project. Examples were the analysis of livelihood and farming of plot holder households, the analysis of collective action among farmers and the analysis of social relationships between irrigation scheme communities and their surrounds. These analytical activities were not entirely wasted on farmers. The method used to analyse farm enterprises proved very enlightening to selected market-oriented plot holders who subsequently adopted this method to monitor and analyse their different operations, leading to improved farm management. The group as a whole also learnt a lot from the feedback sessions on the dynamics of their collective action in the different domains that were studied.

iii. As indicated, the methods used for the conduct of on-station and on-farm research were not always conducive to participation and in some cases even prevented participation. For example the research activities that investigated the nutrient response of Chinese cabbage and nightshade, two important African leafy vegetables at Dzindi, was done in the greenhouse facilities of TUT in Pretoria. Research on the effects of planting date and irrigation strategy on the yield of Chinese cabbage, which was done on the experimental plot at Dzindi, paid insufficient attention to involving farmers in the planning, monitoring and evaluation of these experiments, limiting the impact of the research on the management practices of farmers. On the other hand, the research associated with the establishment of the poultry project and the research aimed at improving green maize production were regarded as successful by farmers. The poultry project was considered successful because it provided a new facility and transferred the technology to run this enterprise to the farmer collective. The green maize research project was successful because it incorporated an important action-learning component and the research results indicated the promise of substantial improvements in the financial returns of this enterprise, which promoted the adoption of improved technology among participants. It needs pointing out that through the process of self-selection only about 20% of farmers actively participated in the green maize research project, all of them actively involved in the production of this commodity.

iv. Students have differing circumstances and priorities and this affects the level of commitment they have towards their studies. Three master's students left the project at various stages of progress. One of them was responsible for the capitalisation of the scheme with specific reference to the acquisition of an additional tractor and the fencing of the scheme. He left the project at the end of proposal preparation. The student assigned to the resurrection of the dairy project was employed as a technician at the University of Pretoria. When he changed employment he abandoned his studies. The student responsible for studying the relationships between Dzindi Irrigation Scheme and the surrounding communities quit the project at a fairly advanced stage of data collection when he was offered employment.

In the end, circumstances and the choices that were made shaped the agenda of this research project. Regular communication (twice yearly) with farmers and the EO was maintained throughout the duration of the project using general meetings as the forum. At these meetings the original flip chart sheets, on which the final list of approved activities had been captured in the presence of farmers, was displayed. Working their way down the list, TUT researchers provided feedback on progress. Feedback presentations were then followed by an open discussion where farmers were invited to ask questions, demand clarifications or raise concerns.

1.6.4 Project activities

Referring to section 1.4 of this report, which lists the specific objectives of this project and the way in which these objectives were interpreted by the team, four categories of project activities occurred, namely (i) stakeholder negotiations; (ii) situation analysis; (iii) participatory technology development; and (iv) monitoring and evaluation. The stake holder negotiation activities have been described in section 1.6.2 of this report. The situation analysis was conducted at Dzindi and also at the irrigation schemes of Khumbe and Rabali. The focus of the situation analysis was on the livelihood of plot holders, the role of farming in these livelihoods, diversity in farm goals and management practices and collective action among farmers. Activities in the category of participatory technology development focused on improving production of two types of African leafy vegetables (Chinese cabbage and nightshade) and of green maize and on the introduction of poultry production into the local farming system. Monitoring and evaluation was limited to a survey conducted towards the end of the project during which the impact of the project activities on the different stakeholders was determined.

In the subsequent chapters of this report an overview of the findings of the different research activities that occurred under the auspices of the project are presented. Details on the methods use to collect and analyse data appear separately for each activity. Full details on each of these activities are contained in separate reports, which are available in electronic format upon request from the WRC. The titles of these reports appear in Appendix B.

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2 THE STUDY SITES

2.1 Methods

Research for this project was conducted at three irrigation schemes that had similar features. They were all smallholder canal irrigation schemes that were established during the first half of the nineteen-fifties in the former homeland of Venda. All three schemes extracted their irrigation water from perennial rivers by means of a weir and conveyed this water by means of a system of primary and secondary concrete-lined canals. This chapter describes the situation at these three schemes. The information is organised using important factors that affect livelihood and farming. Dzindi was selected as the main site and Rabali and Khumbe served to verify to what extent the findings at Dzindi had wider application.

The history of Dzindi Irrigation Scheme was reconstructed by means of the conduct of a time line. The timeline method is a participatory method of capturing and verifying oral history (Matata *et al*., 2001). It is a group activity during which participants share their recollection of important events and processes that occurred in their community. During the construction of the time line, participants are encouraged to interrogate the information that emerges to ensure that the information is as accurate as possible. Once consensus on a particular event or process is reached, the information is recorded on large sheets of paper, which remain on display throughout the process. The other information on Dzindi was collected using key informants, field observations and the use of secondary sources of information. In addition a soil survey was conducted.

The entire research team was involved in the analysis of the situation at Rabali and Khumbe, which occurred over a period of two weeks during the winter of 2005. The appraisals at Khumbe and Rabali were guided by the research findings of the team at Dzindi in terms of the various factors that influence smallholder irrigation at farm and scheme level. The study of the situation at Khumbe and Rabali employed a rapid appraisal approach. This approach was selected because the time available to conduct the study was limited to one week at each scheme. Focus groups were the main data collection method. The choice of using focus groups to collect data suited the limited time that was available. For most purposes this participatory method proved appropriate, yielding relatively rich data that were cumulative and elaborative, since the discussions stimulated participants to jointly recall and reach consensus on issues and incidences. The style of facilitation kept the proceedings flexible, allowing participants to talk freely and explore the themes that were raised. On occasions the interactions resulted in the surfacing of important incidental data. Other methods that were used included a survey involving short structured interviews with individual farmers and field observations.

2.2 Dzindi

2.2.1 Brief history of Dzindi

Talks about the establishment of an irrigation scheme using water from the Dzindi River started shortly after WWII. Initially Chief Tshivhase who presided over the area, did not accept the idea but in 1951, the Department of Agriculture finally convinced him to agree to the establishment of the scheme and surveying of the land commenced. In 1953, workers from elsewhere were employed to construct the first canals at block 4, closest to the weir. That same year the workers went on strike complaining about low wages. They abandoned the site and left, creating employment opportunities for local people, who got hired to replace them.

The construction of the scheme was completed in 1954. Conditions for plot occupation were laid down and included the following stipulations:

i. plot-holders had to be full-time farmers;
ii. plot-holders would be replaced if they did not utilise their plot;
iii. plot holders were to pay a rental fee of £3 per annum for their plots;
iv. one family could only hold one plot;
v. plot-holders were prohibited to hold any land other than the irrigation plot; and
vi. the rearing of goats was prohibited but the rearing of large stock, for which grazing was available at the scheme, was allowed.

Homesteads whose land was incorporated into the scheme were first in line when plots were allocated. For the others a waiting list was drawn up but the list was short. People appeared not to be interested in farming at the scheme. Plot 1 was allocated to Headman Makumbane, who refused it, stating that he had enough land already. As a result, plot 1 was not allocated to anybody and later on it became the research plot. The other plots were allocated by means of a lottery. Pieces of paper on which the plot numbers were written were put in a container and people drew their lot from the container.

Still in 1954, government tractors arrived at the scheme to plough the land and farming started. Subsequently plot holders had to pay for the services rendered by tractors and as a result many plot holders continued to make use of animal draught, using cattle or donkeys. Mr Thelele from Middleburg was appointed as the first extension officer at Dzindi. Farmers made use of kraal manure to increase the fertility of their land. They were aware of the positive effect of kraal manure on crop yield from observations that old kraal sites produced persistently high yields. Kraal manure was bought collectively and trucked to the scheme.

In 1957, Mr Thelele was replaced by Mr Nesengani who encouraged plot holders at Dzindi to form a farmers' association.

In 1961, Commissioner Potgieter and staff of the Department of Agriculture inspected the scheme. Plot holders who had not paid the annual rent and those who did not utilise their plot appropriately were identified and they were warned that unless they changed their ways they would be expelled from the scheme. Chemical fertilisers were used at the scheme for the first time. Later on the purchase of chemical fertilisers became a collective action arranged through the farmers' association.

In 1962, a second inspection occurred and non-payment of rent or under-utilisation of plots caused many plot holders to lose their land rights. Since holding an irrigated plot was linked to holding residential land, households that were expelled also had to vacate their houses. Agricultural technicians instructed the farmers to plant pigeon peas instead of the maize, bambara groundnuts and vegetables they were growing.

In 1963, staff of the Department of Agriculture actively searched for suitable replacements of evicted plot holders because in many cases the new farmers that had joined the scheme performed as poorly as the evicted farmers they had replaced. To identify suitable farmers, the Department searched for people who utilised river water for irrigation and invited them to join the scheme. The Department withdrew the instruction to grow pigeon peas and reintroduced the planting of vegetables. Hybrid maize seed was introduced at the scheme by a white priest. Farmers tried it out but the incidence of cob rot was very high.

In 1964, farmers were instructed to plant cotton, but this crop turned out not to be profitable. The next year farmers were instructed to plant tomatoes but the marketing agent discriminated against Dzindi farmers by allocating a very small portion of his loading space to them, whilst reserving the rest for White farmers, who were also growing tomatoes. A large proportion of the tomatoes produced by Dzindi farmers ended up rotting.

In 1966, farmers were instructed to plant a wheat and cotton rotation but this initiative was not a success mainly because of marketing problems. Farmers had to maintain this particular crop rotation for the next two years but problems persisted.

Starting in 1969 and lasting until 1974, plots at Dzindi were reallocated, as Venda was being prepared for self-government. Plot holders who were Shangaan (Tsonga-speaking) were forced to vacate their plots and were moved to Gazankulu, a homeland created for Tsonga-speaking people[3]. Four Venda farmers, who the Department regarded as progressive farmers, were allocated multiple plots. One person was even allocated four plots. Other vacated plots were allocated to new arrivals at Itsani. To obtain a plot, the new residents of Itsani had approached Headman Makumbane who allocated residential sites and irrigation plots at a cost of R3.00. Plot holders not utilizing their farms continued to be expelled from the scheme but they retained their residential sites and their houses.

In 1970 a dairy project was established at Dzindi and in 1971 the era of the Venda homeland administration commenced. Farmers were informed that they could plant the crops of their choice. That year Chinese cabbage dominated winter production. The Commissioner stopped visiting the scheme and farmers missed his personal attention, because the high-powered representatives of the Venda homeland, who replaced him, never showed up. During the Venda homeland era the supply of soil preparation services was superior. Government tractors were available whenever farmers needed them. Bookings were made with Mr. Nesengani, the resident extension officer. Farmers referred to this period as the time during which they built or expanded their dwellings, but farming was not particularly intensive. At the end of

[3] Lahiff (2000:69-70) explains that these events followed the subdivision of the African population of the Transvaal along ethnic lines by the creation of three Territorial Authorities in 1962, namely Thohoyandou for the Venda, Matshangana (later Gazankulu) for the Tsonga-Shangaan and Lebowa for the Northern Sotho. Removals (both voluntary and forced) affected people who 'lived on the wrong side of the fence' and was not limited to Tsonga-Shangaan living in Venda but also affected Venda people living in Gazankulu.

1974, when all vacated plots had been reallocated, holders of multiple plots had to return extra plots for allocation to landless people.

In 1976 there was a bad drought that caused yields to be very low. The Venda government donated chemical fertilisers to farmers. Each plot holder at Dzindi received six 50 kg bags.

In 1977 the rains were particularly heavy and floods prevented farmers from cultivating their lands from February to June. The river was very full and a hippopotamus roamed around the plots. At Itsani many of the huts that were made of wattle and daub collapsed.

In 1980 a conflict arose between Headman Makumbane and Headman Tshikororo because Headman Tshikororo started to allocate residential sites to new households arriving at Itsani. These new sites were close to the main canal and this breached the agreement reached between Headman Makumbane and the Dzindi plot holders. Settling people near the canals resulted in pollution of the irrigation water because people washed their clothes and bodies in the canals. Theft of produce and wood from the rangeland belonging to the scheme also occurred. The new residents also destroyed parts of the scheme fence. For the first time the rules governing the use of irrigation water were written down in a mass meeting.

In 1981, the dairy project that was started in 1970 collapsed and in 1983 most of the livestock of Dzindi farmers perished because of a terrible drought. The amount of water entering the canal during that year was so limited that farmers could only irrigate part of their plot. The irrigation timetable was changed from once per week to once per fortnight. Crop yields were very low.

In 1984, Dzindi farmers entered into a contract with a company in Phalaborwa. The contract involved the supply of cabbages, carrots and beetroot. The contract looked very good, but the Department of Agriculture interfered. When the client arrived to collect the vegetables, the Department brought produce from elsewhere and gave it priority. As a result, only small amounts of the produce supplied by Dzindi farmers were bought. Farmers were upset and terminated the contract. In 1985, the farmers' association was transformed into a registered co-operative.

In 1986, Agriven (ARDC) arranged a tomato production contract for farmers with a processing company in Tzaneen[4]. The ARDC convinced farmers to sign contracts. Farmers who entered contracts were given production loans by the ARDC. Large quantities of tomatoes were produced, but the tomato processing company only bought a very small portion. Large amounts of tomatoes were left to rot in the plots because of a lack of market. Farmers earned very little from their consignments and most farmers were unable to repay their production loans to the ARDC. Some farmers ended up in court for failing to repay their loans.

In 1989, selected farmers obtained permission from the scheme management committee (SMC) to utilize non-scheduled land. In 1990, the political uprising that

[4] Lahiff (2000:89) reported that Agriven established a tomato-canning factory at Makhado. The contract which farmers at Dzindi signed with Agriven was probably to supply this cannery.

affected the entire country also arrived at Itsani. The youth of Itsani revolted against the SMC, accusing the committee of forcing their parents to work without reward.

In 1994, Mr. Nesengani was replaced by Mr. Netshithuthuni as the resident extension officer. The Republic of Venda was re-incorporated into South Africa and the African National Congress government came into power. Farmers received donations of fertilisers from the government. The flow in Dzindi River was very low that year. People from the neighbouring settlements lowered the weir by hacking away part of the top to prevent all river water from entering the main canal of Dzindi. They needed the river to run to get at water below the weir to wash cars. This did not affect the farmers much, because the damage was limited.

In 1996, farmers received vouchers from government with which they could purchase agricultural inputs and farming equipment, such as hand hoes, rakes, and garden forks. The Department of Agriculture told the scheme committee to apply for grants of R15 000 per plot, but farmers did not succeed in acquiring these grants.

In 1998, the government withdrew its tractors from Dzindi and also the workers who helped to maintain the scheme infrastructure. Some state tractors were sold by public auction, whilst others were taken to Polokwane. Maintenance of canals became problematic because the public service engineers no longer came to the scheme. Shayandima Township took part of the land near Block 1 for the expansion of the township. The scheme committee (SMC) applied to the Thulamela Local Municipality for the return of this land but the application was not successful.

In 1999, plot holders of Dzindi collectively purchased a second hand tractor and implements.

In 2000, a major flood ravaged the north of South Africa. The fences and the pipe that conveyed water to the dam in Block 1 were destroyed as a result.

In 2001, the collaboration between Tshwane University of Technology (then called Technikon Pretoria) and Dzindi started when researchers visited the scheme to investigate the use of organic fertilisers by local farmers.

2.2.2 Physical factors

2.2.2.1 Climate: The climate at Dzindi can be described as semi-arid and subtropical with a mean annual rainfall of about 700 mm and no frost. Most of the rain falls during summer, from October to March. Cloudy conditions during that period limit evaporative demand. As a result, potential evapotranspiration tends to peak during early and late winter instead of summer.

2.2.2.2 Geology: Litho-stratigraphically, Dzindi is situated on the Goudplaats Gneiss unit, which is the oldest unit in the area and the base of the Swazian (Brandi, 1987). Dzindi is situated near the north-western edge of this unit (Department of Mineral and Energy affairs, 1985). The rocks in this unit consist of light and dark grey biotite gneiss and migmatite. Mineralogically, the rocks in this unit consist primarily of oligoclase (An_{20}), quartz, biotite and hornblende (Brandi, 1987). Before reaching the irrigation scheme, the Dzindi River flows through rocks of the Sibasa Formation, which forms part of the Soutpansberg Group. These rocks occur west of Dzindi (Department of Mineral and Energy affairs, 1985). The Sibasa Formation is a volcanic succession with sparse intercalations of quartzite, shale and tuff. Its thickness is estimated to be around 2000 m. The lavas are blackish or greenish black in colour and consist of altered pyroxene and plagioclase with minor amounts of olivine and opaque minerals. The groundmass is often intensely epidotised and chloritised (Brandi, 1987).

2.2.2.3 Topography: Dzindi Irrigation Scheme is situated about 550 m above sea level and forms part of a gently to moderately undulating plateau found south of the Soutpansberg mountains, where the relief is considerably steeper than on this plateau (South Africa, 1989). Most of the command area of Dzindi is located on hill sides and has been terraced.

2.2.2.4 Vegetation: Dzindi forms part of the vegetation unit called the North-eastern Mountain Sourveld (Acocks, 1988). Locally this unit is found along the southern edge of the Soutpansberg mountain range. It is a strongly sour, *Themeda*-dominated veld, which is less dense than southerly sourveld types, but the tufts may be larger. Dominant species are *Themeda triandra*, *Loudetia simplex* and *Rendlia altera*. Typically rows of *Cyathea dregei* occur along streams in the grassveld.

2.2.2.5 Soils: The establishment of Dzindi Irrigation Scheme was preceded by a soil survey conducted by Murray (1951) over a period of two weeks. He identified four main soil types in the area commanded by the weir in Dzindi River that was to supply water to the scheme. These were reddish brown clays, grey sands, grey clays and alluvium. The report rated the grey sands as soils not recommended for irrigation, the grey clays as poor irrigable soils, and the reddish brown clays as good irrigable soils. With few exceptions the reddish brown clays were reported to have a rooting depth of at least four feet (1220 mm). The occurrence of alluvium was so limited that for practical purposes it was ignored. The survey of the soils of Dzindi was limited in scope and did not determine the physical and chemical properties of the soils by means of laboratory analyses. The water-related properties of the soils in the field, such as infiltration rate, field capacity and permanent wilting point, were also not measured.

During the planning of the project farmers had expressed the need to improve knowledge about their soils (see section 1.5). Consequently, a soil survey of Dzindi was conducted during the period August to October 2004. The soils were mapped using a 50 m square grid of observations, resulting in four observations per ha. Arial photographs of the four blocks on a scale of approximately 1:5000 were used as a base map. Five profile pits were dug to obtain information on the soils prevailing in the Scheme. Two of the profiles, which combined represented 95% of the soils at Dzindi, were described in detail and sampled for laboratory analysis. Observations of the soil for the purpose of mapping soil bodies were made by auguring to a depth of 1200 mm. Each position was indicated on the base map using a reference number and observations were recorded in a field book against the corresponding reference number. Once all the grid observations in an irrigation block were completed, the boundaries between soil bodies were drawn on the map. Whenever there was a need, additional observations were made to enable the drawing of the soil boundaries as precisely as possible.

Five soil units were identified at Dzindi. The first two units, which appear as A1 and A2 on the soil maps (Figures 2.1 to 2.4) had a similar morphology, but differed in particle size distribution. Both were deep red well-drained soils of the Hutton form (Soil Classification Working Group, 1991) with an effective rooting depth in excess of 1200 mm (probably in excess of 2000 mm in most cases). Soils designated as mapping unit A1 had a B-horizon clay content that was estimated to range between 25 and 35%. The B2-horizon of the soils occurring in mapping unit A2 had higher clay content (>35%) and was extremely laborious to auger. The third soil unit, designated B on the soil map, consisted of soils with impeded drainage. They were classified as soils of the Westleigh form (Soil Classification Working Group, 1991). Generally they were deep soils, but the morphology of the B-horizon (distinct high-chroma mottles embedded in a grey-coloured matrix) indicated that root development was subject to restrictions as a result of occasional water logging. The final two units, designated C1 and C2 on the soil map consisted of shallow sandy soils, often stony, and were associated with a quartz vein that ran through the landscape. Depending on soil depth they were classified as Mispah form soils (shallow) or Glenrosa form soils (deeper) (Soil Classification Working Group, 1991). These two units were separated on the basis of soil depth. Soils designated C1 had an effective rooting depth of at least 300 mm. Soils in unit C2 were very stony and had an effective rooting depth of less than 300 mm.

The spatial distribution of the soil units that were identified at Dzindi are shown for each block separately in Figures 2.1 to 2.4 and the aerial distribution of the different soil units in Table 2.1.

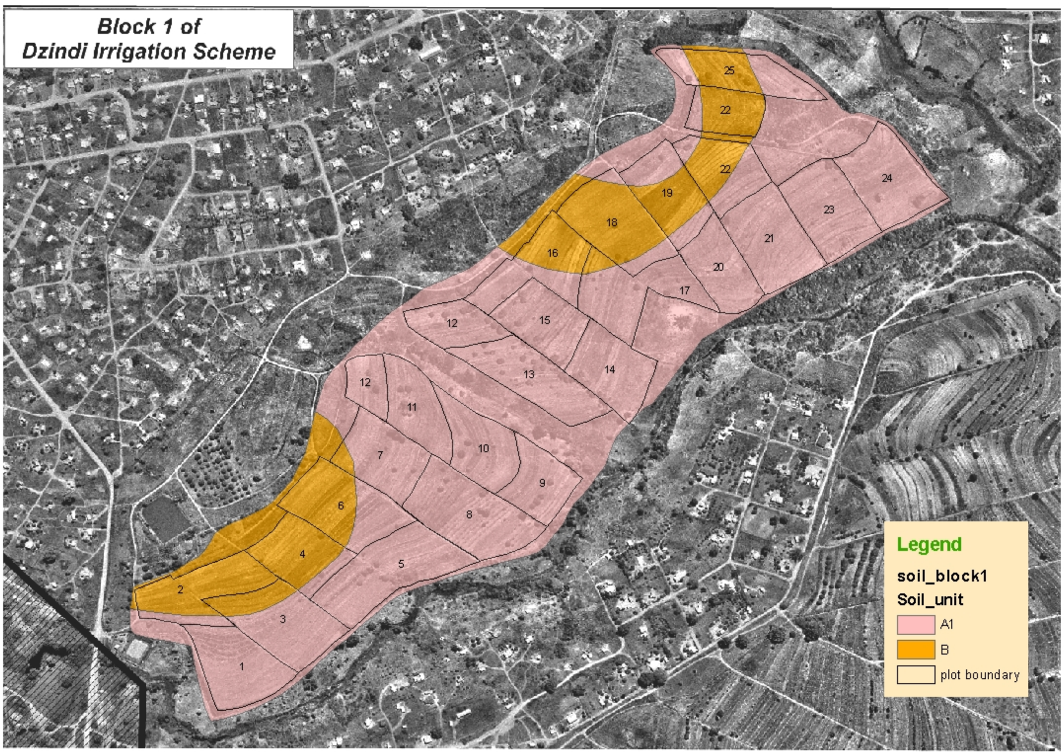

FIGURE 2.1: Distribution of soil types in Block 1 of Dzindi Irrigation Scheme

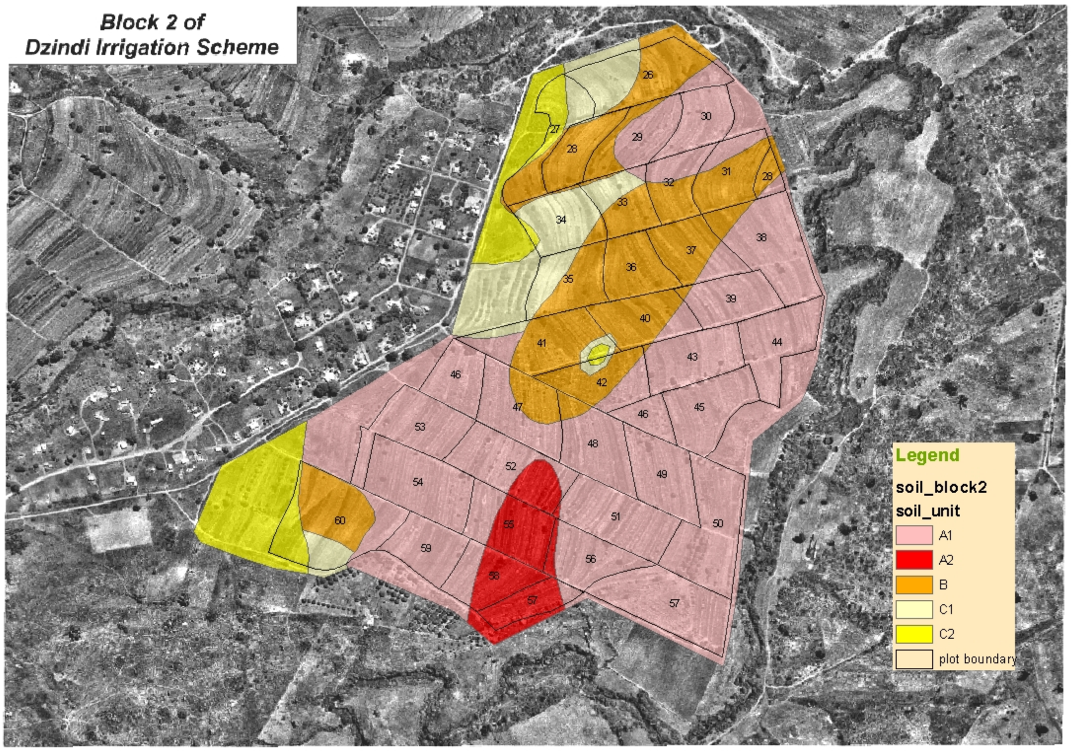

FIGURE 2.2: Distribution of soil types in Block 2 of Dzindi Irrigation Scheme

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FIGURE 2.3: Distribution of soil types in Block 3 of Dzindi Irrigation Scheme

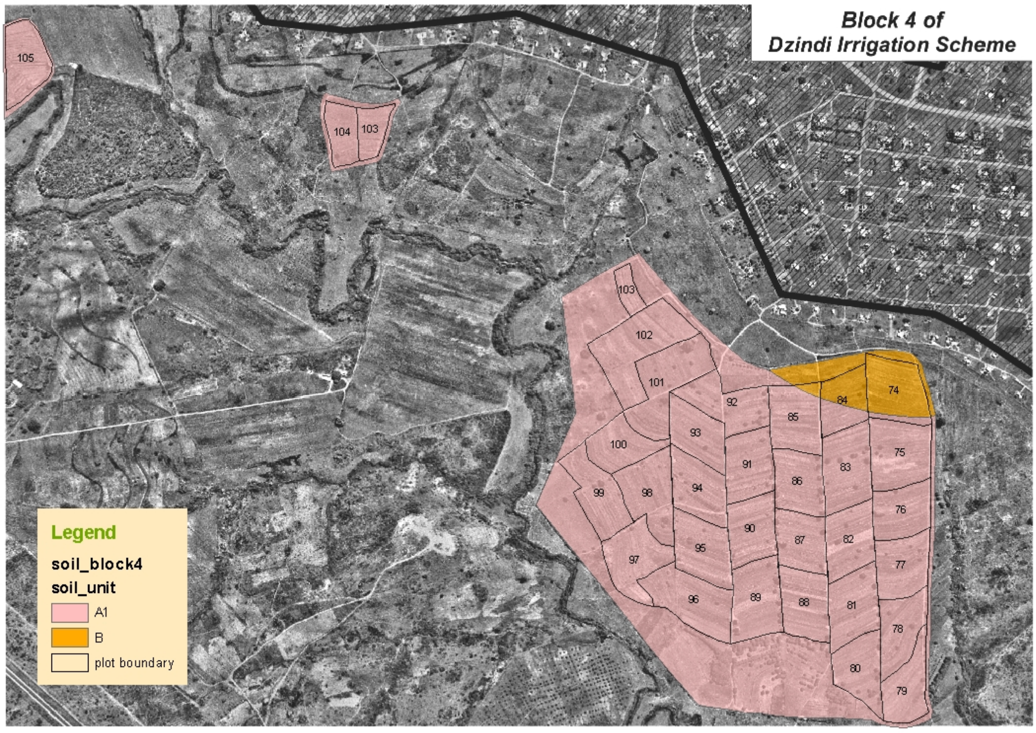

FIGURE 2.4: Distribution of soil types in Block 4 of Dzindi Irrigation Scheme

TABLE 2.1 Distribution of the different soil units occurring at Dzindi

Soil unit	**Description**	**Coverage**	
		Proportion of irrigated surface (%)	Area (ha)
A1	Deep Hutton-form soil with a clay content of 25-35% in the B2 horizon	75	101.75
A2	Deep Hutton-form soil with a clay content of >35% in the B2 horizon	2	2.52
B	Westleigh form soils	20	26.14
C1	Sandy Glenrosa form soils with a rooting depth of at least 300 mm	2	3.32
C2	Stony and sandy Mispah form soils with a rooting depth less than 300 mm	1	1.96
TOTAL		**100**	**135.68**

Important for farming at Dzindi is that 75% of the area under irrigation has a soil type (soil unit A1) that is well suited for irrigation purposes. The soils found in remaining quarter of the irrigated area are mostly moderately well suited for irrigation (soil units A2 and B) and only about 5 ha (3% of the area) is covered with soils that are poorly suited (soil units C1 and C2).

Additional information on the soils of Dzindi is presented in the dissertation prepared by Mr Barnabe Adriaens, a Belgian Bio-engineering student, for submission to the Hogeschool Gent (Adriaens, 2005). Details of this dissertation, which is available in electronic format from the Water Research Commission, appear in Appendix B of this report.

2.2.3 Infrastructural factors

Infrastructure can be classified into two categories namely, physical and social infrastructure. Physical infrastructure includes roads, canals, dams and buildings. Social infrastructure refers to services such as education, recreation, health, extension, credit and marketing (Ilaco, 1981). The presence or absence of infrastructure in a particular area affects both the economic activities and the quality of life of its residents.

2.2.3.1 Description of the irrigation infrastructure: Irrigation infrastructure is defined as the facilities used for storage and delivery of water for irrigation purposes (Van Averbeke *et al.*, 1998). The design of Dzindi conforms to an irrigation scheme development model that was widely implemented by the South African government during the period 1930 to 1960. This model involved the establishment of a source of irrigation water, usually by means of stream diversion, and a water distribution system that consisted of concrete canals. The use of earth dams to moderate water supply was also common. When this model was applied to the development of smallholder schemes, plots were typically about 1.5 to 2 morgen[5] in size (The Commission for the Socio-economic Development of the Bantu Areas within the Union of South Africa, 1955).

The total irrigated area at Dzindi amounts to 136 ha. Dzindi consists of four irrigation blocks which are spatially separated from each other (Figure 2.5). Water to the scheme is supplied by a diversion of the Dzindi River, a perennial river that flows south of Itsani village by means of a concrete weir (Figure 2.6). A primary concrete canal distributes the water to the four irrigation blocks and secondary concrete canals or furrows bring it to the farmers' plots. The distribution of furrows has been designed to allow water to enter the fields at regular intervals. In three of the four irrigation blocks, the main canal directly supplies the secondary distribution canals, which bring the irrigation water to plot edge. In Block 1, the canal supplies water to an earthen dam, from where it is transferred to the secondary canals and the plots. The plots are subdivided into a variable number of strips. The number of strips or beds per plot ranges between 10 and 36.

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[5] According to Giliomee (2003), the morgen is a Dutch land measure that was used in South Africa until the adoption of the metric system and more or less represented the area of land that could be ploughed during a morning. One morgen is equivalent to 0.8567 ha.

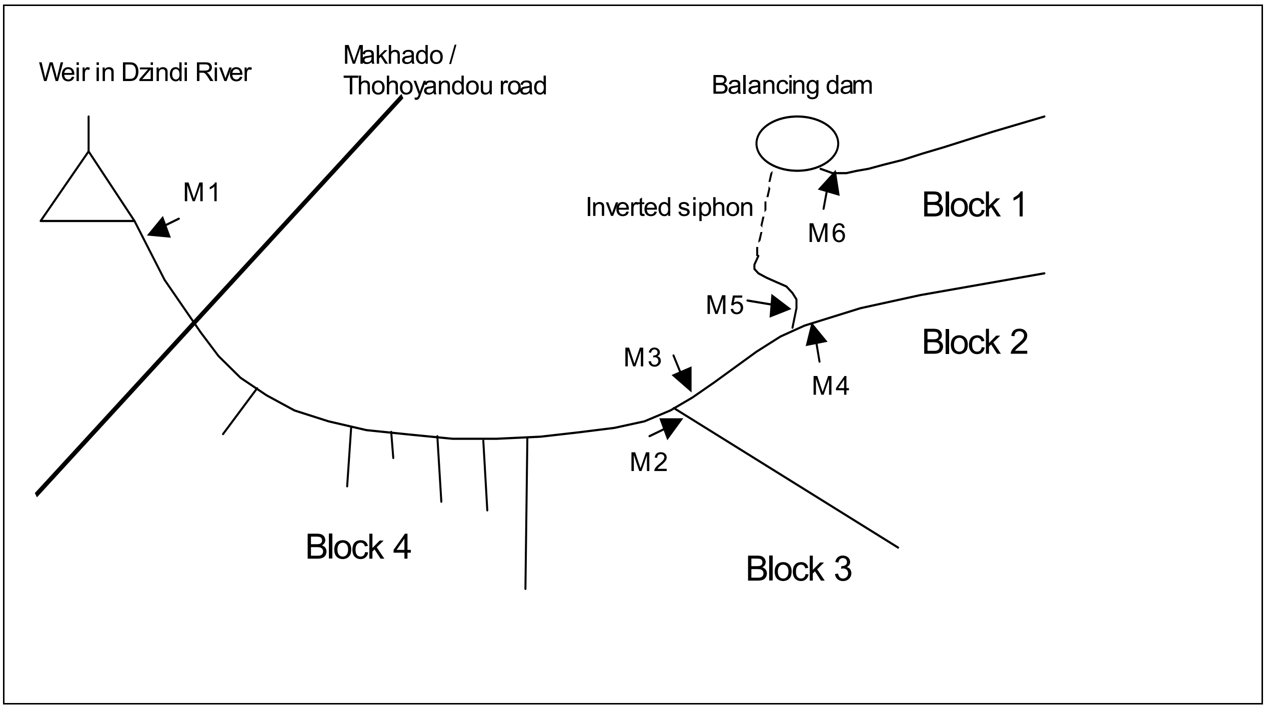

FIGURE 2.5: Layout of the water distribution network at Dzindi (from Van der Stoep and Nthai, 2005)

FIGURE 2.6: The concrete weir on the Dzindi River that diverts water to the Dzindi Irrigation Scheme

2.2.3.2 Evaluation of the water distribution system: The water distribution system at Dzindi was evaluated by Van der Stoep and Nthai (2005). Flow data were collected over a period of 45 days, from 15 October to 30 November 2004.

At the weir in the Dzindi River, water was continuously being diverted into the canal. At the inlet, the sluice used to adjust the rate of in-flow was no longer in place, preventing the regulation of the in-flow rate. The average inlet flow rate over the full period of measurement was 0.36 m^3 s^{-1} (1 296 m^3 hr^{-1}), but substantial fluctuations were recorded. These were ascribed to fluctuations in the flow depth upstream or downstream of the measuring structure, disturbances in the stilling basin (waves) and blockages at the canal inlet caused by plastic bags and other obstacles.

Table 2.2 shows that most of the water diverted into the canal at the weir was consumed between the weir and the off-take to Block 3. This consumption would have consisted of the water diverted into the secondary canals of block 4, which were not measured, as well as evaporation, seepage and spills along the canal sections. Of the total volume of water entering the main canal, 7% was diverted to Block 3, 26% to Block 2 and 7% to Block 1.

TABLE 2.2: Water allocation of recorded flows to the different system components of Dzindi Irrigation Scheme during the 45 day period of measurement (October-November 2004) (after Van der Stoep and Nthai, 2005)

Allocation	Inflow (m3)	Outflow (m3)	Outflow (%)	Area (ha)	Area (%)
Total volume abstracted at weir	1408213				
Volume consumed between weir and Block 3		756667	54	42.24	31
Volume abstracted for Block 3		102878	7	16.64	12
Volume consumed between Block 3 and Block 2		78747	6		
Volume abstracted for Block 2		371096	26	44.80	33
Volume abstracted for Block 1		98826	7	32.00	24
Total	1408213	1408213	100	135.68	100

When the sizes of the four blocks are considered, it is evident that the volumes abstracted for the different irrigation blocks were disproportional. Block 1 and Block 3 received much too little water relative to their contribution to the irrigated area. Proportionally, Block 2 also received somewhat too little water, whilst indications were that Block 4 received too much. This is indicated by the volume consumed between the weir and Block 3 (54% of the total volume), whereas Block 4 only contributes 31% to the total irrigated area.

Approximately 85% of the water diverted at the weir reached the secondary canals leading to the irrigated areas. The losses, therefore, were about 15% of the inflow. About two-thirds of the losses (9.5% of the inflow) resulted from evaporation and seepage, which left 5.5% unaccounted for.

The main losses of water occurred at block level. It was estimated that between 40 and 60% of the water that reached the secondary canals was not used for irrigation and consisted of return flow. Most of this water moved through the system at night.

The short furrow irrigation system that was evaluated had an application efficiency of 70.1% and a distribution uniformity of 66%. On average, 19 mm of water infiltrated the soil during an irrigation event.

The canal capacity makes it possible to abstract the equivalent of 22.9 mm per day gross application for the whole 136 ha. At a conveyance efficiency of 85% it means that the equivalent of 19.5 mm can reach the block off takes. If 50% of the water is then lost between the block off take and the field there should still be 9.7 mm per day for a farmer to divert into his plot, which when applied at an application efficiency of 70.1% results in an average application of 6.8 mm per day to the soil. At a distribution uniformity of 66%, this means that a minimum of 4.5 mm can be applied in all the beds, whilst SAPWAT estimates the peak daily reference evapotranspiration to be 4.9 mm in January (Van der Stoep and Nthai, 2005).This calculation is based on a 24 hour schedule and would be reduced to half if only daylight hours are considered.

2.2.3.3 Communication services: Communication services denote the means by which residents of an area communicate with the outside world. For farmers such services are important as they enable them to make arrangements with clients and suppliers without needing to travel. In Itsani, which incorporates Dzindi, there are no public fixed-line telephones but these are available in Shayandima. However, there are several public cellular phone operators at Itsani and one runs this business at the main gate of Dzindi. Several of the farmers have their own cellular phone. Farmers have access to mail and fax services at the post office in Shayandima, and Thohoyandou and residents of Itsani rent a post box.

2.2.3.4 Transport infrastructure and services: Many factors contribute to economic and social progress. Among these factors, mobility is especially important because the ingredients of a satisfactory life, from food and health to education and employment, are generally available only if there is adequate means of moving people and goods, which is referred to as transport (Hilling, 1996). In the study area the different means of transport available include busses, taxis, pickups and trucks. The main gate of the scheme is on the gravel road that connects Itsani to Shayandima Township. This road joins the tarred Main Street of Shayandima, which, in turn, links up with the R524 regional road. Public passenger transport in the form of taxis and buses operates daily between Itsani and Thohoyandou, via Shayandima. Busses and taxis to major urban centres such as Polokwane and Pretoria leave from Thohoyandou or Sibasa. The nearest railway station is located at Makhado. Farmers who want to rail their produce to the main markets in Gauteng have to transport it over a distance of 70 km to Makhado using trucks or pick-ups.

2.2.3.5 Financial services: It is widely accepted that access to financial services is important for economic development. The Land Bank is a financial institution that targets farmers, assisting them with loans for production or capitalisation purposes. However, very few if any farmers at Dzindi apply for these loans. The main factor appears to be distance, because the nearest Land bank branch is located in Polokwane, making it difficult for farmers to get to the Bank. At no stage did Dzindi plot holders express poor access to financial services to be a serious constraint. For regular banking services, farmers go to Thohoyandou. Banks with branches in Thohoyandou include First National Bank, Standard Bank, ABSA, Peoples Bank, and VBS Mutual Bank. In 2003 none of the plot holders at Dzindi reported to have borrowed money for farming purposes from any of these banks or any other financial institution that lends money to people.

2.2.3.6 Storage and processing facilities: Storage and processing facilities are important in agriculture. They help to prevent losses in case farmers are unable to sell or consume their produce immediately after harvesting. No central storage facilities are available at Dzindi. The store allocated to the co-operative was only used to hold inputs, such as chemical fertilisers. This theme will be revisited when the maize commodity chain is analysed and discussed.

2.2.3.7 Market infrastructure: Access to both input and produce markets is considered a critical factor in agricultural development. Farmers at Dzindi purchase their agricultural chemicals, fertilisers and seeds mainly at the Magnifisan Farms Community Shop in Muledane, which is situated between Shayandima and Thohoyandou. Dzindi farmers purchase and transport their inputs individually. In the past, farmers collaborated when purchasing inputs through a farmers' association, which they had created. This association purchased inputs in bulk and offered these for sale to farmers at favourable prices. Another advantage of buying as a group was that suppliers transported the goods to Dzindi free of charge.

The crops produced at Dzindi are mainly sold locally. In 2003, all winter vegetables were sold in Thohoyandou and surrounding suburbs. Usually vegetables are sold at plot edge. Besides people buying for own consumption there are hawkers who purchase vegetables at Dzindi to resell in Thohoyandou (Figure 2.7).

FIGURE 2.7: Hawker selling Chinese cabbage and Swiss chard produced at Dzindi

The majority of hawkers who purchase vegetables at Dzindi reside at Itsani and Muledane. Many use public transport to bring the vegetables to Thohoyandou where they retail them from small stalls. They are not allowed to bring more than one large bag (80 kg maize meal bag) of vegetables on board the bus or taxi. As a result, it is difficult for them to sell cabbages, because these are too bulky. Cabbages are bought and sold by a small group of better-off hawkers who own pick-up trucks.

Few farmers send produce to distant markets, such as Johannesburg and Pretoria. Accessing remote markets in the past was also limited to selected commodities, such as sweet potatoes and chillies. When using these markets, farmers had to get their produce to Levubu where long-distance transport for crops and vegetables called Landmann Transport (Ltd) is available. Besides transportation of fruit or vegetables to the fresh-produce markets in Pretoria or Johannesburg, Landmann also performs an agency function, which ensures that the consignment is received and paid for when it arrives at these markets. Whenever farmers made use of this marketing option, they had to enter into an agreement, which stipulated the costs of transport and handling of the produce. Once the consignment had been sold, the agent at the market divided the revenue among the three actors as per agreement.

2.2.3.8 Electricity: Energy is another important factor that affects both economic activity and quality of life. Of particular relevance in modern society is the availability of electricity. When this project started in 2003, Itsani and Dzindi did not have electricity, but during the course of the project the area was electrified. The purchase of refrigerators has enabled selected homesteads at Dzindi to preserve small quantities of fresh produce by cooling or in some instances by freezing.

2.2.3.9 Social infrastructure: In the category of social infrastructure, access to education and health rank as the most important indicator of quality of life. In Itsani village there is one crèche, one pre-school, two primary schools and one high school. Nearby tertiary educational institutions include the Venda University for Science and Technology in Thohoyandou, the Venda Nursing College in Tshisahulu and Techniven in Makwarela. People in Itsani obtain primary health care services in Shayandima Clinic. The nearest hospital is Tshilidzini Hospital, which is located in Tshisahulu. This hospital is situated about 10 km north of Itsani.

2.2.4 Organisational and institutional factors

On canal irrigation schemes farmers have to collaborate in order to manage certain essential activities, such as the sharing of water and the maintenance of infrastructure. Management of collaboration is achieved through the formation of an organisation. This organisation needs to be structured in order to establish a chain of command and reporting relationships, which are necessary to divide, coordinate and control the various tasks (Mullins, 1999; Robbins, 2001).

Since the establishment of Dzindi plot holders have been organised. The leadership of this organisation is in the hands of the Scheme Management Committee (SMC). The SMC consist of nine members who are all plot holders and who are elected by farmers. According to the constitution of this committee the term of office is three years. The SMC's written constitution outlines the committee's aims as; (a) to encourage and improve farming at the scheme; (b) to maintain and improve good relations with the government in addressing farmers' needs; (c) to promote commercial farming at the scheme; and (d) to encourage co-operation among farmers at the Scheme. The main functions of the committee as stipulated in the constitution are; (a) to employ and supervise two temporary workers, one helping at the demonstration plot and the other for fence repairs; (b) to announce dates and venues of meetings and to organise and control the farmers at Dzindi; and (c) to monitor the sharing of irrigation water with the assistance of the bailiffs and to impose fines on offenders.

Canal irrigation creates linkages among farmers because resources have to be shared. Resource sharing needs to occur with the aid of rules and conventions, which are collectively referred to as institutions (Bromley, 1982:3). Swift and Hamilton (2001), Hubbard (1997) and Eicher (1999) describe institutions the rules and regulations that govern individuals and groups in a community. Institutions provide the social rights and obligations and are closely connected to social capital. Institutions are normative systems of expectations, which may be powerful enough to impose conformity upon all members of a group or community. The research team identified three very important domains of collaboration among farmers on smallholder irrigation schemes. Sharing of irrigation water among farmers and maintenance of the irrigation infrastructure are two domains of collaboration that are particular to canal irrigation. Collaboration among farmers in relation to markets is a domain that is important to smallholder farming in general. Collaboration in these three domains is the topic of Chapter 6 of this report.

2.2.5 Human, social and economic factors

Early on the research team made the decision to adopt a livelihood approach to the analysis of the human, social and economic factors that prevailed at the study sites. Chapter 4 of this report presents the findings of the livelihood studies at the three schemes and no further attention is given to these factors here.

2.3 Khumbe and Rabali

The study of the situation at Khumbe and Rabali employed a rapid appraisal approach. This approach was selected because the time available to conduct the study was limited to one week at each scheme. Focus groups were the main data collection method. The choice of using focus groups to collect data suited the limited time that was available. For most purposes this participatory method proved appropriate, yielding relatively rich data that were cumulative and elaborative, since the discussions stimulated participants to jointly recall and reach consensus on issues and incidences. The style of facilitation kept the proceedings flexible, allowing participants to talk freely and explore the themes that were raised. On occasions the interactions resulted in the surfacing of important incidental data. Other methods that were used included a survey involving short structured interviews with individual farmers and field observations

2.3.1 Brief history of Khumbe and Rabali

The development of Khumbe Irrigation Scheme commenced around 1950 when tribal land of Chief Tshikhobokhobo was demarcated and prepared for establishment of the scheme. Khumbe was commissioned in 1952 and started with 55 plot holders. Subsequently, additional plots were allocated as households made applications. This process continued until all 224 plots had been assigned.

The process of establishing Rabali started more or less at the same time as at Khumbe. In 1950, a government representative approached Chief Ramabulana and local Chief Rabali and requested the tribal leaders to make available land for the purpose of an irrigation scheme. The Chiefs agreed, because they considered the proposed irrigation project to be of benefit to their people. An area of 87 ha situated along the Ndzhelele River was identified as suitable for project implementation by both the traditional leadership and the government officials. On parts of this land selected farmers already practised irrigation using earth furrows to channel water from the river to their lands. In 1951, the land was cleared and 68 plots were demarcated. At that time, the Rabali settlement counted 68 homesteads and each homestead received a plot that was held by means of the Permission to Occupy (PTO) certificate, which stipulated the conditions of land occupation. The scheme started functioning in 1952. Initially, plot holders planted wheat and peas in winter and maize in summer. In 1967 tomatoes replaced wheat and peas as the main winter crop. Later on, farmers introduced a wide range of vegetables for production during winter, but throughout the existence of the Scheme maize has remained the principal summer crop.

2.3.2 Physical factors

Enquiries were made with the Institute for Soil, Climate and Water of the Agricultural Research Council to obtain soil and climate data for Khumbe and Rabali. This Institute archives a large range of soil data that were collected during the 1950s, including soil data collected at Dzindi, consisting of a survey report and a map showing the soil units that were identified. Unfortunately, no information on Khumbe and Rabali was available at the Institute.

Physiographically, Khumbe is located on a gentle to moderate slope. The high-lying parts found in the north of the Scheme consist of red soils which are similar in appearance to those occurring at Dzindi. Lower down the colour of the topsoil changes to grey-brown and surface stoniness suggests that these soils are shallow. Towards the bottom of the Scheme evidence of water logging was observed in the form of sedge species. Generally the impression was gained that from a soils perspective there were considerable quality differences among the plots. In terms of climate Khumbe appeared to be very similar to Dzindi.

Rabali is located on a gently sloping terrace of the Ndzhelele River. On the opposite side of the Scheme is a steep, rocky hill. The terrace consists of sandy material of which the depth and sand content increases towards the River. In 2000, when the region was hit by a heavy storm, the Ndzhelele River changed its course and cut away the western bottom part of the Scheme land. Climatically, Rabali is situated in the dry Ndzhelele River Valley. The mountains to the south of the valley, which enjoy a high rainfall, create a rain shadow, which limits the amount of rain that falls in the Valley. Although the rainfall distribution at Rabali is probably similar to that at Dzindi and Khumbe, the amount is expected to be substantially lower. Reduced cloud cover during summer is also expected to raise potential evapotranspiration relative to Dzindi and Khumbe.

2.3.3 Infrastructural factors

Khumbe is a canal irrigation scheme that obtains its water from a weir (Figure 2.8) in the Dzondo River. Similar to Dzindi, the amount of water entering the Scheme at the weir (Figure 2.9) is sufficient only to permit farmers one day of irrigation per week.

There are two dams at Khumbe. The large dam (Figure 2.10) is about 2 km from the weir and is used to store water overnight, which is then released for irrigation into the main canal. The small dam situated just outside the command area is used on days when the main canal or the large reservoir need cleaning or repairs. Such operations demand the interruption of flow in the main canal. On these occasions the small dam is used to store irrigation water for use on the plots.

FIGURE 2.8: The Dzondo River near the Khumbe weir

FIGURE 2.9: The main concrete canal at Khumbe

FIGURE 2.10: The large reservoir at Khumbe

At establishment in 1952, Khumbe had a total command area of 145 ha grouped into four irrigation blocks. In 2005 only 132 plots, covering an area of about 86 ha, were functional. Deterioration of the conveyance system in the form of cracks in the secondary concrete furrows, and subsidence of parts of the main canal are factors that further limit the availability of irrigation water. This availability is worst during winter when the Dzondo River runs low. Farmers claim that in recent times water has become less available. They identified water extraction from the River above the weir for the irrigation of a state-owned orchard as the cause for the reduction in the flow of water that reaches the weir. Khumbe village has one primary school but no high school. For health services the community uses the clinics of Lwamondo and Hamutsha, which are located at a distance of 8 and 17 km from the village, respectively. There are a variety of churches for religious worship. The Rhema Ministry is the largest among them.

Rabali forms part of a complex of 16 smallholder irrigation schemes that draw their water from the Ndzhelele River. Rabali also obtains its water from a weir (Figure 2.11). Secondary concrete furrows convey water from the main canal to the plots (Figure 2.12). The weir and the conveyance system at Rabali were completely refurbished as part of a disaster relief programme following the 2000 floods.

FIGURE 2.11: The weir on the Ndzhelele River that supplies water to Rabali

FIGURE 2.12: Secondary canals convey the irrigation water to the plots at Rabali

When the scheme was established, Rabali was a small community of 67 households but since then it has grown substantially and now counts about 1200 households, primarily as a result of the immigration of people who left White commercial farms[6]. Reportedly, immigration started from the late nineteen-fifties and has continued ever since. Immigration has affected large parts of Ndzhelele River Valley turning it into a densely settled area.

Rabali has one primary school, but there is no high school. Rabali pupils attend secondary school in neighbouring settlements. The Rabali community also has no clinic of its own. The nearest clinic is 7 km away. Members of the community follow diverse religious pursuits. The largest denomination is said to be the Zion Christian Church (ZCC). The houses in Rabali are electrified. There is no land-line telephone system. Instead people make use of cellular phones for telecommunication. Rabali has a shed to store agricultural inputs, but this facility is no longer used.

2.3.4 Organisational and institutional factors

At Khumbe plot holders are organised in the same way as at Dzindi and the leadership of their organisation is also in the hands of the Scheme Management Committee (SMC). Khumbe plot holders elected their first Scheme Management Committee (SMC) in 1954, following a request for such an organization by the agricultural extension officer. This elected ten-member body has been in existence ever since. It consists of a chairperson, vice-chairperson, secretary, vice-secretary, treasurer, vice-treasurer and four additional members. Elections take place every five years and serving members are eligible for re-election. The SMC is the only committee at the

[6] Section 1.2.2 of this report provides background information

scheme. The main functions of the SMC are to organize collaboration and co-operation of plot holders, resolve conflicts, and to represent plot holders in the external world. The formal constitution detailing the composition and functions of the SMC was compiled in 1983.

Rabali Irrigation Scheme has had an elected Scheme Management Committee (SMC) since inception. The SMC consisted of seven members who were all plot holders. Elections were held every three years and the SMC was composed of the chairperson, vice-chairperson, secretary, deputy-secretary, treasurer and two additional members. This structure persisted until 1993, when staff of the Water Care Programme involved in rehabilitation work persuaded plot holders to assign portfolios to committee members, making them responsible for specific domains and functions. The revised organisational structure, which was still in place at the time of the fieldwork, is presented in Figure 2.13.

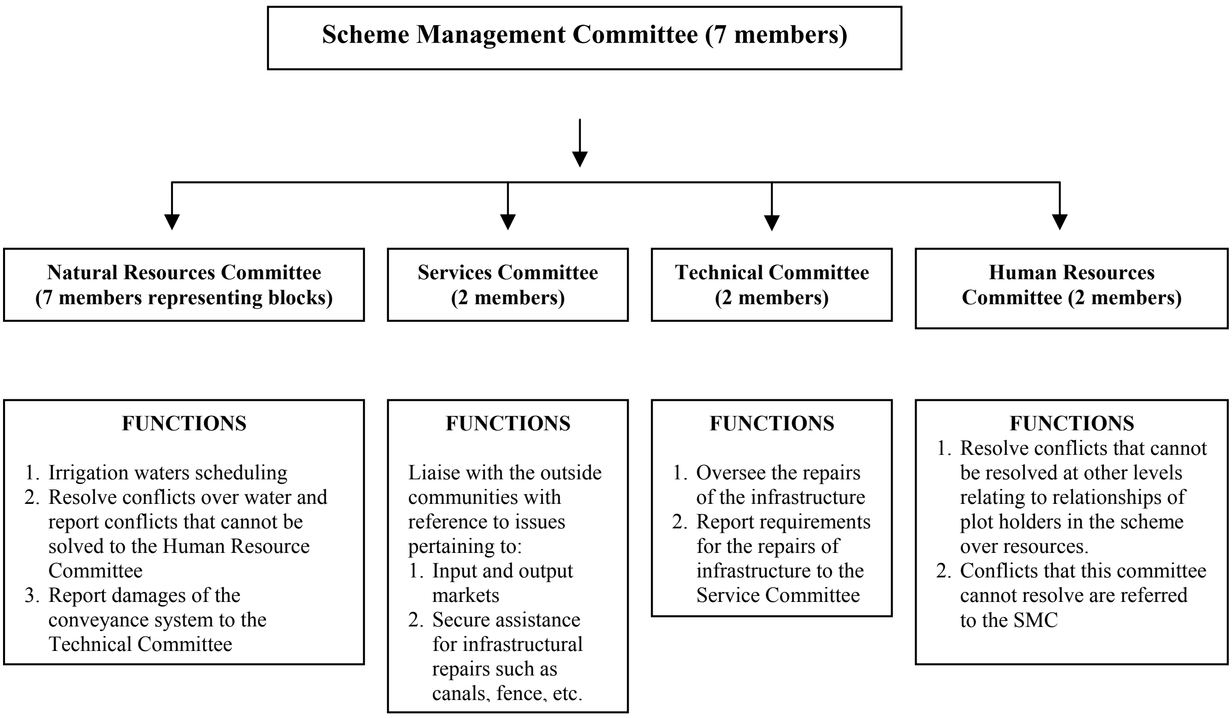

FIGURE 2.13: The composition and functions of the management structure at Rabali

2.4 Conclusions

Circumstances at the three smallholder irrigation schemes are fairly similar in terms of the general factors that affect livelihood and farming. All three schemes make use of an irrigation system that consists of a weir that diverts river water into a primary concrete canal, which conveys the water to secondary concrete canals or furrows that lead the water to the individual plots. All three schemes were established during the first half of the nineteen-fifties and are more or less similar in size and number of plot holders. At all three schemes plot holders are organised in a similar way and their organisation is lead by an elected body of plot holders. Legal ownership of all three schemes rests with the Limpopo Department of Agriculture and plot holders hold their land by means of Permission to Occupy certificates.[7]

There are also differences between the three schemes. The plot size at Khumbe (0.65 ha) is smaller than at Dzindi and Rabali (1.28 ha) and deterioration of the canals at Khumbe has reached the extent that part of the scheme has been decommissioned. At Rabali, on the other hand, the irrigation infrastructure has been partially refurbished following serious damage during the 2000 floods. Climatically, Khumbe and Dzindi are similar. Both receive a substantial amount of rainfall during summer and the associated cloud cover limits evaporative demand during that period. Rabali, on the other hand, is situated in a dry valley and receives less rainfall than Dzindi and Khumbe.
Generally, Dzindi appears to have better quality soils than Rabali and Khumbe. Three-quarters of the area under irrigation at Dzindi has good-quality soils. At Khumbe a major portion of the irrigated area has soils that were shallow or hydropmorphic. At Rabali the soils tend to be coarse in texture.

Circumstances at Dzindi are also superior in terms of market access. Dzindi borders the densely populated urban area of Thohoyandou and access to the market places in this town is convenient and relatively inexpensive. Rabali is also located in a densely populated area but is far from urban centres. The area around Khumbe is more sparsely populated, but being close to a regional road, access to urban centres is more convenient than in the case of Rabali.

In terms of social infrastructure, particularly access to education and health services, circumstances at Dzindi are also superior to those at Rabali and Khumbe.

Considering these differences it can be concluded that plot holders at Dzindi are probably in a better position to develop good-quality land-based livelihoods than their counterparts at Khumbe and Rabali.

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[7] Section 5.4 provides details on land tenure arrangements at the three schemes

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3 COMMODITY SYSTEMS

For applied research aimed at improving the production practices of farmers to be relevant and of practical value to farmers, it is important to first find out which crops they produce, why they grow these crops and how they produce them. This information can be obtained by identifying the different crops being grown during the different seasons and by analysing the chain of activities and transactions that occur during the process of producing, transforming, storing, transacting and consuming these crops.

3.1 Land use at Dzindi, Khumbe and Rabali

To identify the different crops being grown at Dzindi, a questionnaire survey was conducted during the initial stages of the project. Subsequently, regular surveys were done of the actual land use at different times during the year. These surveys involved the recording of the land use on each individual strip of land on all of the 105 plots being farmed at the scheme. Since the number of strips per plot differed among farmers, ranging from 10 to 34 strips per plot, the mean size per strip was calculated for each plot individually. This provided fairly accurate estimates of the area assigned to the different land uses. For each land use the total area was obtained by adding up the sizes allocated to that land use on the different plots. These totals were then converted to proportions of total scheme area by dividing them by the total irrigated area. Only land scheduled for irrigation was considered. Crops growing on the bunds, mostly sugar cane and in some cases bananas and mangoes, were also not taken into account.

Land use surveys were also conducted at Khumbe and Rabali during July 2005, but here differences in the size of the strips were not taking into account, meaning that proportional land use data were based solely on counting strips. The data obtained for these two schemes were also not based on a survey of all the plots. Instead a sample of plots was surveyed. In both cases the total area surveyed was about 30 ha. The results of the land use surveys are presented in Table 3.1.

At Dzindi there was substantial diversity in the crops being grown and land use changed with the seasons. Maize occupied the lion share of the area under cultivation during mid-summer (December) but pulses, particularly groundnuts, and pumpkins were also important. Vegetables featured most prominently during autumn and winter. Among these the African leafy vegetable species Chinese cabbage and night shade were very important as well as white cabbages. At any one time, a substantial proportion of the irrigated area was being fallowed. For the period for which data were collected, this proportion ranged between 22.9% and 61.3%. Fallowing tended to be least during mid-summer. It was 34% in December 2005 and 23 % in December 2006. During winter the proportion of land being fallowed ranged between 34% (August 2005) and 42% (June 2006). The area under fallow tended to peak during autumn (61% in March 2006 and 44% in March 2007), mostly because this is a transitional season. There was evidence that differences between years for particular seasons were associated with water availability. During 2006 water supply to the scheme was more abundant than during 2005, which was a particularly dry year.

TABLE 3.1: Land use at Dzindi, Khumbe and Rabali

	Dzindi							Khumbe	Rabali
Land use	**Aug-05**	**Dec-05**	**Mar-06**	**Jun-06**	**Aug-06**	**Dec-06**	**Mar-07**	Jul-05	Jul-05
	Proportion of total irrigated area (%)								
Fallow	**34.23**	**33.91**	**61.26**	**41.62**	**36.58**	**22.90**	**44.27**	**26.59**	**47.10**
Prepared	**23.52**	**8.66**	**16.06**	**27.74**	**32.33**	**11.73**	**23.06**	**11.87**	**17.20**
Maize	**22.70**	**47.37**	**13.65**	**2.12**	**8.65**	**58.60**	**6.98**	**9.42**	**7.00**
Wheat	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.30**
Indigenous leafy vegetables	**4.27**	**0.00**	**3.80**	**15.13**	**7.97**	**0.00**	**11.66**	**10.75**	**5.50**
Chinese cabbage	0.79	0.00	3.75	10.28	3.02	0.00	10.95	7.75	3.00
Nightshade	3.48	0.00	0.05	4.85	4.95	0.00	0.71	1.57	2.40
Kale	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.10
Exotic leafy vegetables	**6.55**	**0.16**	**2.30**	**8.88**	**8.92**	**1.05**	**5.98**	**2.06**	1.80
White cabbage	3.74	0.05	2.30	6.52	5.64	1.05	5.71	1.47	1.50
Swiss chard	2.85	0.11	0.00	2.36	3.28	0.00	0.27	0.59	0.30
Root and bulb crops	**2.95**	**1.28**	**0.99**	**2.25**	**2.13**	**1.19**	**3.06**	**15.66**	**2.30**
Sweet potatoes	1.53	1.11	0.99	1.75	0.77	0.81	2.98	7.46	0.60
Onions	1.42	0.00	0.00	0.40	1.22	0.00	0.08	7.75	1.60
Beetroot	0.00	0.05	0.00	0.10	0.15	0.24	0.00	0.22	0.10
Carrots	0.00	0.11	0.00	0.00	0.00	0.14	0.00	0.23	0.00
Vegetable fruits	**0.69**	**0.69**	**0.07**	**0.14**	**0.52**	**0.40**	**1.71**	**10.93**	**11.40**
Tomatoes	0.69	0.16	0.00	0.00	0.42	0.32	0.84	10.70	11.40
Green peppers	0.00	0.32	0.07	0.14	0.10	0.08	0.05	0.23	0.00
Chillies	0.00	0.21	0.00	0.00	0.00	0.00	0.82	0.00	0.00
Cucurbits	**3.35**	**3.75**	**0.25**	**0.00**	**0.41**	**1.40**	**0.02**	**2.06**	**0.30**
Pumpkins	3.35	3.54	0.18	0.00	0.11	0.37	0.02	1.86	0.00
Butternut	0.00	0.21	0.07	0.00	0.30	1.03	0.00	0.22	0.30
Pulses (fresh and dry)	**1.74**	**4.18**	**1.62**	**2.12**	**2.49**	**2.73**	**3.26**	**9.52**	**7.10**
Dry and green beans	1.32	0.16	0.49	1.81	2.22	0.00	2.31	5.79	6.80
Bambara groundnuts	0.00	0.11	0.24	0.00	0.00	0.00	0.19	0.00	0.00
Groundnuts	0.42	3.91	0.89	0.00	0.00	2.73	0.76	0.00	0.00
Peas	0.00	0.00	0.00	0.31	0.27	0.00	0.00	3.73	0.30
Perennial crops	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.08**	**0.00**
Bananas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00
Sugar cane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00

At Khumbe, where the plots were half the size of those at Dzindi, land was used more intensively during July 2005 than at Dzindi. There were also qualitative differences. Farmers at Khumbe tended to grow a wider variety of crops. As in the case of Dzindi indigenous leafy vegetables, particularly Chinese cabbage, were important. They covered about 11% of the irrigated area. Unlike at Dzindi, root and bulb crops, particularly onions and sweet potatoes, were important at Khumbe. They covered about 16% of the irrigated area at Khumbe, whilst at Dzindi they never exceeded 3%. There was also a major difference between the two schemes in the area planted to vegetable fruits, particularly tomatoes. At Dzindi, the proportion planted to vegetable fruits remained below 2% throughout the monitoring period, whilst at Khumbe 11% of the irrigated area was planted to these crops during July 2005. The area planted to pulses, particularly beans and peas, was also higher at Khumbe (9.5%) than at Dzindi, where it remained below 5% throughout the monitoring period. On the other hand, cabbages were relatively rare at Khumbe (1.5% of the irrigated area) whereas at Dzindi this crop occupied between 3.7% and 6.5% of the irrigated area during winter. Khumbe was also the only scheme where some of the scheduled land was planted to perennial crops (bananas and sugar cane). At Dzindi sugar cane was only grown on the bunds separating the strips and on non-scheduled land adjacent to some of the plots, which farmers had taken into production.

At Rabali, where the plot size was the same as at Dzindi, the intensity of land use was least of all three schemes during the 2005 winter. The main difference between Rabali and the other two schemes was the importance of tomatoes, which covered almost 11% of the irrigated area. As at Khumbe, beans were also an important crop.

The observed differences in land use between the three schemes suggested that farmers have adapted land use to the prevailing conditions at their schemes. The importance of tomatoes at Rabali was thought to be partially due to the dry conditions that prevail, limiting the incidence of fungal diseases and partially because of the history of the scheme, because for a long time Rabali farmers produced tomatoes for a canning factory. Dzindi farmers, on the other hand, have had bad experiences with tomato production[8] and this could explain why this crop hardly features at Dzindi. The wide diversity of crops found on the individual plots at Khumbe appeared to be associated with the prevailing objective of farming at that scheme, which was to produce food for own consumption. The relatively small size of the plots at that scheme was seen as one of the reasons why land at Khumbe was used more intensively than at Rabali and Dzindi during the winter of 2005.

Dzindi being the primary study site, the decision was made to focus on those crops that prevailed at that scheme, namely maize and leafy vegetables, including white cabbages. In the following sections the commodity system of these crops is described and analysed.

[8] Section 2.2.2 provides details of the experiences of Dzindi farmers with tomato production.

3.2 Important commodity systems at Dzindi

3.2.1 Theoretical framework

Farming involves more than just production. It also concerns storage, and when crops are sold, the social process of transactions features prominently. The study of such a system is complex. The filière approach, illustrated in Figure 3.1, can be used to develop detailed knowledge on the way agricultural commodities are produced, stored, transformed, transacted and consumed in a particular locality or region (Leplaideur, 1994 and Moustier *et al*., 1997).

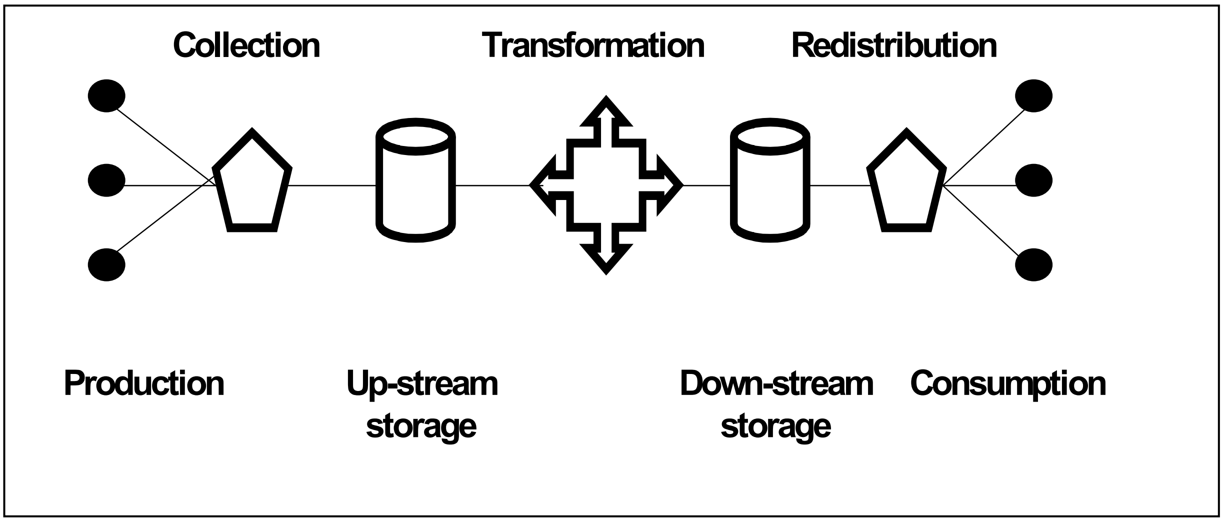

FIGURE 3.1: Analytical framework used in the study of a filière (after Leplaideur, 1994)

To guide the study of indigenous knowledge that surrounds existing economic activity in a smallholder setting the general analytical framework used in the filière approach was adapted. The adapted framework, called the Triple-A framework (Van Averbeke and Khosa, 2004) is presented in Figure 3.2.

In the Triple-A framework the people or agencies involved in a smallholder food commodity chain are referred to as actors, what they do as activities, and what they use in the conduct of their activities as artefacts. These three elements constitute the core of an indigenous knowledge system that is applied in a smallholder commodity chain. Indigenous knowledge resides within the actors. Through experimentation actors in a commodity chain develop, adopt or adapt material and social technology that suits a particular set of circumstances. Since this technology is a human creation, it can be said to consist of artefacts. Usually the term artefact refers to a material object, but for the purpose of this study the concept was expanded to include both tangible and intangible creations of people, and included crops and their particular varieties, equipment and materials, techniques and institutional arrangements. These artefacts are employed in the various activities that make a food commodity chain, i.e. production, collection, up-stream storage, transformation, down-stream storage, redistribution and consumption.

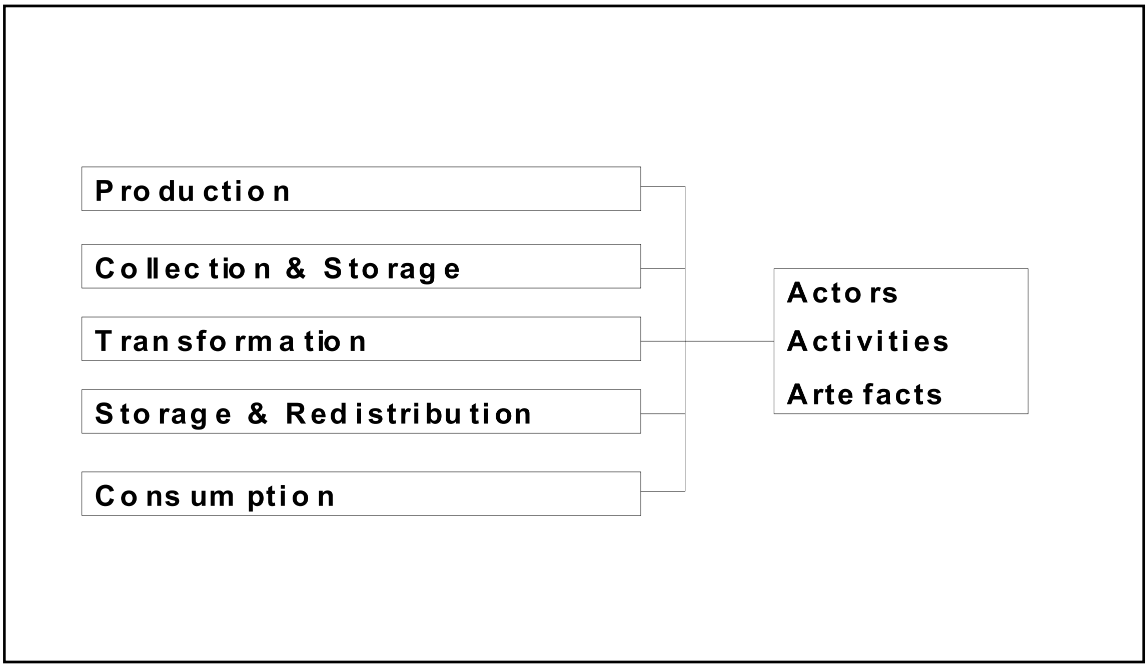

FIGURE 3.2: The Triple-A framework for the analysis of rural people's knowledge related to food commodities

3.2.2 Research methods

The objectives of this study were to investigate and characterize the important commodity chains at Dzindi and to identify possible components in these chains that could be subject to improvement through participatory adaptive research and development interventions as required by the terms of reference of this project. Two commodity chains were selected for investigation, namely maize and leafy vegetables. The study of these commodity chains involved three methods of data collection. The results of a situation analysis at Dzindi conducted during 2002 and documented by Van Averbeke *et al*. (2004) were used to develop an instrument for use in a survey of plot holders at the scheme to obtain data on the production component of the crops involved. The survey was conducted during July and August 2003 and involved face-to-face interviews with a probability sample of plot holders at Dzindi. Data on production covered the entire process, from acquiring of seed until harvest of the crop, including yield estimates. Data on the collection of the crops were also obtained during the survey of plot holders and covered allocation of produce to sales, home consumption and transformation. In each case the structured interview with plot holders was followed by a visit to the farmer's plot in the presence of the respondent. At the plots, farmers were requested to demonstrate selected production practices, including how the different vegetables were planted and spaced, and how fertilisers were applied quantitatively, enabling the determination of the rates of nutrient application they used. The field visits were also used to obtain photographic evidence of activities and artefacts. The second method was used to obtain information from people who purchased produce from farmers and took care of retail to consumers, and from people who transformed the crops. Semi-structured interviews with purposely selected informants (actors) involved in these activities were used to obtain the information. As in the case of plot holders, photographic evidence was collected of the actors, and their activities and artefacts. The last method involved a presentation of the findings to a general meeting of plot holders. The meeting was attended by 63 (61%) of the 102 plot holders. The purpose of the presentation was to verify the trustworthiness of the results, and to obtain additional explanations for the observed phenomena.

The survey covering the maize commodity chain at Dzindi involved a probability sample of 21 farmers (20% sampling fraction) and enquired about maize production during the 2001/02 production season.

The survey covering the leafy vegetable commodity chain involved a probability sample of 34 farmers (33% sampling fraction) and enquired about vegetable production during the winter of 2003.

3.2.3 The maize commodity chain at Dzindi

3.2.3.1 Description: During the 2001/02 summer, maize covered about 95% of the cropped area, which amounted to 60% of the total irrigated surface. This was not out of line with the land use data presented in Table 3.1, considering that maize at Dzindi is planted over a long period even though most maize is grown during mid-summer. In Table 3.2 information on area planted to maize, planting density, rate of nutrient application and grain yield is presented.

TABLE 3.2: Area planted to maize, planting density and rate of nutrient application used, and grain yield obtained by farmers at Dzindi (n = 21; 2001/02 season)

Variable	Mean	Median	Range	Standard deviation
Net area planted (ha)	0.56	0.48	0.16 - 9.6	0.24
Planting density (plants m^{-2})	4.64	3.34	3.34 – 6.67	1.58
N supply (kg ha^{-1})	81.8	85.8	6.4 – 205.8	53.0
P supply (kg ha^{-1})	26.2	23.5	6.4 – 88.7	18.5
K supply (kg ha^{-1})	14.9	14.2	4.3 – 37.8	8.2
Grain yield (kg ha^{-1})	2649	2112	910 - 4984	1230

On average, farmers planted a net area of a little more than 0.5 ha to maize and obtained a mean grain yield of about 2.6 tons ha^{-1}. This provided them with a harvest of about 1.5 tons of grain on average. The planting density used varied relatively little, with most farmers employing a density of 3.34 plants m^{-2}. Application rates of NPK fertilisers varied considerably and the mean was high for the yields that were obtained, especially for P. Statistically, grain yield was positively correlated with application rate of N ($r = 0.61^{**}$), application rate of K ($r = 0.60^{**}$) and planting density ($r = 0.44^{*}$), but not with application rate of P ($r = 0.30$). Farmers produced maize using a combination of modern and traditional technology (Table 3.3).

TABLE 3.3: Activities, artefacts and actors featuring in the production, collection, storage, transformation and transaction of maize grown at Dzindi

Activity	Artefact	Actor
Land preparation		
➢ Primary cultivation	Tractor or cattle and mouldboard plough.	Tractor operator employed by the farmer collective and private operators. A singl farmer prepared his land using animal draught.
➢ Disking	Tractor and disk.	
➢ Ridging	Tractor or cattle and ridger, hand hoe.	A minority of farmers ridge by hand.
Planting	95 % hybrid seed (primarily SNK2147) and 5 % ope pollinated farmer selection.	Hybrid seed supplied by Magnifisan Community Shop. Farmers or farm worker plant by hand
Nutrient application	NPK-mixture at planting and LAN side dressing Cattle manure and broiler litter.	Chemical fertilisers supplied by Magnifisan Community Shop. Broiler manure supplied by local commercial poultry units, and cattle manure b smallholders in surrounding areas. Farmers or farm workers apply fertilisers by hand.
Irrigation	Short-furrow irrigation without exception.	Farmers or farm workers irrigate the plots
Plant pest control	Ground maize grain without poison is used as bait fo rodents and cutworm. Granular dipterex is used agains maize stalk borer.	Farmers prepare bait. Magnifisan Community Shop supplies dipterex. Farmers or farm workers apply bait and dipterex by hand.
Weed control	Hand hoe.	Farmers or farm workers control weeds by hand.
Harvesting	None.	Hawkers harvest green maize for retail purposes Farmers or farm workers harvest mature cobs
Transportation	Bags, wheelbarrows and occasionally small trucks.	Hawkers carry green maize in bags and board public transport. Farmers or farm workers bag de-husked mature cobs and bring the bags home fo further drying.
Shelling	Stones	Women and children shell the cobs and winnow the grain.
Storage	On-farm store rooms, bags, phostoxin tablets to contro weevils. Off-farm storage in grain silo.	Farmers. Magnifisan Milling Company in Shayandima.
Transformation	Small-scale grain mills employing two-step process. Large-scale grain mill employing integrated process.	Small-scale grain mill operators (grinding and milling) and women (washing an soaking of cracked grain). Magnifisan Milling Company.

Modern technology in maize production at Dzindi included the use of hybrid seed, mono-cropping, relatively high planting densities, mechanical land preparation and the application of chemical fertilisers and registered pesticides to protect the plants. Traditional technology included the use of animal manures (limited), short-furrow irrigation, the control of weeds by hand-hoeing, open-pollinated varieties and harvesting by hand.

Figure 3.3 shows that on a mass basis, nearly 85% of the maize produced during the 2001/02 season at Dzindi was grown for grain and the rest was harvested as green cobs but in monetary terms the maize harvested as green cobs contributed more than 40% to the gross value of maize production. The results show that grain production for transformation into maize meal for homestead consumption was important for farmers at Dzindi. Two ways of storing and transforming maize grain were used, namely off-farm storage and transformation using the facilities and services provided by the commercial mill in Muledane and on-farm storage and transformation using small-scale milling facilities around the scheme. About 30% of total maize production was sold or given away as grain.

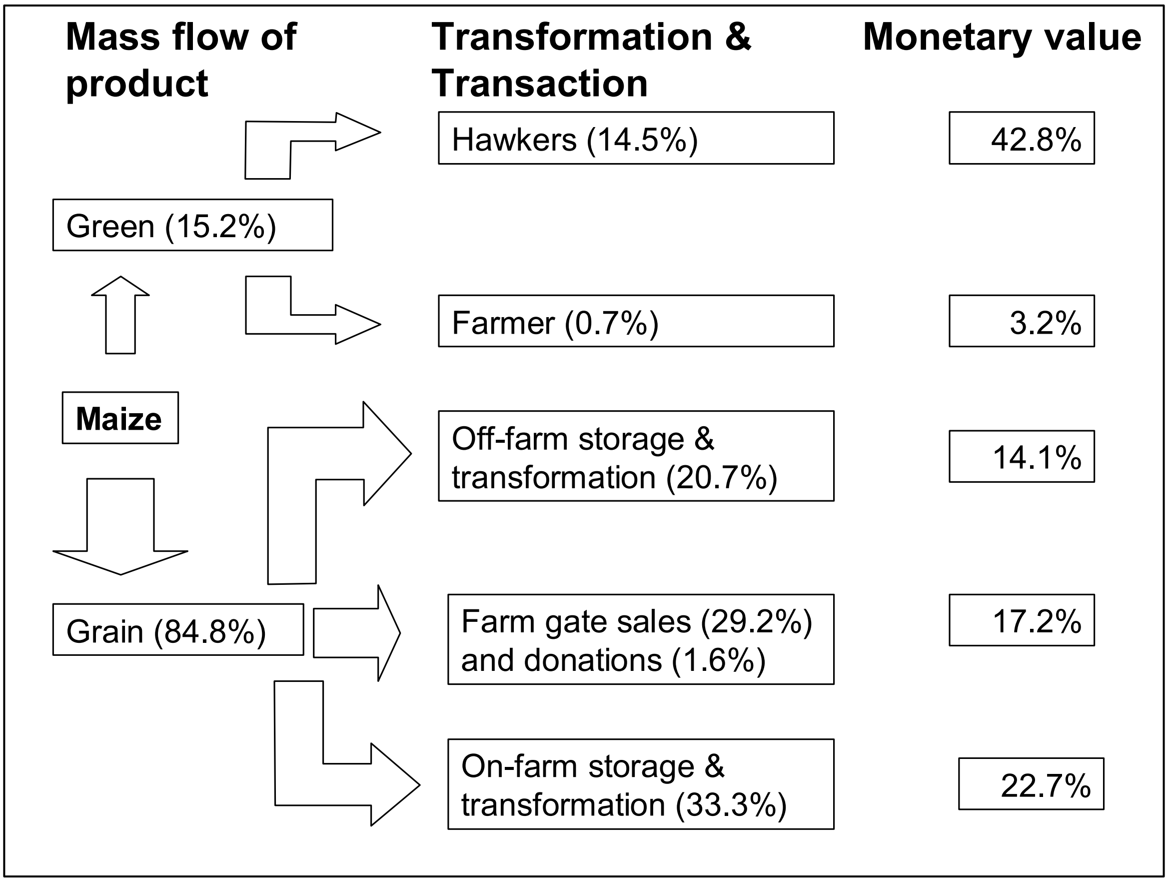

FIGURE 3.3: Allocation and transformation of maize produced at Dzindi

When grain was stored on-farm, it was milled in small quantities as the need for maize meal occurred. Typically homesteads brought a single bag containing 25 to 50 kg grain to one of the two privately-owned, small-scale grain mills operating in the vicinity of Dzindi (Figure 3.4), where milling involved two separate processes. The first consisted of a coarse grind, during which the grain was broken into small particles and the bran was removed. At the time of the study, the mills charged R6.00 per 25 kg grain for this service. Typically, the coarse-ground grain was returned home where it was rinsed in water to remove any remaining bran and foreign particles and to allow the grain to absorb water. The grain was then partially dried in a bag overnight and returned to the mill the next day for milling into meal. The mills charged R4.00 per 25 kg batch for the milling. Important is that both mills offered a delivery service. Upon prior arrangement they collected clients and their grain from their residences with a small truck, and brought them home. At the time of the study, the small-scale mills charged a fee of R2.00 per 25 kg processed grain for this service.

FIGURE 3.4: One of the small-scale maize mills near Dzindi where maize grain

Storing and transforming the grain at the industrial Magnifisan mill in neighbouring Muledane (Figure 3.5) was subject to restrictions. The Magnifisan mill only accepted white maize grain that met national quality norms. The mass of the delivered grain was determined on a weighing bridge and farmers were issued a credit note, which they were able to exchange for maize meal whenever they wanted. The exchange system was based on equivalent mass, i.e. delivery of a particular mass of grain gave right to the same mass of maize meal. The mill was compensated for storage and processing by charging farmers a fee of R65 per bag of meal. The mill also derived income from the difference in moisture content between meal and grain. During the processing of maize grain into meal, the grain was immersed in a water bath to absorb moisture. As a result, 80 kg of grain produced more than 80 kg of meal. Furthermore, the mill generated income from the sale of bran, which was separated and removed from the grain during the transformation process.

FIGURE 3.5: The industrial (Magnifisan) maize storage and transformation centre in Muledane

Maize was also consumed and sold as green cobs. Home consumption of green maize by farmers was limited, but it was the main way in which the crop was turned into cash (Figure 3.3). On a mass basis, 43.7% of the total crop was sold, about one-third as green cobs and two-thirds as grain. However, the third that was sold as green cobs generated about two-thirds of the cash income generated from maize sales.

Hawkers, who cooked the cobs and offered them for sale on markets in the Thohoyandou area, controlled the green maize trade. They regularly visited the plots in search of merchandise. Farmers wanting to sell green maize informed hawkers of the date when one or more of their beds would be opened for green maize collection. On the set day, hawkers selected and harvested the cobs that met their quality requirements. The important criteria used for selection were size of the cobs, uniformity of grain filling, and the absence of damage by pests. They left the cobs that did not meet their requirements on the plants for farmers to harvest as grain. Harvest of green cobs in a designated area was completed within one or two days.

The analysis of the variable costs in maize production at Dzindi is presented in Table 3.4.

TABLE 3.4: Mean variable costs in maize production at Dzindi (2001/02, n = 21)

Variable cost	Number of farmers incurring cost	Mean cost (all 21 farmers)	Proportional contribution to total variable costs (including labour)	Proportional contribution to total variable costs (excluding labour)
		(R ha^{-1})	(%)	(%)
Soil preparation	20	414.20	16.2	22.5
Seed	20	178.57	7.0	9.7
Fertilisers	21	1137.24	44.6	61.9
Plant protection	19	108.10	4.2	5.9
Full-time labour	4	622.86	24.4	-
Part-time labour	6	88.57	3.6	-
TOTAL	-	2549.52	100	100

The results in Table 3.4 clearly demonstrate the important contribution fertilisers made to the variable costs in maize production at Dzindi, especially when the cost of labour was excluded. The use of labour, particularly full-time labour, was limited to a minority of farmers and was linked to a particular farming style, as is explained in more detail in Chapter 4 of this report.

The gross margins above variable costs of the 21 maize enterprises that were studied are illustrated in Figure 3.6.

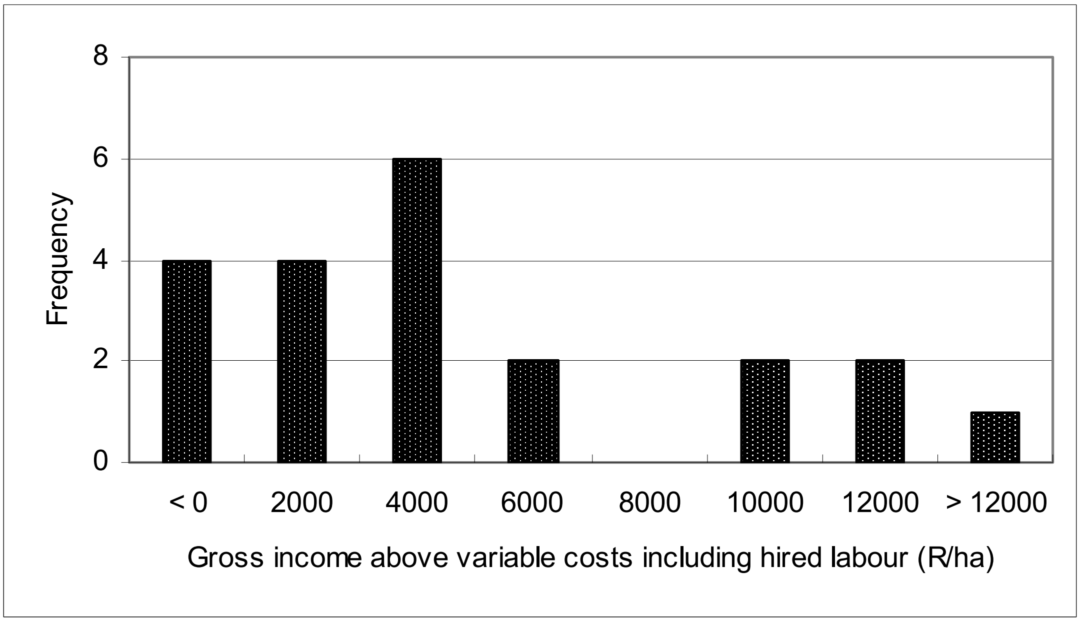

FIGURE 3.6: Gross margin above variable costs of maize enterprises at Dzindi including cost of hired labour (2001/02; n = 21)

In Figure 3.6, gross margins are expressed on a unit area (ha) basis to allow comparison among enterprises. The frequency of gross margins of the 21 enterprises was not normally distributed. When the cost of hired labour was included, three frequency peaks were identified. One peak, situated on the extreme left of the graph, represented farmers who had maize enterprises with a negative gross margin. For three of the four farmers in this category the high cost of hiring a full-time farm worker was the cause of the negative gross margins (–R1793 ha^{-1}, -R3139 ha^{-1} and –R25 369 ha^{-1}) they obtained. The second peak was situated between the gross margin limits of R2000 and R6000 ha^{-1} (Figure 3.6). The mean gross margin of this group of 12 maize enterprises (60% of total) was R2683 ha^{-1}. The third peak occurred on the right of the graph at gross margins in excess of R8000 ha^{-1} (Figure 3.6). The mean gross margin of this group of five maize enterprises (24% of total) was R10 576 ha^{-1}. The overall mean gross margin above variable costs was R2568 ha^{-1}.

Removing the cost of hired labour from total variable costs (Figure 3.7) resulted in all but one maize enterprise returning positive gross margins and caused the three peaks observed in Figure 3.6 to be reduced to two.

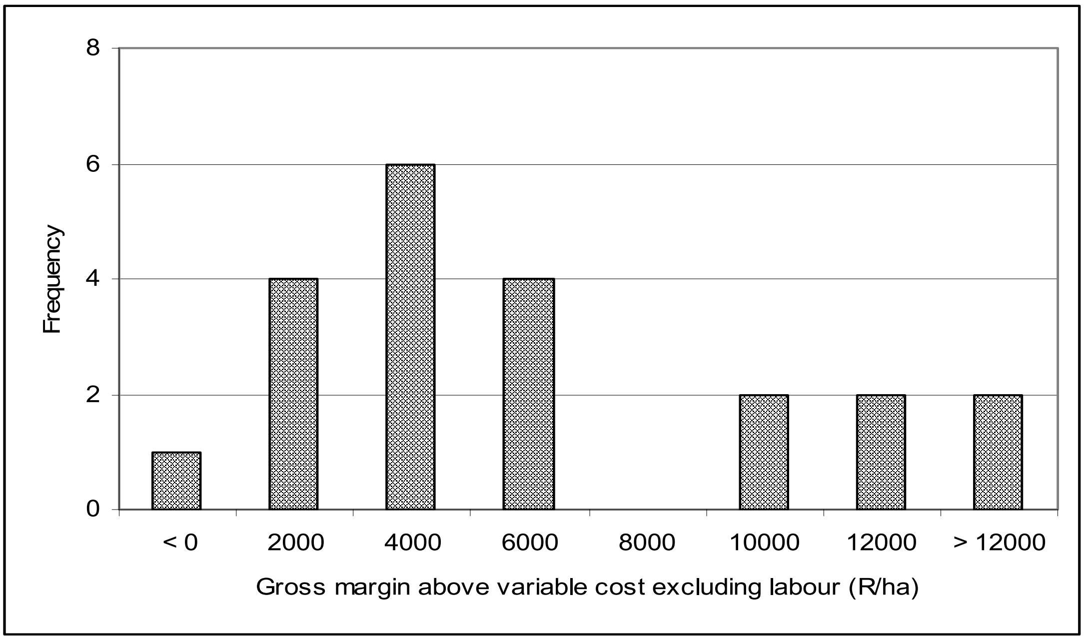

FIGURE 3.7: Gross margin above variable costs of maize enterprises at Dzindi excluding cost of hired labour (2001/02; n = 21)

The variability in the gross margin above variable costs excluding hired labour among the 21 maize enterprises was to a large extent associated with the proportion of plants that were sold as green cobs, as is shown in Figure 3.8.

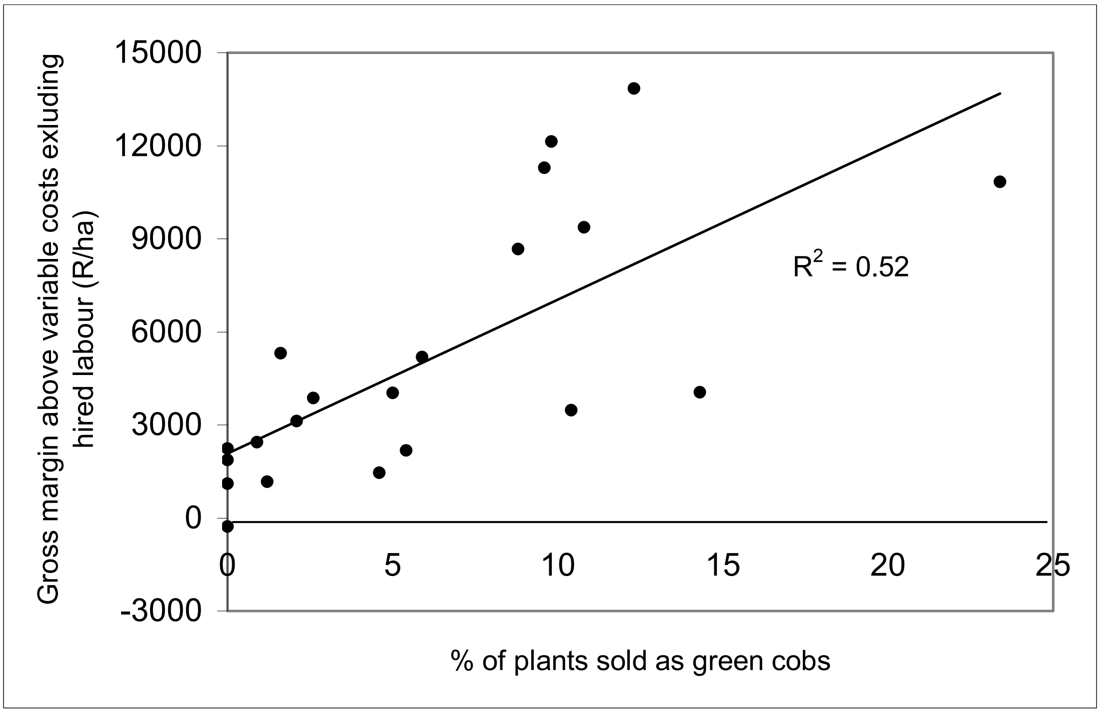

FIGURE 3.8: Relationship between gross margin above variable costs excluding hired labour of maize enterprises at Dzindi and the proportion of plants that were sold as green cobs (2001/02; n = 21)

One reason why some farmers did not sell maize green and use the income earned to purchase grain was that they rated their own maize meal as better-tasting and longer-lasting (more meals per unit quantity of meal) than the commercial alternative. Another reason for not exploiting the market for green maize more widely was that hawkers controlled the green maize market, with quality being a key concern. This meant that crop husbandry co-determined the proportion of maize plants with cobs that met the requirements of hawkers. A correlation analysis showed that this proportion was positively correlated with the application rates of N (r = 0.72**), K (r = 0.61**) and P (r = 0.53*), but not with planting date (r = 0.38), expenditure on plant-pest control per plant (r = 0.07) and planting density (r = -0.04).

To an extent, producing maize for harvesting as green cobs has agronomic requirements that differ from those that apply when growing the crop for grain. Planting density is a key factor, because it affects grain yield per plant (Van Averbeke and Marais, 1992; 1994), which is correlated with cob size. As planting density is increased above a certain level, which is a function of the combination of growth factors, yield per plant and cob size are reduced. Since hawkers use cob size as one of the main criteria for the selection of green cobs, farmers seeking to sell maize green are expected to benefit from adjusting their practices, especially planting density, to maximise the number of plants per unit area that produce cobs that make the size grade.

3.2.3.2 Conclusions: The results of the study of the maize commodity chain showed that under certain circumstances maize can simultaneously serve as a high-value cash crop and as a food crop in smallholder agriculture. At Dzindi these circumstances were present. The close proximity of the local urban centre of Thohoyandou ensured the availability of a sizeable market for green maize cobs. Sites of production located close to major roads offer similar opportunities (Khuvutlu and Laker, 1993). The use of maize for the purpose of green maize sales was closely associated with smallholders obtaining high gross margins in maize production. Hawkers, to whom most green maize produced at Dzindi was sold, applied quality control measures, thus limiting the proportion of cobs being collected for sale. Plants with cobs that did not make their quality standards were left in the field for farmers to harvest as grain at maturity.

The importance Dzindi farmers attached to the role of maize grain in the food security of their households was re-enforced by the availability of two storage and transformation systems, which enabled farmers to process their grain into maize meal for consumption. The proximity to Dzindi of an industrial mill where grain could be exchanged for meal using a system of credits, which permitted long-term storage of grain for emergencies, was coincidental. The supply of maize by Dzindi farmers to the industrial mill, which sources its grain mainly from producers in the maize quadrangle, was of no consequence to the turn-over of the mill. The presence of two small-scale, privately-owned grain mills at Itsani, of which Dzindi is part, was not coincidental. These small mills appeared to generate sufficient business from the presence of irrigated maize grain production at the scheme and dryland production in the surrounds. A third, identical mill operated within a distance of 5 km from Dzindi, confirming the ability of these enterprises to survive financially from transforming smallholder produce. This observation is important for smallholder maize production areas where the post-production component of the maize filière is poorly developed, such as the maize belt in the Mbashe Local Municipality of the Eastern Cape (ISER, 2001). The importance of local small-scale mills in smallholder maize production was also pointed out in the work of Eskom in Bizana in the Eastern Cape (Eskom, 2007).

Maize production practices at Dzindi appeared to address the key growth requirements of the crop, using both modern and traditional technology, but the relatively low yields, equivalent to about 2.5 tons grain ha^{-1} on average, suggested room for improvement. High gross margins were related positively with a large proportion of the available plants on a farm being harvested for green cobs. In turn, this proportion was positively related to the rate of N, P and K applications used. Other factors, such as planting date and especially planting density, which is known to influence degree of plant barrenness, ear-filling and number of grains per cob, were not correlated significantly with the proportion of plants being harvested for green cobs.

The results obtained in this study indicate that smallholders at Dzindi can obtain high gross margins from maize when the crop is sold green but unlike with many other crops, the portion of the crop that does not find a market is not wasted. Leaving the plants to complete their life cycle produces a valued food in the form of maize grain. Among many plot holders, holding substantial amounts of maize in storage is an important component of achieving household food security. The association between maize grain in storage and household food security was strengthened further by the availability of the necessary infrastructure to transform the grain into the desired products for consumption. For this reason, attempts to replace maize with other crops on smallholder irrigation schemes where circumstances are similar to Dzindi are likely to meet with resistance from farmers.

The findings of the analysis of the maize filière at Dzindi resulted in the decision at a general meeting of farmers and representatives of the team in January 2005 to develop a technology package aimed at optimizing green maize production at Dzindi. Details on this initiative and the findings obtained to date are presented in Chapter 9 of this report.

3.2.4 Leafy vegetable commodity chains at Dzindi

3.2.4.1 Description: During the winter of 2003, the 34 farmers that were sampled cropped a total combined net area of 10.24 ha to four vegetables. Two traditional leafy vegetables, namely Chinese cabbage (*Brassica rapa* subsp. *chinensis*), called *mutshaina* in Tshivenda and nightshade (*Solanum retroflexum* Dun.), called *muxe* in Tshivenda, were the most important. The two other vegetables were Swiss chard (*Beta vulgaris* L.) and white cabbage (*Brassica oleracea* L. var. *capitata*). The relative area occupied by each of these four vegetables during the winter of 2003 is shown in Figure 3.9 and the frequency of farmers planting each of the four crops in Figure 4.10.

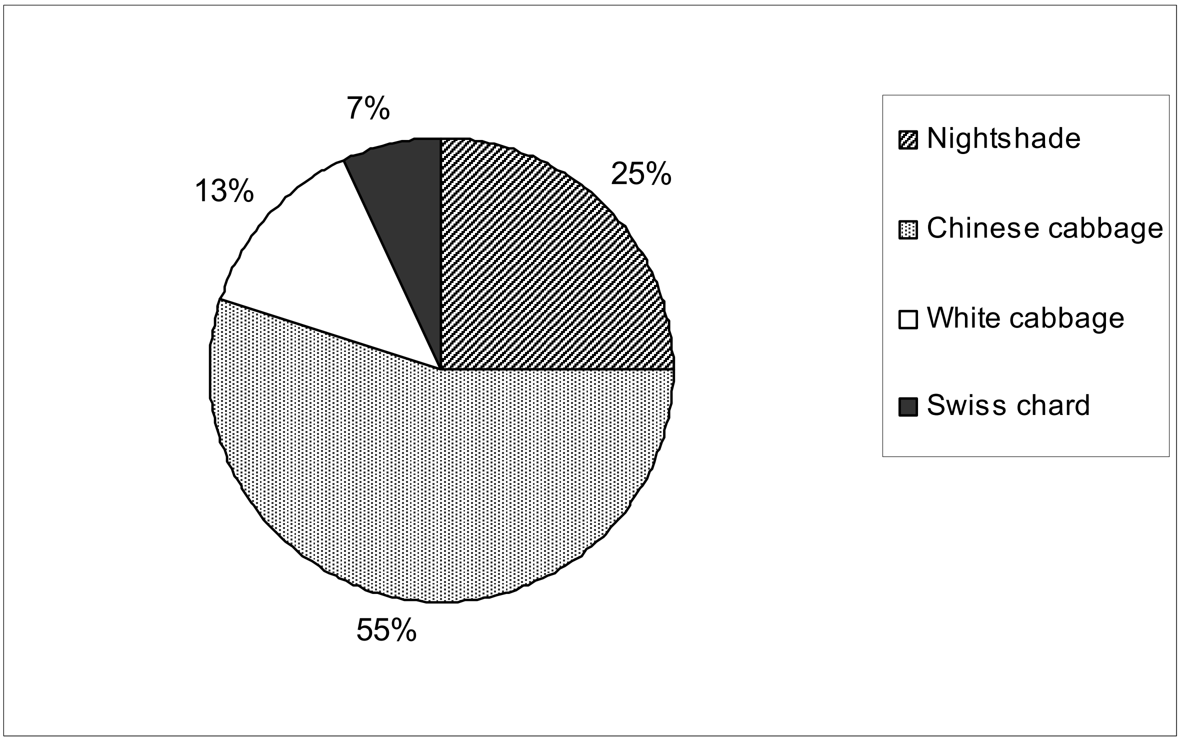

FIGURE 3.9: Relative importance of four types of vegetables at Dzindi in terms of area planted (data show the proportion of the total area planted to the four vegetables to each of the four crops) (n = 34; 2003)

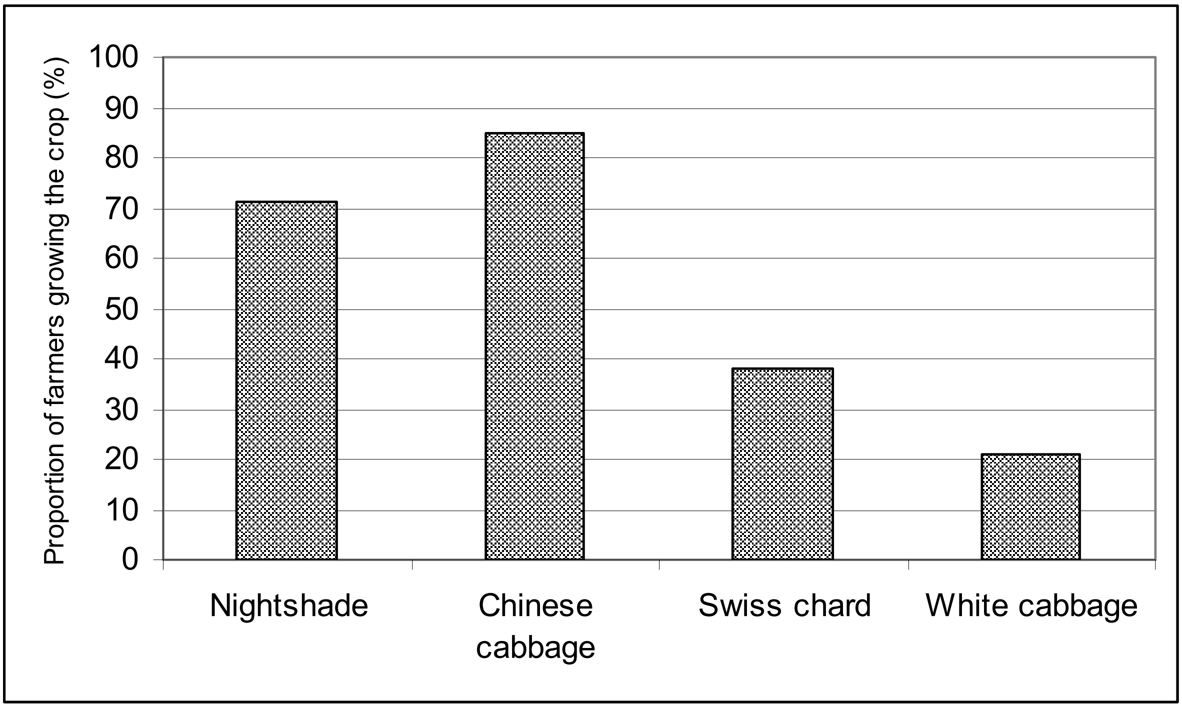

FIGURE 3.10: Proportion of farmers planting each of the four species of vegetables at Dzindi (n = 34, 2003)

The total cropped area represented 29.4% of the total net area available to the 34 farmers combined. This was higher than the proportion of the area planted to these crops recorded by means of the land use surveys (Table 3.1) in August 2005 (10.8%), June 2006 (24.0%) and August 2006 (16.9%). The observed difference is partly due to the difference in the method of data collection. The 2003 farmer survey data covered the entire winter season, whilst the land use data presented in Table 3.1 were momentary recordings of what was growing in the lands.

For all four vegetables land preparation was done mechanically and consisted of ploughing, disking and ridging, followed by the construction of short furrows using a hand hoe to enable irrigation. Farmers accessed tractors in two ways. A minority (12%) hired a private contractor, whilst the majority (88%) used the tractor belonging to the Dzindi farmer collective. Private contractors were about 30% more expensive than the Scheme tractor, but they supplied their services at short notice, whilst the Scheme tractor had a long waiting list, which interfered with optimum planting date.

In the case of nightshade and Chinese cabbage, all but one farmer selected and used their own seed and all but one farmer, who used direct seeding, prepared transplants in specially prepared seedbeds enriched with both organic and chemical fertilisers at the edge of their plots. Seed of these two traditional vegetables was not available commercially, but could be purchased from farmers. Producers of Swiss chard purchased commercially available seed and prepared seedlings in the same way as for the two traditional vegetables. Five of the seven cabbage farmers purchased transplants and two purchased seed and prepared their own seedlings.

Nutrient supply was primarily by chemical means and differed little among the four vegetables. Typically, an NPK mixture was applied at planting, and this was followed top-dressing with LAN, usually after weeding the crop, which in all cases was done by hand using a hoe. On average, the two traditional vegetables received fewer nutrients than cabbage and Swiss chard, but for all four crops the average rate of application, shown in Table 3.5, was very high. For example, South African fertiliser guidelines (Bornman *et al*., 1991) recommend the application of 160 kg N ha^{-1} in cabbage production, whilst the mean rate at Dzindi was 268.7 kg ha^{-1}. Use of kraal manure was rare. One farmer applied it to nightshade, Chinese cabbage and Swiss Chard, and two to cabbages.

TABLE 3.5: Supply of N, P and K to four vegetables by farmers at Dzindi (2003; n = 34)

Crop	**N**			**P**			**K**		
	.... (kg ha^{-1})...................................								
	Mean	Median	SE	Mean	Median	SE	Mean	Median	SE
Nightshade	191.8	168.3	30.9	41.7	33.3	5.9	26.2	21.0	3.8
Chinese cabbage	193.7	168.8	24.1	40.1	36.6	4.3	43.0	36.6	5.3
Cabbage	268.7	201.3	109.5	35.6	24.1	11.9	59.9	24.1	27.3
Swiss chard	329.6	297.7	65.3	85.3	70.8	20.4	45.4	47.4	5.9

Plant protection was by chemical means for all four crops. A total of four registered chemicals were used. These were applied by means of a knapsack sprayer, both preventative and to control observed infestations.

The average total variable costs excluding the cost of labour for the four vegetable enterprises are presented in Table 3.6.

TABLE 3.6: Average total variable costs excluding the cost of labour for four vegetable enterprises (Dzindi, 2003)

Crop	Soil preparation	Nutrient supply	Planting materials	Crop protection	Total
	-------------------------------(R ha^{-1})---				
Nightshade	1195	1639	0	133	2967
Chinese cabbage	1051	2502	0	111	3664
Swiss chard	1683	3029	412	128	5252
White cabbage	863	3154	1571	79	5667
Average contribution to total (%)	27.3	58.8	11.3	2.6	100

Differences in the average cost of land preparation among the four vegetable enterprises were due to farmers using different resources to do cultivation, including the use of the scheme tractor, private tractor services, animal draught and even ridging by hand. These differences were more related to diversity in approaches to land preparation among farmers than to enterprise-specific differences. Nutrient supply contributed about 55% to the total variable cost excluding labour in the case of nightshade and 68% in the case of Chinese cabbage. The question arose whether the high rates of fertiliser application farmers used were warranted, considering that traditional vegetables are expected to respond poorly to fertiliser additions.

At Dzindi, micro-vendors largely controlled the produce market for nightshade, Chinese cabbage and Swiss chard. Early in the morning, these vendors, nearly all women, scoured the plots in search of these vegetables. Invariably the vendors harvested the leaves and when they were ready they negotiated the price with the farmer concerned. From the field they proceeded to their vending sites using public transport. By selecting and harvesting only those leaves that met their requirements micro vendors controlled product quality. To an extent they also controlled the farm-gate price of vegetables, especially that of Chinese cabbage. As soon as the supply of Chinese cabbage exceeded demand, which occurred from about mid-July to mid-August, they bargained to reduce its price. Typically, the farm-gate price of the three leafy vegetables ranged between R0.50 and R1.00 per kg of fresh produce in 2003 with farmers making a profit at a price of R1.00 per kg but not at R0.50 per kg.

Marketing of cabbages was handled differently. Cabbages are bulky and to retail this vegetable vendors need transportation. Only a small number of vendors had a truck. Farmers who produced cabbages contacted these particular vendors by cell phone whenever their cabbages approached the marketing stage to negotiate a transaction. As with the other vegetables, the vendors controlled quality, removing only the heads that met their standards. In 2003, the farm-gate price of cabbages that were purchased by vendors was R3.00 per head.

All four vegetables were produced primarily for marketing, but small proportions were also used for home consumption and as gifts to support the social networks of producers. Not all the vegetables that were grown found a use. This was especially the case for Chinese cabbage. To limit losses, the wives of selected farmers processed parts of what remained on their plots into dried vegetable powder. This involved the squeezing of boiled fresh leaves into balls followed by sun-drying on a zinc roof sheet. Some proceeded by grinding the dried vegetables into a vegetable powder. In 2003, vegetable powders were sold at R2 per 250 ml in the neighbourhood or at pension pay points. The low price of this product suggested that drying vegetables was more of a value-rescuing than a value-adding activity.

Nightshade and Chinese cabbage plants were left in the field after harvesting had ceased. The plants were allowed to complete their growing cycle, where after they were collected and heaped at field edge to recover the seed, without using particular selection criteria. Chinese cabbage seed was obtained by rubbing the dry seed pods between the palms of both hands, Nightshade seed was obtained by squeezing the content of the ripe berries onto a piece of newspaper and letting it dry in the shade or more importantly by squeezing the berries in a bucket filled with water, followed by repeated filling of the bucket water, stirring and decanting the supernatant until the water remained clear indicating that the seed had been separated from the fruit (Figure 3.11). Seed of Chinese cabbage and nightshade was stored in sealed containers for use during the next winter season.

FIGURE 3.11: Harvesting the seed of nightshade by squeezing the berries and decanting the supernatant containing the skins and flesh of the berries (Tshiombo Irrigation Scheme, September 2006)

Table 3.7 shows the allocation to sales, home consumption, gifts and processing of the four vegetables and also presents a budget for these four vegetable enterprises.

TABLE 3.7: Allocation of four vegetables to different uses and financial analysis of the four vegetable enterprises at Dzindi (2003)

Vegetable	Proportional allocation				Financial analysis		
	Sales	Home consumption	Gifts	Processed	Total variable costs[1]	Gross income	Gross margin
	(%)				($R\ ha^{-1}$)		
Chinese cabbage	76	13	9	2	2967	6498	3531
Nightshade	88	6	3	3	3664	7985	4321
Swiss chard	89	6	5	0	5252	16570	11318
White cabbage	99	1	0	0	5667	53989	48322

[1] Excluding the cost of labour

Table 3.7 indicates that the Chinese cabbage enterprise provided farmers with the lowest gross margin followed by the nightshade enterprise. Table 3.7 also indicates that the production of cabbage at Dzindi was highly lucrative, but managerially farmers considered it to be the most demanding vegetable, explaining why only seven of the 34 farmers planted it. Generally, farmers were a lot more confident about their ability to produce the two traditional vegetables. The study showed that the prevailing produce marketing system represented both strength and weakness. Its strength was that agents collected and purchased all four vegetables on-farm and concluded the transactions on the spot and in cash. Its main weakness was that demand was limited by the size of the local market for fresh vegetables. Production on each farm individually was too small to consider the option of accessing distant markets, because the cost of transportation of small quantities of produce eliminated the possibility of making a profit. To access distant markets large quantities of produce need to be supplied and transacted to reduce the contribution of transport to total cost per unit produce. Hasnip (2001) and Chancellor, Shepherd and Upton (2003) reached similar conclusions from their assessment of constraints affecting smallholder irrigation enterprises in the Southern African region. At Dzindi, the potential to supply substantial quantities of produce, particularly of Chinese cabbage and nightshade, to distant markets existed but realisation of this potential depended on the development of new institutions and systems to manage the collective marketing of fresh produce.

3.2.4.2 Conclusions: The major importance of the two traditional leafy vegetables (Chinese cabbage and nightshade) in the vegetable chain at Dzindi was evidence of their integration in the food-culture of the local (mainly Venda) people. The main elements of the commodity system of these two leafy vegetables at Dzindi were also found at other smallholder irrigation schemes in the region, including Khumbe and Rabali (Van Averbeke, Tshikalange and Juma, 2007).

High, seemingly excessive use of fertilisers, which accounted for about 40% of the total variable costs of production of these two indigenous vegetables at Dzindi, was identified as an opportunity for improving gross margins in production. Development of fertiliser guidelines for these two vegetables was, therefore, identified as a suitable topic for a research and development intervention. Progress on this investigation is presented in Chapter 8 of this report.

Since the market for vegetables produced at Dzindi was essentially limited to the Thohoyandou area which was too small to absorb local supply, the financial sustainability of the vegetable enterprises was affected, especially that of Chinese cabbage. Expanding the existing market for Chinese cabbage was identified as the main opportunity to improve farm income of Dzindi farmers. Indications were that exploring new markets needed the development of new systems to enable collective marketing, because the size of production of individual farmers was too small. A large urban area, such as Tshwane, counts substantial numbers of Venda people among its population and its potential as a market for indigenous vegetables produced by farmers at Dzindi warrants exploring. However, since 2007 farmers in Gauteng and North-West Province have started to supply Tshwane with Chinese cabbage, casting doubt that this potential is realisable.

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4 LIVELIHOOD AND FARMING ON SMALLHOLDER IRRIGATION SCHEMES

4.1 The livelihood concept

The livelihood concept is a means of understanding the factors that influence people's lives and well-being, particularly those of the poor in the developing world (Bagchi *et al*., 1998; Bernstein *et al*.; Davies, Carney, Rennie and Singh as cited by Soussan *et al*., 2001). In its general sense a livelihood refers to the means people use to make a living. Chambers and Conway (1992:6) define livelihood as "comprising of the capabilities, assets (stores, resources, claims and access) and activities required for a means of living". The definition of livelihood by Chambers and Conway (1992) is but one of the many definitions that are in use. It is one of the early definitions and it is particularly attractive because of its simplicity and openness. This definition has been adopted, sometimes with minor modifications, by several authors, including Carswell (1997), Carney (1998), Hussein and Nelson (1998), Scoones (1998), Drinkwater and Rusinow (1999), Ellis (2000) and Swift and Hamilton (2001).

The livelihood concept as defined by Chambers and Conway (1992) considers livelihood to consist of four parts, namely,

i) people and their livelihood capabilities;
ii) assets, including both the tangible (resources and stores) and intangible (claims and access), which provide the material and social means that are used to construct livelihoods;
iii) activities, i.e. what people do; and
iv) a living, which refers to the outcomes of what people do.

Livelihood capabilities refer to the ability of individuals to realise their potential as human beings, both in the sense of being, such as being adequately nourished and free of illness, and of doing, such as exercising choices, acquiring skills, knowledge and experiences, and participating socially. Livelihood capabilities are also seen as the ability to cope with stresses and shocks, and being able to find and make use of livelihood opportunities (Chambers and Conway, 1992).

The inclusion of assets as one of the core components of livelihood has its roots in the work of Swift (1989), which deals with the problem of coping with vulnerability to famine. When discussing the portfolio of assets rural people rely upon to cope with vulnerability to famine, Swift (1989) categorises assets into three broad groups, namely investments, stores and claims. Investments include those assets that are expected to contribute to production. Among others, these can include farm equipment, education, soil conservation works and the harnessing of water sources. Stores include food stocks, money, bank accounts and jewellery. Claims include appeals and demands on other households within the community, or on patrons, the state or the international community (Swift, 1989). Investments and stores are resources that are under the individual control of households. Claims involve a wider range of social and political processes and their activation depends on collective decisions. Stores, claims and certain investments are assets that may be cashed in when households face a crisis. For example, farm equipment can be sold, granaries and bank accounts emptied, loans recalled and community support mechanisms activated (Swift, 1989). Generally, assets are building blocks, which people are able to use to undertake different economic activities, engage in labour markets and participate in the overall economy in their attempts to construct different types of livelihoods (Ellis, 2000). Control over assets may be through ownership, in which case the owner has decision-making powers over the assets concerned. People can also have access to assets that do not belong to them. In such cases their decision-making powers in relation to these assets are restricted to various extents (Ellis, 2000; De Satgè *et al*., 2002). Ellis (2000) and De Satgè *et al*. (2002) agree that assets are affected by historical trends. Chambers and Conway (1992) rearranged and developed the categorisation of assets by Swift (1989) by separating out stores and resources as tangible assets, and claims and access as intangible assets. Assigning stores and resources into the single category of tangible assets is helpful when analysing the multiple roles of assets, because some assets are both a store and resource. For example, in many rural African societies livestock constitutes an asset that has the attributes of both a store and a resource (Livingstone, 1986; Ornäs, 1990; Shackleton, Shackleton and Cousins, 2001; Dallimore, 2003; Ainslie, 2002; 2003; Ashley and Nanyeenya, 2005; Ellis and Freeman, 2005b). As a store, livestock can be slaughtered, used to pay bride-wealth, or sold at a time when cash is needed. As a resource, it can provide manure or draught power in farming. In addition, some of the livelihood functions of livestock are not related directly to income. These include their role in rituals and their use in developing and maintaining social relationships (Ferguson, 1990; Ntsebeza, 2002; Kepe, 2002; Ainslie, 2003; Ashley and Nanyeenya, 2005).

Claims and access are the intangible assets of people. Claims are demands and appeals, which can be made for material and other forms of support (Chambers and Conway, 1992). They are often made at times of stress or shock, or when other contingencies arise. These may include the claiming of groceries from other households, welfare grants from the state, or relief packages of food and medicines from donor agencies. Access is the opportunity in practice to use a resource, store, or service, or to obtain information, materials, technology, employment, food or income (Chambers and Conway, 1992; Ellis, 2000). When a resource is common property, access is defined by the rules and social norms that determine the differential ability of people to own, control, claim or make use of that resource (Scoones, 1998).

Livelihood activities are sets of actions through which households gain their means of survival. Conventionally, they are subdivided into (i) production activities, which are activities that produce goods and services and usually contribute to income; and (ii) reproduction activities, which are household maintenance activities, including childcare, cooking and cleaning (Soussan *et al*., 2001; Ellis and Freeman, 2005).

To make a living is the outcome of a livelihood, which results from interactions and relationships among the main livelihood components, as illustrated in Figure 4.1.

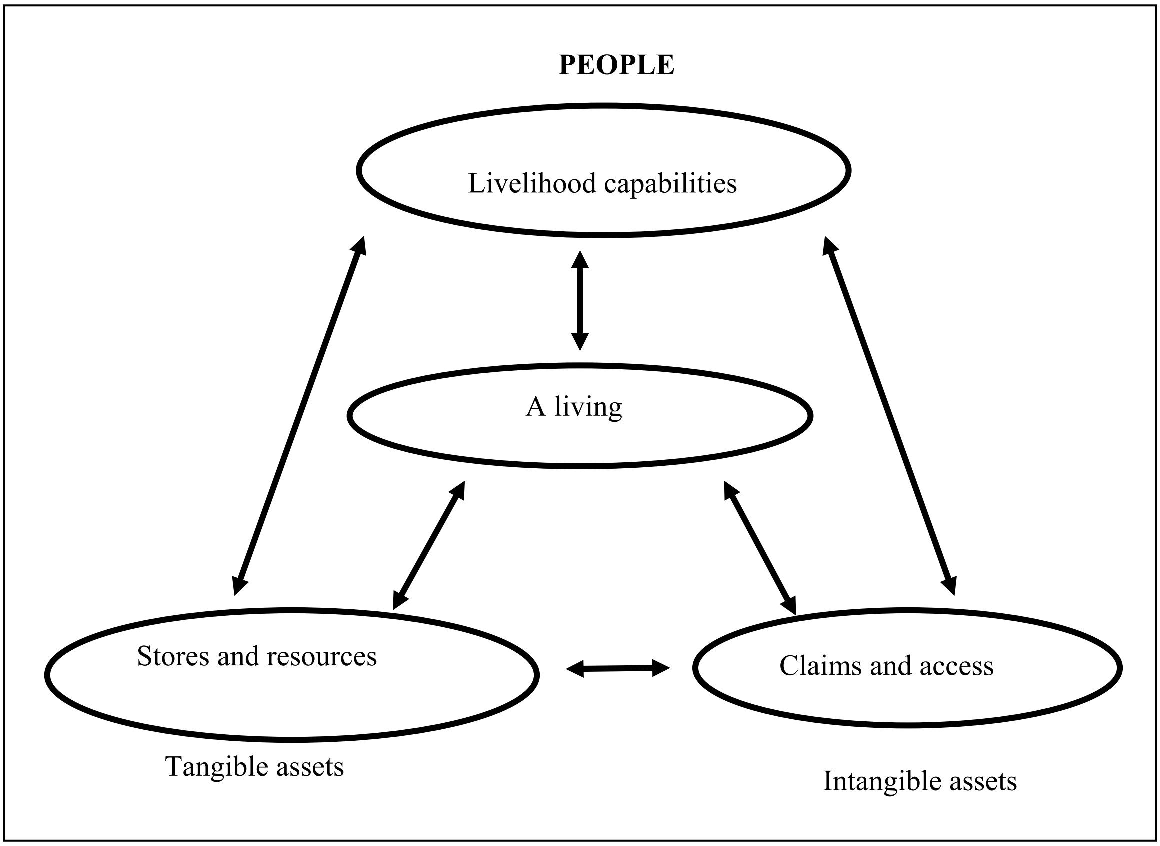

FIGURE 4.1: Livelihood components and their relationships and interactions (after Chambers and Conway, 1992)

4.2 Livelihood strategies

Livelihood strategies are the overarching term used to designate the range and combination of activities that individuals or households undertake in pursuit of their livelihoods. Ellis (2000:40) defined livelihood strategies as the complement of activities that generate the means of household survival. The primary purpose of understanding livelihood strategies is to shed light on how and when individuals, households and groups negotiate among themselves, and with other communities, markets and societies. They enter these negotiations to improve or maintain their existing livelihood by appropriating benefits from their assets, activities, and investments (Scoones, 1998; Valdivia and Gilles, 2001; Valdivia and Quiroz, 2001; Winters, Corral and Gordillo, 2001).

The analysis of livelihood strategies is of special interest to rural development policy (Barrett and Swallow, 2005). Livelihood strategies reflect the processes of choosing activities and asset investment for maintaining or improving particular livelihoods. The choice of a particular livelihood strategy that can best provide people with reasonable livelihood outcomes depends on the assets they possess, the structures and processes that impact on them, and the vulnerability context under which they operate (Cahn, 2002; Soussan *et al*. 2001; Freeman and Ellis, 2005). The multiple, diverse and dynamic nature of rural livelihood strategies are the result of people's attempts to manage risks, reduce vulnerability and enhance their livelihood security (Cousins, 1998).

Generally, three broad rural livelihood strategies are identified, namely (i) agricultural intensification or extensification; (ii) livelihood diversification; and (iii) migration (Scoones, 1998; Hussein and Nelson, 1998; Swift and Hamilton, 2001).

Agricultural intensification aims at more output per unit resource, be it land, water, vegetation or livestock, by applying more labour, capital or technology. Agricultural extensification aims at expanding the resource base being utilised. This can be by increasing the area under cultivation or by increasing livestock herds, whilst simultaneously raising levels of labour, capital or technology to maintain productivity (Tiffen, Mortimore and Gichuki, 1994; Zeller *et al*., 2000; Ellis, 2000; Ntshona, 2004).

Livelihood diversification refers to the strategy of households constructing an increasingly varied portfolio of activities and assets in order to make ends meet or to improve their living. Typically this involves widening the range of either on-farm or off-farm sources of income or both (Ellis, 2000; Toulmin *et al*., 2000; Barret, Reardon and Webb, 2001). Ashley *et al.* (2003) distinguish two types of livelihood diversification, namely (i) pull or positive diversification, when new activities generate higher returns than before; and (ii) push or negative diversification, when new occupations offer lower returns than before. The pull or positive diversification usually leads to asset accumulation or improvement of living standards, whereas push or negative diversification is adopted out of necessity, and is usually a response to shocks or a downward trend in the economy.

Migration is a livelihood strategy that involves people moving away from their initial sources of livelihood, seeking livelihoods elsewhere, either temporarily or permanently (McDowell and De Haan, 1997; De Haan, 2000; Ellis, 2000; Ellis and Freeman, 2005). Ellis (2000) distinguishes four types of migration, (i) seasonal migration; (ii) circular migration; (iii) permanent migration (rural-urban); and (iv) international migration. Seasonal migration refers to temporary migration, and is typically associated with movement away from rural areas during the slack season and the return of migrants for the peak periods of labour input in the agricultural calendar. Circular migration is a type of migration that is not necessarily linked to seasonal factors in agriculture and it may vary in duration, depending on the cyclical needs for labour in non-farm markets. Circular migrants usually do not arrange permanent living places where they work. Permanent migration (rural-urban) typically involves a long-term move of migrants to a different location, typically from rural to urban areas. When in urban areas, migrants set up a domicile, but often they continue to regularly or intermittently remit back home. International migration usually involves movements of migrants across international boundaries. In South Africa, all different types of migration occur. During the last decade of the 20th century, the country experienced considerable permanent migration from rural to urban areas and migration of foreigners into South Africa is growing (Boraine, 2004).

When agriculture, which traditionally has been at the centre of most rural livelihoods in developing countries, fails to provide for adequate livelihoods, households typically add off-farm and non-farming sources to agriculture in order to cope. Identifying the livelihood strategies that rural people pursue is necessary to understand livelihood processes and dynamics.

4.3 Rural livelihoods in South Africa

In South Africa, the role of farming in the livelihoods of rural African people has changed substantially during the past century. In pre-colonial times, agriculture was central in the livelihoods of African households, mainly in the form of subsistence production (Thompson, 1990). At present, agriculture merely supplements the livelihoods of most rural African households (Carter and May, 1999; Fraser, Monde and Van Averbeke, 2003). Political and economic changes played an important role in bringing about the historical shifts in the livelihoods of black South Africans.

When livelihoods based on agriculture became stressed, many South African rural households adopted migration as a livelihood strategy. Migration of black people in South Africa was organised in response to the demand for labour by white-owned enterprises, particularly in mining and farming. This became important from about 1900 onwards (Yawitch, 1982; Beinart, 2001). The drive by the mining and agricultural sectors to satisfy their labour needs was supported by the state through legislation that forced black people to earn a living off-farm for at least part of the year (Bundy, 1988). This legislation included various forms of taxes creating a need among black people for cash income, and also restrictions that prevented black people from accessing adequate land to continue to make a living from farming.

Initially mainly African men migrated to the cities, leaving women and children at their rural homes (Yawitch, 1982). Male migration affected the traditional organisation of households in the African areas, as well as their productive capacity, especially in agriculture (Yawitch, 1982). Yawitch (1982) reported that when male migrants returned home from working elsewhere, they often saw themselves as 'resting' and did not participate in the productive affairs of their households, such as agriculture, to the same extent as before. As the 20th century progressed, the livelihoods of rural African households became increasingly reliant on non-farm sources of income.

Until the 1970s, remittances from migrant workers were the dominant source of off-farm income for many rural households. Thereafter, other forms of off-farm income became increasingly important, including local employment in the civil service of the homelands (Sperber, 1997) and public welfare grants. Claiming against the state, initially mainly in the form of old age pensions, and more recently also in the form of child support grants, has developed into the principal off-farm source of income of rural households in South Africa (Monde-Gweleta *et al*., 1997; Van Averbeke, Bediako *et al*., 1998; Møller and Devey, 2003; Schmidt, 2005; Seekings, 2005). The growth in the importance of state transfers in the livelihoods of rural African households has been due to policy that increased the real value of these grants, particularly old age pensions paid out to black people (Van Averbeke, Bediako *et al*., 1998) and policy change that broadened access to child support grants. Another reason is that access to public welfare grants has enabled people to remain resident in rural areas.

In 2003, an estimated six million people in South Africa were receiving a public welfare grant. This number corresponded to one of seven South Africans, or more than one in four adult South Africans and a higher proportion of households (Seekings, 2005). During the period 2002 to 2005, the national budget allocation to social grants increased from R42.9 billion to R73.2 billion, an increase of 20% per annum (Manuel, 2006). This increase was due to annual increases in the value of the grants and due to an increase in the number of eligible beneficiaries (Manuel, 2006). For example, between April 2005 and March 2006, the number of South African children in receipt of a child grant increased from 5.67 million to 7.08 million (Leatt, 2006). In 2006, the monetary value of public welfare grants represented about 3% of the GDP of South Africa, which was nearly two-thirds the contribution primary agriculture makes to the GDP (Nattrass, 2006).

Figure 4.2 illustrates the types of general changes that have occurred in the structure of the livelihoods of rural Africans in South Africa during the past century using the Ciskei region of the Eastern Cape as an example. Figure 4.2 shows the declining role of agriculture, the importance of remittances during the first half of the 20th century, the importance of wage and salary income during the homeland era, especially during the period 1950-1990, and the increasing significance of state transfers from about 1990 onwards.

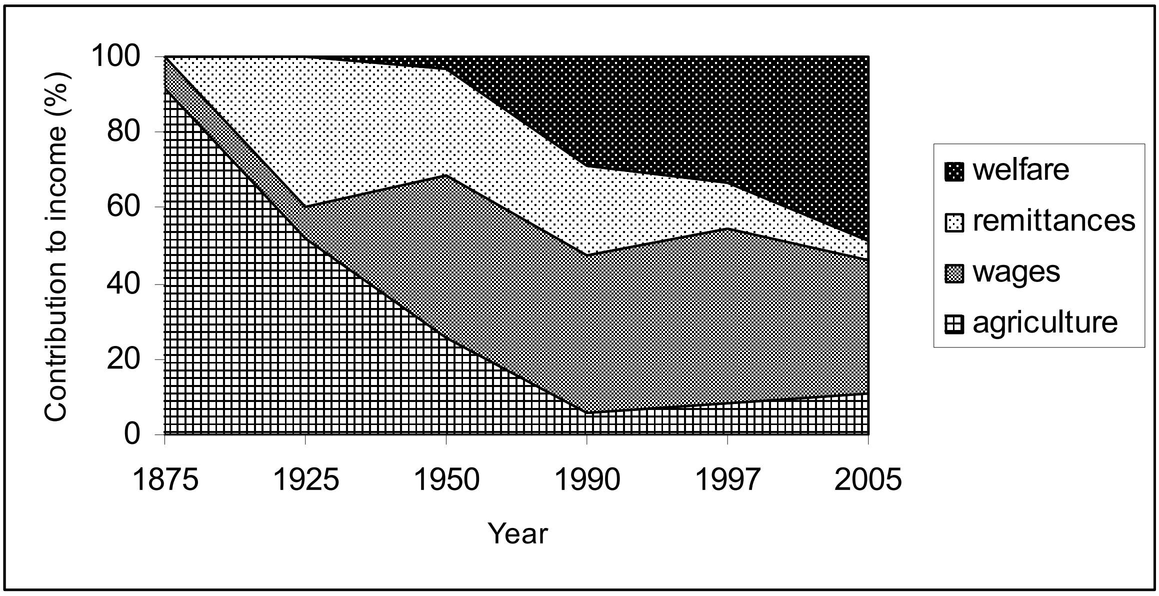

FIGURE 4.2: Relative contribution of different sources to the income of rural households in the Ciskei region during the period 1875 to 2005 (adapted from Hebinck and Van Averbeke, 2007)

Despite the declining role of agriculture in rural African livelihoods in South Africa, most rural households still engage in agriculture as part of their livelihood strategy. Rates of participation in agriculture are high, although there is evidence of a reduction in scale. Studies by ARDRI (2001), Khosa (2003) and Monde (2003) in different rural parts of the country report rates of participation that ranged between 75% and 90%, but the mean contribution of farming to total household income was usually small, as is shown in Table 4.1.

TABLE 4.1: The contribution of various sources to household income in different rural areas of South Africa

Source of income (%)	Rural KwaZulu-Natal [1]	Momane & Rantlekane (Limpopo)[2]	Koloni & Guquka (Eastern Cape)[3]	Rural Mbashe Municipality (Eastern Cape)[4]	Ga-Molekane (Limpopo)[5]	Sekuruwe (Limpopo)[5]
Year of survey	1993	1994/5	1997	2001	2001	2001
State grants	17.9	15.3	26.5	38.4	30.4	40.0
Remittances	16.4	7.6	10.5	10.7	27.9	37.0
Wages	53.6	51.6	33.3	30.0	25.3	5.5
Private pensions	-	-	-	2.6	-	-
Non-farming	5.3	17.6	17.8	9.9	8.8	11.2
Agriculture	6.8	7.9	11.9	8.5	7.5	6.4
Total	100	100	100	100	100	100

[1]May, 1996; [2]Baber, 1996; [3]Van Averbeke, Bediako *et al.*, 1998; [4]ARDRI, 2001; [5]Khosa, 2003

In the six study areas featuring in Table 4.1, the contribution of agriculture to mean rural household income was limited. On average, it ranged between 6% and 12%. Depending on the study area and the time of the study, state grants, remittances, or salaries and wages constituted the main source of income. The mean contribution of non-agricultural local economic activities, such as trade and provision of services, ranged between 5% and 18%. Across study areas the contribution of state grants to rural household income tended to increase over time and that of wages to decline. This supports the notion that rural livelihoods in South Africa are increasingly becoming dependent on claims against the state. As a result, South African rural livelihoods are somewhat of a special case when viewed in the global development context. In other developing countries agriculture plays a more important role in the livelihoods of rural people than in South Africa (Chambers, 1988; Ellis, 2000; Brabben *et al*, 2004; Chimhowu and Hulme, 2006).

4.4 Livelihood of plot holder households at Dzindi

4.4.1 The household concept

Many studies that investigated rural livelihoods or rural incomes have used the household as the unit of analysis (Baber, 1996; Leibbrandt and Sperber, 1997; Van Averbeke, Bediako *et al*., 1998; Ellis, 2000; Fraser, Monde and Van Averbeke, 2003). Ellis (2000) considered the household as the social unit that was most appropriate for investigating livelihoods and for advancing the understanding of the policy implications of diverse livelihoods. He pointed out that the household was the site where particularly intense social and economic interdependencies occurred between a group of individuals. Actions by individuals in that group could not be interpreted separately from the social and residential space they inhabited. According to Ellis (2000), this was sufficient reason for the household to be the relevant unit of social and economic analysis. However, he also pointed out that the household was a variable social arena, which was difficult to define in various cultural settings.

De Wet and Holbrook (1997) called the household an elusive concept. They identified four aspects that contributed to the concept of the household, namely the kinship aspect, the task related aspect, the aspect of co-residence and the aspect of identity and social markers. They pointed out that in specific situations some of these four aspects were more important than others and also that none of the four aspects on their own were sufficient to define the concept of household. According to Carter as cited by De Wet and Holbrook (1997), the kinship or familial aspect of the household is defined by the origin of the links between its members. The origin of these links are culturally defined relations of birth, adoption and marriage, regardless of whether those who are so linked live together or engage in any shared tasks. Citing McNetting *et al.*, De Wet and Holbrook (1997) described the task-related aspect as consisting of pooling and sharing of resources, food processing, cooking, eating, shelter from the elements, protection and socialization. The aspect of co-residence emphasizes the sharing of a physical space (Ellis 2000). The aspects of co-residence and sharing of tasks are usually linked and with it the making of joint decisions over resource allocation and income pooling (Meillassoux as cited by Ellis, 2000). Consequently, in many studies the aspect of co-residence dominates the definition of the household concept. However, De Wet and Holbrook (1997) argued that tasks and ties, which are part of what makes up a household, do not need to take place in one physical locality. For this reason they emphasized the importance of the aspect of identity and social markers of the household. Central to this aspect is the phenomenon of migration and what migrants consider as being their home. They identified two different types of households, namely single homestead households and multiple homestead households. In single homestead households migrants still see themselves as having only one home, to which they make remittances and return visits and to which they assume they will retire (De Wet and Holbrook, 1997). In multiple homestead households, migrants set up their own household near their places of work, usually in urban areas, but they continue to maintain close contact with their natal rural household, through frequent visits and the sending of goods and money (De Wet and Holbrook, 1997).

In contemporary South Africa, links between migration from rural to urban and income flows from urban to rural through remittances are no longer as self-evident as in the past. In this study, three types of resource or income flows that occurred between the rural household and urban areas were identified. The first type was the classical urban to rural flow of money and goods resulting from a household member being employed in an urban area. The second type was a rural to urban flow of money and goods in support of one or more household members, usually belonging to the second or third generation, who pursued further education in an urban area. The third was a rural to urban flow of money and goods in support of one or more household members, usually young men, who resided in urban areas, but who were not finding lasting employment. When in need, these urban dwellers claimed against the rural household to which they belonged. As a result, for the purpose of analysis, it was decided to link membership of the household not only to spatial patterns of income generation, but also to spatial patterns of consumption characterizing households in the study area. In the analysis of income related characteristics, remitting migrants were included as household members, because they contributed materially to the income available to the rural co-resident group. In the analysis of consumption related characteristics, particularly adult equivalent income, remitting migrants were excluded from the household, but non-remitting migrants were included, irrespective of whether they were students or unemployed urban dwellers. This decision was justified, because remitting migrants typically supported themselves, whilst students and unemployed urban dwellers made claims against the rural group.

4.4.2 Data collection methods

The study of the livelihood of plot holders at Dzindi involved a household census conducted in 2003, a household survey of a sample of plot holders in 2005 and the development of household portraits using a qualitative approach to data collection.

The 2003 census made use of a structured questionnaire and face-to-face interviews and was conducted during August and September 2003. The census collected information on household composition, age, gender, education level and occupation of household members, household sources of income, amount of income and monetary savings for the period 1 July 2002 to 30 June 2003. Data collection was aimed at obtaining information on the different elements that make up livelihoods. Household composition and age, gender, education level and occupation of household members were selected as variables, because they are indicators of livelihood capabilities. Sources of income were selected, because they indicate livelihood activities, or in the case of welfare grants and remittances, they indicate livelihood claims. The amounts of income obtained from the different sources were selected, because they indicate livelihood outcomes. Monetary savings were selected as a variable, because they indicate livelihood stores. Although farming is a source of income, be it in cash or kind, it was treated separately during data collection. Collection of data on farming was aimed at developing a balance sheet for each of the commodities that were produced on the individual plots during the year of study. This was done by asking participants to first state all the crops they had planted during that year. For each crop the number of strips planted to that crop was recorded. Knowledge of the exact number of strips on each plot enabled the calculation of area planted to the different crops. Thereafter, the total variable costs of producing each crop were determined. Lastly, gross income obtained from the different crops was determined, including the allocation of the harvest to home consumption, sales and donations. This information was recorded on a flip chart to show the balance sheet to the respondents. After each interview, the information on the flip chart was transferred to the blank reverse sides of the pages contained in the interview schedule. Additional information on the transformation of farm related data is presented in section 4.6.1, which deals with the analysis of diversity in farming. During the household census, the plot set aside for research and demonstration was excluded, leaving 105 plots held by a total of 102 plot holders. Ninety-nine plot holders held a single plot and three had two plots. Ninety-seven of the 102 plot holder households were interviewed. Combined they held 100 of the 105 plots, which meant that all three holders of double plots were included in the survey. Interviews with the remaining five plot holders could not be conducted. Two were sick and away from their residences for treatment. One had just passed away and arrangements to take over his plot were not yet finalised. The other two were not in the village during the entire period of the census. Of the 97 plot holders who were interviewed, one did not plant her plot at all during the period under consideration. For this reason, only 96 plot holder households occupying 99 of the 105 plots were considered in the analysis of farm enterprises. In the analysis of livelihood, all 97 plot holder households that were interviewed were included.

The 2005 household survey involved a probability sample of 48 of the 102 households at Dzindi and was conducted during the period November to December 2005. The objective of this survey was to study change over time in the livelihood and farming style of plot holder households at Dzindi. Participants were selected by systematic random sampling using a list of all plot holders that were included in the 2003 census as the sampling frame. Data on different sources of income and farm enterprises were collected for the period 1 July 2004 to 30 June 2005, using the same questionnaire as was employed in the 2003 household census. Data collection procedures were identical to those used during that census.

The 2003 household census and the 2005 household survey collected data retrospectively, which eased decisions on household membership. Surveys, however, are snapshots. In real life, characteristics of production and consumption in households continuously change. Babies get born, working adults change jobs, get retrenched or retire, the elderly pass on, the unemployed find jobs or return home to farm and students graduate. A single snapshot does not reveal these realities, but two snapshots, taken a few years apart do show up change and so do life histories. By incorporating these in the design of this study the changing shape and size of households were brought to light.

Qualitative data were collected to obtain detailed information on the different livelihood types and farming styles that were identified during the analysis of the census data. Qualitative data collection persisted from 2004 to 2006. Purposive sampling (Strydom and De Vos, 2001) was employed to select typical representatives of each of the identified livelihood types and farming styles at Dzindi. Data collection involved semi-structured interviews guided by a checklist of themes related to livelihood and farming. For livelihood, the themes included the origin of the current livelihood (life history), livelihood and farming, constraints in the current livelihood and farming, the strategies being used or planned to overcome these constraints and the livelihood goals and expectations. Themes related to farming included farm enterprise objectives, ownership of farm assets, access to farm assets, choice of crops, plot use intensity, specialization and diversification and key constraints. Collection, analysis and interpretation of data occurred in cycles, as recommended by Van Averbeke (2005). After each round of data collection, the data were analysed and interpreted in function of the identified themes. During this process information gaps and interesting issues for further exploration were identified and these were the subject of the subsequent interview. At the start of each follow-up of interview, the researcher presented his interpretation of the data obtained during the previous interview to the participant and invited the participant to interrupt and comment whenever he or she felt the need to do so. This procedure yielded two important benefits. It enhanced the trustworthiness of the interpretation and it created a shared platform for the interview that followed. Interviews were conducted at the homes of respondents or at their plots. During the conduct of each interview, two Venda-speaking field assistants were present. One field assistant translated the interview, whilst the second recorded the interview in Tshivenda. The researcher recorded the English translation of the interview. The interviews lasted between one and two hours and were recorded in note books. Immediately after leaving the field, the interviews were written out in full. During this process the contents of the two sets of notes, one in Tshivenda and one in English, were carefully compared. Inconsistencies that were identified were discussed among the researcher and the two field assistants and when no consensus could be reached, the participant was approached the next day for clarification. Once written out in full, the interviews were captured electronically using MS Office Word.

4.4.3 Data analysis

The process of analysing the 2003 and 2005 survey data commenced by coding the data followed by their capture on a PC using MS Office Excel spreadsheets (Neuman, 1997). All gross income data were transformed to an annual basis, enabling the calculation of total gross income for the 12 month period under consideration. Total monthly income was obtained by dividing this total by 12. Household members were separated into two main groups, namely economically active and economically inactive. Tait *et al*. (1996) defined economically active persons as persons aged between 15 and 64 years old and economically inactive persons as persons younger than 15 years old or older than 64 years old. The separation of household members into these groups enabled calculation of the number of adult equivalents (Carter and May, 1999) using equation 1 and the labour force ratio as defined by Hayami (1978).

Number of AE in a household = $(A + \frac{1}{2} C)^{0.9}$ [***equation 1***]
whereby:
AE = adult equivalents
A = number of adults in the household (people aged 15 years and older);
C = number of children in the household (people younger than 15 years old); and
0.9 = A scaling factor which reflects that as household size increases less money per individual member is required to achieve a particular living standard.

The labour force ratio of a household is an indicator of labour availability and it was calculated by dividing the number of economically active members of the household by household size.

The household typological procedure described by Perret (1999) was used to analyse livelihood diversity among households at Dzindi. For that purpose households were first categorised on the basis of their main source of income. Other researchers conducting work on rural livelihood and poverty in South Africa, such as Baber (1996), Lahiff (2000) and Turner (2001), used amount of income instead of source of income to categorise households. Using their analytical approach, households are subdivided, usually in quintiles, on the basis of the amount of income. Subsequently, the different categories of households are compared in terms of sources of income and other variables. In this study, sources of income were used as the variable to obtain the primary categorisation of households. The choice to use source rather than amount of income was justified, because as indicated in section 2.4 of this report, sources of income are related to livelihood activities, livelihood claims and indirectly also to livelihood outcomes. When a household obtained 50% or more of its total income, in cash or kind, from a particular source, it was assigned to a category that was named after that source. When there was no dominant source that contributed at least 50% to total household income, the household was assigned to the category called diversified-income households. Grouping households in function of their 'main' source of income is expected to be sensitive to the lower limit of the proportion this source had to contribute to total household income. In the categorisation used in this study the lower limit was set at 50%.

The different primary categories that were identified were further subdivided using characteristics that were important to each of the specific primary categories to produce the final categories called livelihood types. Two of the primary categories, namely households active in the informal sector and diversified income households were not subdivided further. For households that had salaries and wages as their main source of income, the type of employment was considered. Type of employment was subdivided into skilled or unskilled, because this distinction was useful to explain differences in the amount of income earned from a particular type of employment. Skilled employment referred to occupations that required professional or formal qualifications (for example, nurses and teachers). Unskilled employment referred to occupations that did not require a professional or formal qualification (for example, cleaners, domestic workers, security guards and construction workers). For households that had state transfers as their main source of income, the number of generations that formed part of the household was taken into account. Since the different public welfare grants have a fixed value, the larger the number of people dependent on a grant, the smaller the amount of money available per individual. As a result, in pensioner households AEI tended to be inversely proportional to household size. For households that had farming as their main source of income, the primary function of farming in the livelihood of the household was considered, be it producing monetary income or food. The primary function of farming was determined by calculating the proportions of the total value of production allocated to own consumption including donations and to sales.

An analysis of variance (ANOVA) (Hatcher, Stepanski and Edward, 1994) was performed using the SAS® version 8 statistical package (SAS Institute Inc., 2000), to identify to what extent the identified livelihood types at Dzindi differed from each other statistically in terms of a selection of social and economic variables.

Analysis of the transcripts of the semi-structured interviews with typical examples of the livelihood types that were identified were used to develop portraits of the different livelihood types. Van der Ploeg *et al*. (1996), Murray and Ferguson (2005) and Richards (2006) recommended the use of portraits to bring about a detailed and well-rounded understanding of the real world of a research phenomenon, such as people's lives and activities. The different portraits that were constructed do not appear in this report. They appear in full in the thesis of Mohamed (2006), which is available electronically upon request from the Water Research Commission.

4.4.4 Results

4.4.4.1 Origin of plot holder livelihood at Dzindi: The life histories of selected plot holders more or less covered a century, from about 1910 to present. Some of the oldest plot holders at Dzindi, aged 70 years and older and still alive at the time of the study, were born around 1930 and their parents around 1910. The evidence that was obtained from the life histories indicated that the generation that was born around 1910 had land-based livelihoods, which were based on dryland cropping and animal production[1]. Their children, born around 1930, grew up helping their parents on the farm. Male children attended school, but only for a limited period and often they only started school at an advanced age. For female children education was not considered important, because they were destined for a life of child care, domestic work and farming, for which the skills were provided at home, not at school.

Reaching adulthood around 1950, the males born around 1930 typically became migrant workers, whilst their parents settled at Dzindi, when the scheme was established in 1954. When a male child got married, his spouse joined his parents' household at Dzindi and took part in their farming. The children of the 1930 generation were born around 1950 and they were sent to school. The money remitted by their father enabled this generation to stay at school longer and in some cases long enough to enable them to obtain a professional qualification.

When the 1950 generation reached adulthood around 1970, their grand parents, the 1910 generation, were gradually passing away. They transferred their plots to their male children, the 1930 generation, who were working in distant urban areas. Having inherited their father's plot, these male migrants were drawn back to the rural homestead. Often they had become tired of working away from their home and families and several among them left their urban jobs to explore a new livelihood based on farming. The available evidence suggests that for most of them this proved difficult, causing them to again look for work, but now closer to home, which was made possible by jobs being created in the homeland. In the mean time, their children, the 1950 generation, also looked for work in Venda or in distant urban areas, but finding secure work in the cities became increasingly difficult, especially during the 1980's, when the South African economy experienced a recession. A few among them returned to Dzindi, whilst still being fairly young, to develop livelihoods based on farming. At present, they constitute the majority of market oriented farmers at Dzindi.

The children of the 1950 generation were born around 1970, reached adulthood around 1990. They were even better educated than their parents, but many of them struggled to find work, explaining the high unemployment rate in the Dzindi community. Several among these fairly well educated children did not consider farming as a suitable livelihood option. Instead they preferred staying with their parents (the 1950 generation) relying on the pensions of their grand parents (the 1930 generation) for survival, whilst looking or waiting for off-farm employment. Many of the contemporary three-generation pensioner households reflected this type of circumstances. Their type of livelihood was being supported by the social security policies of the South African state. Others of the 1970 generation became involved in the informal sector engaging in petty trade or the provision of services, mostly in the building sector (households active in the informal sector), or found local jobs often as unskilled workers in the security and retail sector (unskilled wage earner households). Among those who had obtained professional qualification some found employment and they were representative of the skilled wage earner households found at Dzindi.

[1] This is in line with the evidence provided by Lahiff (2000) which indicates that homesteads in Venda retained their land-based livelihood until about 1930.

4.4.4.2 Diversity of plot holder livelihood at Dzindi: Using principal source of income (cash and kind), which was defined as the source of income that contributed at least 50% to total household income, to categorise livelihood among plot holder households, five main livelihood categories were identified on the basis of the 2003 census data. Subdivision of the main livelihood categories yielded nine livelihood types. These were:

(i) One-generation pensioner households (3/97);
(ii) Two-generation pensioner households (16/97);
(iii) Three-generation pensioner households (17/97);
(iv) Wage-earner households reliant on skilled formal employed (8/97);
(v) Wage-earner households reliant on unskilled formal employment (13/97);
(vi) Market oriented farming households (15/97);
(vii) Subsistence farming households (5/97);
(viii) Households active in the informal sector (11/97); and
(ix) Diversified-income households (9/97).

Tables 4.2, 4.3, 4.4 and 4.5 provide social and economic statistics for the nine livelihood types identified at Dzindi.

One-generation pensioner households (3/97) constituted a small group. They consisted of a single generation of old people, either a couple or a single person. The average age of the head of household in this type was 88 years (Table 4.2). These households had no economically active members and no children (Table 4.2). Households in this type derived most of their income from welfare grants, mainly in the form of old-age pensions. On average, old-age pensions contributed about 69% to total household income and amounted to an average of R11 200.00 per annum (Tables 4.3 and 4.4). Agriculture was the second most important source of income, contributing on average R4 580.00 (31%) to mean total household income (Tables 4.3 and 4.4). On average, one-generation pensioner households realised 55% of their gross farm income in the form of sales (Table 4.5). The mean total income of these households was R15 780.25 per annum and the adult equivalent income R1 038.00 per month (Table 4.3), which was well above the poverty line of R461.44 that applied.

Two-generation pensioner households (16/97) consisted of parents and their children living together. Six of the 16 were female-headed, either widowed or divorced, and 10 were headed by married men (Table 4.2). The mean age of the head of household was 70 years (Table 4.2). The mean household size was 3.7 and the mean number of adult equivalents was 3.1 (Table 4.2). The labour force ratio was 56% (Table 4.2). Old-age pensions were the most important source of income of these households, contributing on average R11 025.00 (68%) to mean annual total (Tables 4.3 and 4.4). Agriculture was the second most important source of income. On average, it contributed R2 869.38 (18%) to mean total household income (Tables 4.3, 4.4 and 4.5). Two-generation pensioner households mainly farmed for the purpose of producing food for home consumption. On average, 67% of the gross value of production was realised in the form of food consumed by the farming household. The mean total household income was R15 664.38 per annum and the mean adult equivalent income R452.74 per month (Table 4.3), which was only R8.70 below the poverty line.

TABLE 4.2: Social characteristics of plot holder households by livelihood type at Dzindi (2003, n = 97)

Characteristic	Pensioner households			Wage-earner households		Farmer households		Households active in the informal sector (n = 11)	Diversified-income income households (n = 9)
	One generation (n = 3)	Two generation (n = 16)	Three generation (n = 17)	Skilled (n = 8)	Unskilled (n = 13)	Market-oriented (n = 15)	Subsistence (n = 5)		
Female headed households	1	6	13	1	0	0	0	3	3
Male headed households	2	10	4	7	13	15	5	8	6
Age of head of household	88.0	70.0	64.0	52.0	53.0	52.5	55.0	51.3	51.2
Household size	1.3	3.7	7.4	8.0	7.3	5.0	7.0	7.0	6.6
Economically active adults	0.0	2.2	4.2	5.0	4.5	3.1	5.0	4.3	3.7
Economically inactive adults	1.3	1.1	0.8	0.5	0.4	0.2	0.0	0.4	0.6
No of children	0.0	0.4	2.4	2.5	2.3	1.6	2.0	2.3	2.2
Number of generations	1	2	3	1, 2 or 3	1, 2 or 3	1, 2 or 3	2 or 3	1, 2 or 3	2 or 3
Labour force ratio (%)	0.0	56.4	55.4	62.4	63.0	61.0	69.4	61.0	53.0
No of adult equivalents	1.3	3.1	5.1	5.4	5.1	3.5	5.0	4.8	4.6

TABLE 4.3: Economic characteristics of plot holder households by livelihood type at Dzindi (2003, n = 97)

Sources of income (R per annum)	Pensioner households			Wage-earner households		Farmer households		Households active in the informal sector (n = 11)	Diversified income households (n = 9)
	One generation (n = 3)	Two generation (n = 16)	Three generation (n = 17)	Skilled (n = 8)	Unskilled (n = 13)	Market-oriented (n = 15)	Subsistence (n = 5)		
Remittances	0.00	750.00	1 200.00	0.00	184.62	0.00	0.00	0.00	0.00
Parental child support	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	316.67
Salaries and wages	0.00	225.00	635.29	58 987.50	33 600.00	400.00	0.00	0.00	0.00
Old-age pensions	11 200.00	11 025.00	9 883.35	7 500.00	3 230.77	2 240.00	0.00	3 054.55	3 733.33
Disability grant	0.00	525.00	494.12	1 050.00	0.00	0.00	0.00	0.00	1 866.67
Child support grants	0.00	120.00	903.53	720.00	443.08	768.00	1 536.00	523.64	1 066.67
Trade and services	0.00	150.00	1 570.59	3 540.00	1 070.00	808.67	948.00	13 736.36	3 108.89
Agriculture	4 580.00	2 869.38	3 477.35	4 739.38	4 095.69	10 436.67	6 529.80	2 774.09	4 791.11
Gross margin of the plot enterprise	1 064.33	721.09	773.00	1 108.38	1 361.08	5 727.60	2 787.60	814.81	2 434.22
All sources	15 780.00	15 664.38	18 163.24	76 536.89	42 624.92	14 653.33	9 013.80	20 088.64	14 883.33
AEI* (R month^{-1})	1 038.00	452.74	322.43	1 346.55	747.39	433.24	167.38	352.81	350.90
Monetary savings	140.00	664.38	925.30	2 757.50	897.85	560.00	860.00	811.00	967.78

*AEI = Adult equivalent income

TABLE 4.4: Relative contribution of different sources to total income of plot holder households by livelihood type at Dzindi (2003, n = 97)

Source of income	Pensioner households			Wage-earner households		Farmer households		Households active in the informal sector (n = 11)	Diversified-income households (n = 9)
	One generation (n = 3)	Two generation (n = 16)	Three generation (n = 17)	Skilled (n = 8)	Unskilled (n = 13)	Market-oriented (n = 15)	Subsistence (n = 5)		
	---Relative contribution to total household income (%)---								
Remittances	0.0	8.2	5.0	0.0	0.8	0.0	0.0	0.0	0.0
Parental child support	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
Salaries and wages	0.0	1.4	3.0	76.5	78.8	2.4	0.0	0.0	0.0
Old-age pensions	69.4	68.0	56.6	11.0	7.3	9.8	0.0	9.0	15.4
Disability grants	0.0	2.4	1.8	1.4	0.0	0.0	0.0	0.0	10.0
Child support grants	0.0	0.6	5.0	1.1	1.2	7.0	13.8	2.8	16.0
Trade and services	0.0	1.2	9.0	3.3	1.5	6.2	11.8	70.7	24.3
Agriculture	30.6	18.2	19.6	6.7	10.4	74.6	74.3	17.5	32.7
All	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 4.5: Plot enterprise characteristics by livelihood type at Dzindi (2003, n = 97)

Characteristic	Pensioner households			Wage-earner households		Farmer households		Households active in the informal sector (n = 11)	Diversified-income households (n = 9)
	One generation (n = 3)	Two generation (n = 16)	Three generation (n = 17)	Skilled (n = 8)	Unskilled (n = 13)	Market-oriented (n = 15)	Subsistence (n = 5)		
Gross farm income (R $annum^{-1}$)	4 580.00	2 869.38	3 477.35	4 739.38	4 095.69	10 436.67	6 529.80	2 774.09	4 791.11
Relative contribution of gross farm income to total household income (%)	30.6	18.2	19.6	6.7	10.4	74.6	74.3	17.5	32.7
Proportion of gross farm income realised as sales (%)	55.0	33.0	44.0	41.0	43.0	79.0	33.0	34.0	49.0
Proportion of gross farm income realised as food for own consumption and for donations (%)	45.0	67.0	56.0	59.0	57.0	21.0	67.0	66.0	51.0

Three-generation pensioner households (17/97) consisted of parents, children, grand children living together. Thirteen were female-headed and four were male-headed (Table 4.2). In four cases the spouses of the children were members of the household. The mean household size was 7.4 and on average the households consisted of 4.2 economically active adults, 0.8 aged adults and 2.4 children (Table 4.2). The mean age of the head of household was 64 years and the labour force ratio was 55% (Table 4.2). Welfare grants in the form of old-age pensions were the main source of income and contributed a mean of R9 883.53 (56.6%) to total household income (Tables 4.3 and 4.4). Agriculture contributed on average R3 477.35 (20%) to mean total household income and was the second most important source. It mainly served to provide food for home consumption. On average, 56% of the gross farm income was realised as food for home consumption (Tables 4.3, 4.4 and 4.5). The annual mean total household income was R18 163.24 and the mean monthly adult equivalent income R322.43 (Table 4.3), which was R139.01 below the poverty line.

Skilled wage-earner households (8/97) on average derived 76.5% of their household income from employment (Table 4.4). At least one household member earned a regular income from a permanent job in the formal sector of the economy. Employers included the civil, parastatal and private sectors. All of these households were headed by married males, who were on average 52 years old (Table 4.2). The average household size was 8 and the labour force ratio 62% (Table 4.2). Salaries and wages contributed on average R58 987.50 to mean total household income (Table 4.3). Welfare grants in the form of old-age pensions, child support and disability grants were the second most important source of income, contributing 14% to mean total household income (Table 4.4). Agriculture contributed only 6.7% (R4 739.38) to mean total household income (Tables 4.3 and 4.4) and was mainly for home consumption. On average, 59% of the gross farm income was realised as food for home consumption (Table 4.5). Among the nine livelihood types, skilled wage-earner households had the highest mean total household income (R76 536.89) and the highest mean adult equivalent income (R1 346.55 per month).

Unskilled wage-earner households (13/97) on average derived 79% of their income from employment (Table 4.4). The average household size was 7.3 and the mean labour force ratio was 63% (Table 4.2). All of these households were headed by males who, on average, were 53 years old (Table 4.2). Mean total annual income from salaries and wages was R33 600.00 (Table 4.3). Agriculture was the second most important source of income contributing on average R4 095.69 (10%) to mean total household income (Tables 4.3 and 4.4). Income from agriculture was mainly in the form of food for own consumption. On average, 57% of the gross farm income was realised as food for own consumption (Table 4.5). Welfare grants in the form of old-age pensions and child support grants contributed about 9% to mean total household income (Table 4.4). Mean total income was R42 624.92 per annum and mean adult equivalent income R747.39 per month (Table 4.3).

Market-oriented farmer households (15/97) relied heavily on agriculture (75%) for their income (Table 4.4). The average household size was 5, typically consisting of two parents and three children (Table 4.2). In all cases the head of these households was male (Table 4.2) and on average he was 53 years old. The labour force ratio was 61% (Table 4.2). Agriculture contributed R10 436.67 to mean total household income (Table 4.3). On average, 79% of the gross farm income was realised as sales (Table 4.5). State transfers, mainly in the form of old-age pensions and child support grants were the second most important source of income, which on average contributed 17% to mean total household income (Table 4.4). Mean total household income was R14 653.33 per annum and adult equivalent income R433.24 per month (Table 4.3), which was R28.20 below the poverty line.

Subsistence farmer households (5/97) farmed primarily to obtain food for home consumption, whilst lacking any other major source of income. Agriculture contributed a mean of 74% (R6 529.80) to mean total household income (Tables 4.3 and 4.4). On average, 67% of their gross farm income was realised as food for own consumption (Table 4.5). The mean household size was 7 and households typically consisted of 5 economically active adults and 2 children (Table 4.2). All these households were male-headed and on average the head was 55 years old (Table 4.2). The labour force ratio of these households was 69.4% (Table 4.2). State transfers, mainly in the form of child support grants, were the second most important source of income, contributing about 14% to mean total household income (Table 4.4). Of all livelihood types, subsistence farmer households attained the lowest mean total household income (R9 013.80 $annum^{-1}$) and adult equivalent income (R167.38 $month^{-1}$) (Table 4.3). From the perspective of absolute poverty these households were ultra poor, because on average their AEI was R63.34 less than half the poverty line of R230.72 $month^{-1}$.

Households active in the informal sector (11/97) had at least one member earning income from activities such as carpentry, building, petty trade, repairing of shoes, radios and bicycles, general piece work or producing and selling goods. Income in these households was principally derived from these non-farm activities. Three of these households were female-headed and eight were male-headed (Table 4.2). The mean age of the heads of these households was 51 years (Table 4.2). The mean household size was 7 and on average these households consisted of 2.3 children, 4.3 economically active adults and 0.4 aged adults (Table 4.2). The mean number of adult equivalents was 4.8 and the labour force ratio was 61% (Table 4.2). On average, non-farm economic activities contributed R13 736.36 (71%) to mean total household income (Tables 4.3 and 4.4). Agriculture was the second most important source of income, contributing about 18% (R2 774.09) to mean total household income (Tables 4.3 and 4.4). Farming was primarily for home consumption. On average, 66% of their gross farm income was realised as food for home consumption (Table 4.5). Welfare grants contributed about 12% (R3 578.19) to mean total household income (Tables 4.3 and 4.4). The mean total annual household income of these households was R20 088.64 and the mean adult equivalent income was R352.81 per month (Table 4.3), which was R108.63 below the poverty line.

Diversified-income households (9/97) were involved in multiple income-generating activities and also claimed against the state, but none of these activities contributed at least 50% to mean total household income (Table 4.4). Three of these households were female-headed and six male-headed (Table 4.2). On average, the head of household was 51 years old (Table 4.2). The mean household size was 6.6 and on average these households consisted of 2.2 children, 3.7

economically active adults and 0.6 economically inactive aged adults (Table 4.2). The mean number of adult equivalents was 4.6 and the labour force ratio was 53% (Table 4.2). Welfare grants in the form of child grants (16%), old-age pensions (15%) and disability grants (10%) were the most important sources of income. Combined these grants contributed 41% (R6 666.67) to mean total household income (Tables 4.3 and 4.4). Agriculture, which on average contributed 33% (R4 791.11) to mean total household income, was the second most important source (Tables 4.3 and 4.4). On average, diversified-income households realised about half of the gross value of their farm production as sales (49%) and the other half in the form of food for home consumption (51%) (Table 4.5). Mean total household income amounted to R14 883.33 per annum and mean adult equivalent income was R350.90 per month (Table 4.3), which was R110.54 below the poverty line.

In Table 4.6 the mean values of selected livelihood capability and livelihood outcome indicators for the different livelihood types are presented.

Overall, skilled wage-earner households had the largest household size, the largest number of children and the largest number of adult equivalents (Table 4.6). Other large households were three-generation pensioner households and unskilled wage-earner households, followed by subsistence farmer households, households active in the informal sector and diversified-income households. Among the different livelihood types, the heads of the wage-earner households had the highest level of formal education, particularly the heads of skilled wage-earner households (Table 4.6). This was not surprising, because the livelihood of households in this category revolved around professional employment, which was associated with holding one or other formal qualification. When the formal education level of heads of households was compared with the highest level of formal education obtained by any member of the household, there were indications of improvement in the level of formal education within households, particularly among the two- and three-generation pensioner households, wage earner households and households active in the informal sector (Table 4.6). This trend was less evident among farmer households and diversified-income households. Of particular interest was the highest level of education attained by any member of the household among the three-generation pensioners. Typical for these households was that they contained one or more members who were unemployed, despite these members having attained a fairly high level of formal education. It can be anticipated that when these individuals do succeed in finding employment, the livelihood type of their household will change from a pensioner to a wage-earner household for as long as these individuals remain a member of the household.

TABLE 4.6: Selected livelihood indicators of plot holder households in the different livelihood types identified at Dzindi (2003; n = 97)

Indicator	Pensioner households			Wage-earner households		Farmer households		Households active in the informal secto (n = 11)	Diversified-income income households (n = 9)
	One generation (n = 3)	Two generation (n = 16)	Three generation (n = 17)	Skilled (n = 8)	Unskilled (n = 13)	Market-oriented (n = 15)	Subsistence (n = 5)		
Livelihood capability									
Household size	1.3_{d}	3.7_{c}	7.4_{a}	8.0_{a}	7.3_{a}	5.0_{bc}	7.0_{ab}	7.0_{ab}	6.6_{b}
No of economically active adults	0.0_{c}	2.2_{b}	4.2_{a}	5.0_{a}	4.5_{a}	3.1_{ba}	5.0_{a}	4.3	3.7_{ba}
No of aged adults	1.3_{a}	1.1_{ab}	0.8_{abc}	0.5_{cd}	0.4_{cd}	0.2_{cd}	0.0_{d}	0.4_{cd}	0.6_{bcd}
No of children	0.0_{c}	0.4_{c}	2.4_{a}	2.5_{a}	2.3_{a}	1.6_{a}	2.0_{a}	2.3_{a}	2.2_{a}
No of adults equivalents	1.3_{c}	3.1_{b}	5.1_{a}	5.4_{a}	5.1_{a}	3.5_{ab}	5.0_{a}	4.8_{a}	4.6_{ba}
Education level of household head (years)	3.3_{c}	2.2_{c}	2.5_{c}	11.5_{a}	8.5_{ab}	6.6_{bc}	5.6_{bc}	5.5_{bc}	5.6_{bc}
Highest education level of any member (years)	3.3_{c}	6.5_{b}	10.6_{ab}	12.5_{a}	11.0_{ab}	7.2_{b}	8.6_{b}	9.4_{ab}	6.0_{b}
Livelihood outcome									
Mean total household income (R annum^{-1})	$15\ 780.00_{c}$	$15\ 664.38_{c}$	$18\ 163.24_{c}$	$76\ 536.89_{a}$	$42\ 624.92_{b}$	$14\ 653.33_{c}$	$9\ 013.80_{c}$	$20\ 088.64_{c}$	$14\ 883.33_{c}$
Minimum	12 780.00	9 630.00	10 850.00	48 490.00	22 285.00	4 220.00	5 440.00	3 490.00	4 465.00
Maximum	21 485.00	22 340.00	32 400.00	131 455.00	77 500.00	33 190.00	11 280.00	39 340.00	33 695.00
Mean total AEI (R month^{-1})	$1\ 038.00_{ab}$	452.74_{c}	322.43_{d}	$1\ 346.55_{a}$	747.39_{bc}	433.24_{c}	167.38_{d}	352.81_{d}	350.90_{d}
Minimum	959.46	193.71	156.63	662.14	322.29	117.51	101.79	53.95	99.84
Maximum	1 089.58	878.85	659.84	3 145.88	1 668.13	1 647.50	335.00	653.61	1 072.62
Gross farm income (R annum^{-1})	$4\ 580.00_{b}$	$2\ 869.38_{b}$	$3\ 477.35_{b}$	$4\ 739.38_{b}$	$4\ 095.69_{b}$	$10\ 436.67_{a}$	$6\ 529.80_{b}$	$2\ 774.09_{b}$	$4\ 791.11_{b}$
Gross margin of plot enterprise (R annum^{-1})	$1\ 064.33_{b}$	721.09_{b}	773.00_{b}	$1\ 108.38_{b}$	$1\ 361.08_{b}$	$5\ 727.60_{a}$	$2\ 787.60_{b}$	814.81_{b}	$2\ 434.22_{b}$

* The ANOVAS were done using livelihood types as factors (columns). Differences between means are differences between livelihood types for a particular variable (row). Statistically, means followed by different sub-scripted letters differed significantly ($p \leq 0.05$).

Among households in the different livelihood types, total household income was subject to considerable variability as indicated by the minimum and maximum values, and the same applied to AEI (Table 4.6). Skilled wage-earner households had the highest mean total household income and AEI, followed by unskilled wage-earner households. Subsistence farmer households were the poorest. The AEI of pensioner households decreased as the number of generations increased. The mean AEI of one-generation pensioner households was double that of two-generation pensioner households and three times higher than that of three-generation pensioner households. Households with large number of economically active adults did not necessarily obtain high levels of income. This was particularly evident among subsistence farmer households and three-generation pensioner households (Table 4.6). Market-oriented farmers had the highest mean gross farm income and the mean gross margin of their plot enterprises was also the highest (Table 4.6). This suggested that households in this livelihood type had a different approach to farming than households in the other livelihood types.

4.5 The farming styles concept

The farming styles concept developed by Van der Ploeg (1994; 2003) is used to guide the analysis of diversity in farming. Van der Ploeg (2003) describes farming styles as an integrating concept that portrays a particular way of practising agriculture. It is an expression of how farmers combine and order the elements that are used in the process of agricultural production. According to Van der Ploeg (2003) farming styles occur and can be studied in different inter-related domains, including strategic, structural, social and cultural.

In the strategic domain farming styles represent different decision-making models. In each style this model is based on a coherent set of strategic notions held by farmers about the way agricultural production should be practised. These strategic notions respond to cost-benefit relationships that have been determined empirically by farmers. In the structural domain a farming style represents an internally consistent and congruous application of specific production practices, techniques and resources. It arises from a selection of farm projects that are implemented in favour of other projects, which are not executed. The projects that are implemented are ordered into a workable model for income generation.

In the social domain a farming style reflects the interaction of farmers with the external world through relationships with other actors featuring in the farming sector, such as other farmers, suppliers of services and goods, traders, government and society at large. Developing and sustaining these various relationships is viewed as an active process, which becomes increasingly demanding as production becomes more market dependent.

In the cultural domain a farming style represents a repertoire, a particular way of practising agriculture that is adapted to local agro-ecology, available technology and markets. A cultural repertoire is a store of indigenous knowledge that is shared and reproduced among farmers, and that acts as a normative framework guiding the handling of land and the objects of farming. It is an open knowledge system that is continuously subjected to feedback, resulting in its affirmation or triggering its modification.

4.6 Farming styles at Dzindi

In Europe and Australia, farming styles research has been conducted in groups where agriculture was at the core of the livelihood of members (Van der Ploeg, 1994; Roep and De Bruin, 1994; Howden *et al.*, 1998; Vanclay, Mesiti and Howden, 1998). Under such circumstances deriving adequate income from farming was the overall objective of agriculture in the different farming styles that were identified. In the world of South African smallholder agriculture the overall objective of farming is not necessarily the generation of monetary income. The reasons for farming may vary between making a partial contribution to the food requirements of farming families to providing a full livelihood (Fraser, Monde and Van Averbeke 2003; Aliber, de Swardt and du Toit, 2005). As a result, strategically, diversity among smallholder farming styles is expected to reflect differences in the objectives of farming. When farming forms part of a broader livelihood strategy, which also includes non-farming projects, as is commonly the case among rural people in South Africa, the structure that characterizes the different farming styles is expected to be the result of an integration of all livelihood projects. This notion led to the analysis of relationships between livelihood types and farming styles, which is presented in section 4.7.

4.6.1 Data collection and analysis

Data on farming were collected during the 2003 census (see section 4.4.2). To investigate diversity in farming at Dzindi an economic analysis of the farm (plot) enterprises was conducted using gross margin and total variable costs as key variables. Gross margins were determined by deducting total variable costs from the gross plot income (Murphy and Sprey, 1983). At Dzindi, gross plot income (Penson, Capps and Rosson, 2002) was realised as sales, home consumption and produce that was given away in support of social networks. To estimate gross plot income the amounts of produce obtained by farmers for the different crops were converted to their monetary values using the farm gate prices obtained by each farmer individually, as described by Baber (1996). This method was selected, because all farmers sold at least a part of the harvest of all the crops they planted, with the exception of maize grain, which at Dzindi had a farm gate price that was not subject to variability. For the other crops the decision to use farm gate prices for each farmer individually was justified, because farmers reported crop yields using a variety of units, such as bunches for leafy vegetables, heads for cabbages and mugs or buckets for groundnuts and beans. Variability in the size of the units and possibly also differences in the quality of the produce were responsible for the observed variability in farm gate prices obtained by farmers for the different crops. Gross farm income was obtained by multiplying the amounts of produce allocated to home consumption, sales and gifts by the price the individual farmers charged when they sold the different crops. Total variable costs were defined as the sum of all variable farm inputs that were used during the year under consideration (Seitz, Nelson and Halcrow, 2002). Included were the costs of land preparation, seeds or planting material, fertilisers, chemicals and hired labour.

The first step in the data analysis aimed at identifying farming styles at Dzindi was to use a scatter diagram, which related gross margin to total variable costs for each plot, to visually identify initial clusters of plots on the graph. Gross margin and total variable costs were selected as independent variables, because they represent the financial balance sheet of a plot enterprise. Since the plots were identical in size, clusters or linear patterns in the distribution of data points on the scatter diagram were assumed to be an expression of differences in farming style. Once these clusters or linear patterns had been identified, key variables that appeared to explain the relative position of the clusters or patterns on the graph were used to quantitatively define farming styles.

Although *de jure* each plot is held by a single person, whose name appears in a register held at the Scheme, the Offices of the Thulamela Municipality and at the Sibasa office of the Limpopo Department of Agriculture, in practice not all plot holders at Dzindi hold user rights over their entire plot. In a survey of 48 farmers, involving probability sampling, it was discovered that only 54% of plot holders at Dzindi had control over their entire plot (see chapter 6). The remaining 46% shared their plots with kin. When responding to farm related questions in the 2003 census and the 2005 survey, farmers probably referred only to that part of the plot to which they had full user rights. This partly explains why some plot holders expressed a need for more land, whereas the survey data indicated that they did not make full use of the land they had at their disposal. It was not uncommon for family members who had been given user rights to one or more strips of a plot not to cultivate that land for several seasons in succession but the official plot holders did not necessarily request the family member concerned for the temporary use of the land, probably to avoid potential future conflict.

Farming styles are not usually defined quantitatively, because the boundaries separating the different styles are diffuse. Instead, the typological approach (Perret, 1999), which uses descriptions of what is typical of elements in the different categories is usually employed. The main advantage of defining categories quantitatively is that it allows for statistical comparisons among categories. One of the disadvantages is that quantitative definitions may fail to capture the essence of the different farming styles, because the number of variables that are used in quantitative definitions has to be limited. Another disadvantage is that the boundaries drawn by the definitions may result in the inclusion of elements that do not belong, or the exclusion of elements that do. The choice to use quantitative definitions was made, because a select number of quantitative variables (indicators) that appeared to account adequately for differences in farming style among farmers at Dzindi were identified.

The existence of the different styles that were identified was verified with farmers in a mass meeting. At this meeting farmers allocated *Tshivenda* names to the different styles. This resulted in a shared understanding among farmers and the researcher of the meaning of the different farming styles and what they represented in practice, which assisted mutual understanding and communication.

An analysis of variance (ANOVA) (Hatcher, Stepanski and Edward, 1994) was performed using the SAS® version 8 statistical package (SAS, Institute Inc., 2000), to identify to what extent the identified farming styles at Dzindi differed from each other statistically in terms of a selection of social, economic and farm enterprise variables.

As was the case for livelihood types, portraits of the different farming styles were developed using the transcripts of the semi-structured interviews. In the portraits livelihood and farming style were integrated to illustrate relationships between them.

4.6.2 Results

As indicated in the previous section, diversity in farming was analysed using a scatter diagram (Figure 4.3) that related gross margins and total variable costs of the 99 plot enterprises that were covered by the survey.

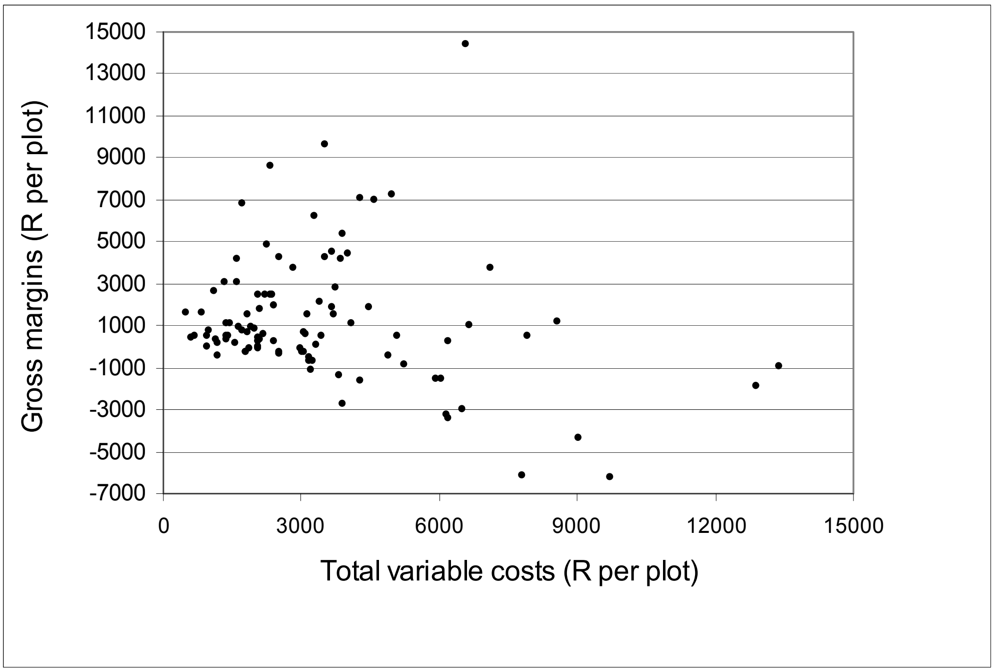

FIGURE 4.3: Relationship between total variable costs and gross margin obtained during the 2002/2003 season on 99 of 105 farm plots at Dzindi

In Figure 4.4 the data points were subdivided visually into three fields or clusters.

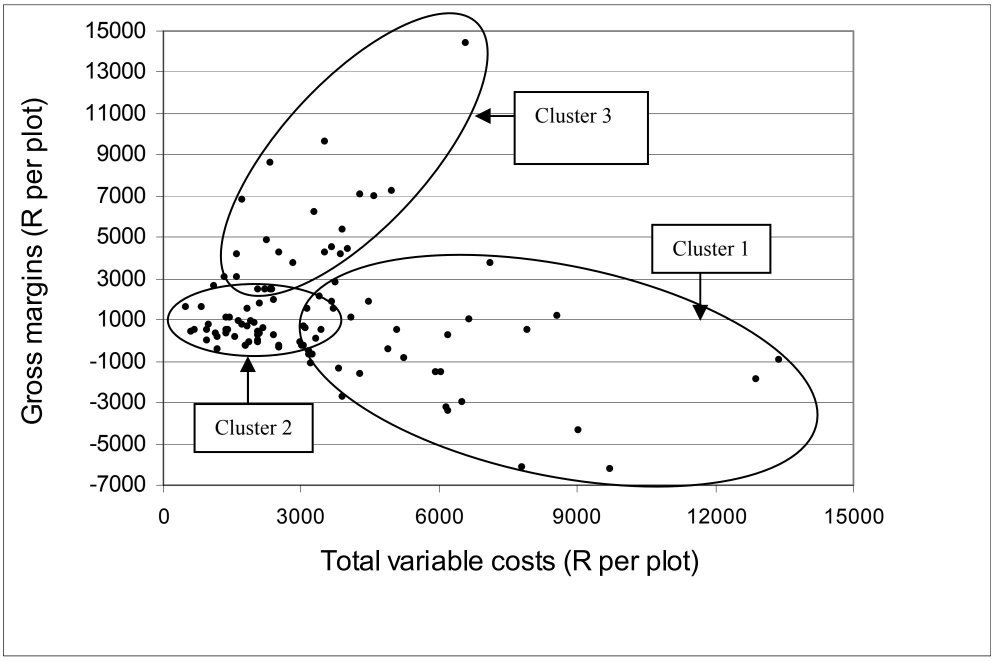

FIGURE 4.4: Preliminary clusters of plots at Dzindi

The first cluster in Figure 4.4 stretched from left-of-centre to bottom-right of the diagram and consisted of plots where the response in gross margin to increases in total variable costs tended to be negative. The second cluster occupied the centre-left of the diagram and consisted of plots where both variable costs and gross margins were low, generally less than R3 000.00. The third cluster stretched from left-centre to top-centre of the diagram and contained plots where the gross margin response to increases in total variable costs tended to be highly positive. Screening the three clusters of plots in function of farm-related variables resulted in the selection of four variables (Table 4.7), which appeared to explain the position of the three clusters on the scatter diagram (Figure 4.4).

TABLE 4.7: Selected farm-related variables characterizing the three clusters of plot enterprises identified at Dzindi (2002/03; n = 99)

Characteristic	Cluster 1	Cluster 2	Cluster 3
Total variable costs	High	Low	Low to medium
Gross farm income	Low to medium	Low	Medium to high
Type of labour	Full-time farm worker	Family labour and occasionally temporary hired help	Family labour and occasionally temporary hired help
Use of produce	Food for home consumption and sales	Mainly as food for home consumption	Mainly for sales

Using these four variables a key was developed to characterise the clusters of plots. Farming on plots in cluster 1 was characterized by high total variable costs and relatively low gross farm incomes. The data showed that in most cases the hiring of at least one full-time farm-worker was responsible for the high total variable costs. This characteristic was used to define the first farming style, which was called *vhalimi vhatholi*. In Tshivenda the word *thola* means to employ and in the ensuing text this farming style is referred to as employers. *Vhalimi vhatholi* or employers were defined as farmers who employed at least one full-time farm worker. Production on plots in cluster 2 was primarily aimed at production for home consumption and relatively little of what was produced was sold. The decision was made to use this characteristic for the identification of plots in cluster 2. Consequently, the second farming style was called *vhalimi vha u difusha.* In Tshivenda the term *u difusha* means to satisfy one's needs. In the case of *vhalimi vha u difusha* it refers to farmers whose agriculture is primarily aimed at producing food for own consumption, in short food farmers. *Vhalimi vha u difusha*, or food farmers, were defined as farmers who realised at least 50% of their gross farm income in the form of food for home consumption.

Market-oriented production characterized plots in cluster 3. Even more typical were the relatively high returns on investment in total variable costs of production the farmers holding these plots achieved. Accordingly, this third farming style was given the name of *vhalimi vhabinduli*. In the Venda language the word *bindu* means business. The term *binduli* refers to the making of money from a business. Farmers in this style all made a profit from farming. For this reason they are referred to in this text as profit-makers. *Vhalimi vhabinduli*, or profit makers, were defined as farmers who realised at least 50% of their gross farm income as sales and achieved a ratio of gross farm income to total variable costs of at least 2.

Following the definition of the three initial farming styles, several units (20 plot enterprises) were identified that did not fit any of these styles. They consisted of farmers who did not employ a full-time farm worker, realised less than 50% of gross farm income in the form of food for home consumption and achieved a ratio of gross farm income to total variable cost less than 2. No particular attributes could be identified for the purpose of characterising and possibly defining these remaining farmers. Instead they seemed to represent transitions between the farming styles that were defined. For the sake of convenience they were referred to as "others" and they do not feature in the discussion of farming styles presented below.

A further analysis of the ratio of gross farm income to total variable cost of enterprises in the different styles showed that food farmers could be subdivided into two sub-types, called food farmer type-1, characterized by a ratio less than 2 and food farmer type-2, where this ratio was at least 2. In Figure 4.5 a step-by-step identification of the key variables used to obtain these farming styles is presented on a tree diagram. Consequently, plot enterprises at Dzindi were assigned into four farming styles and Figure 4.6 shows the different farming styles on the same scatter diagram that was used in Figures 4.3 and 4.4.

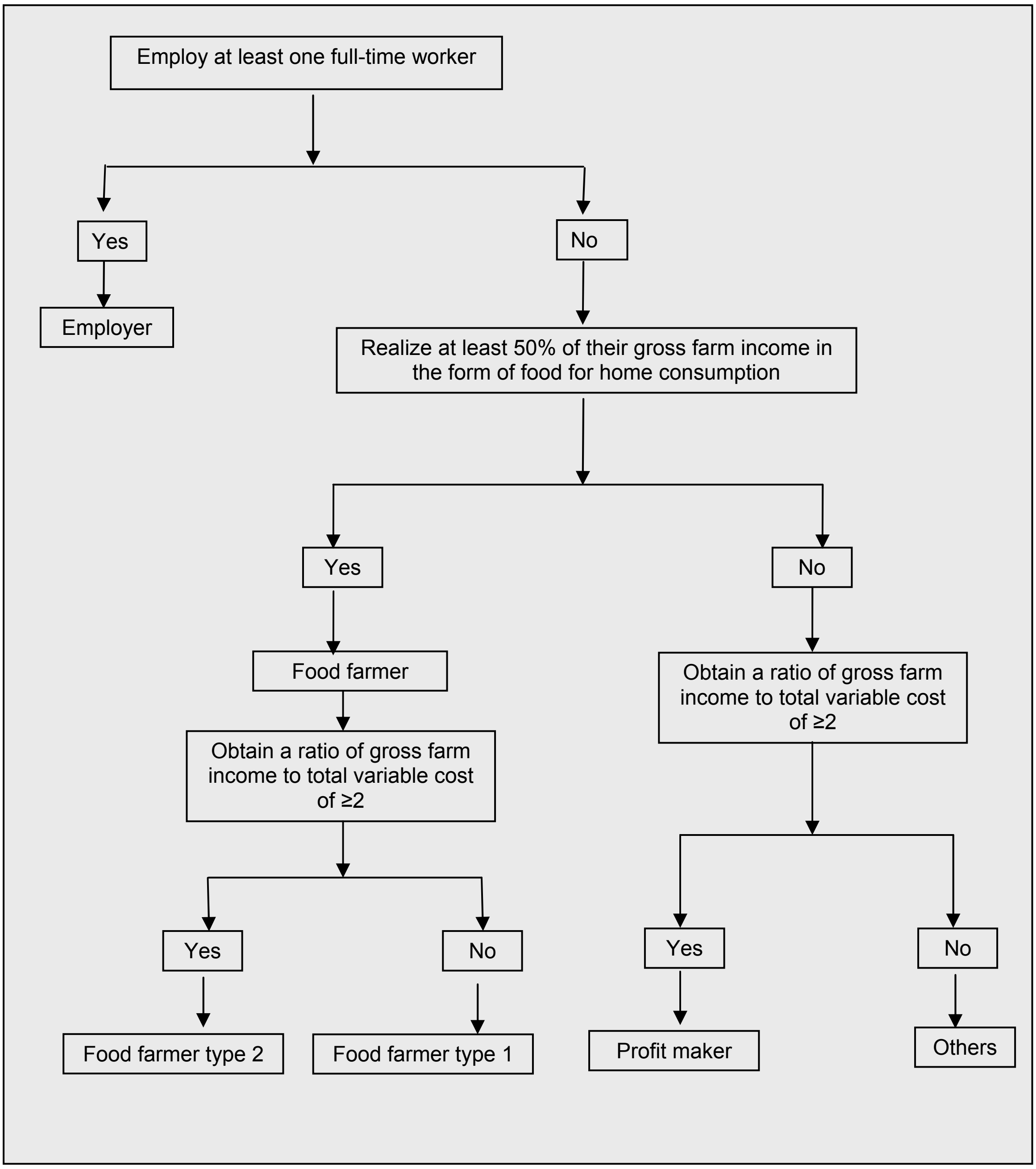

FIGURE 4.5: Key used to categorise plot enterprises at Dzindi for the development of farming styles

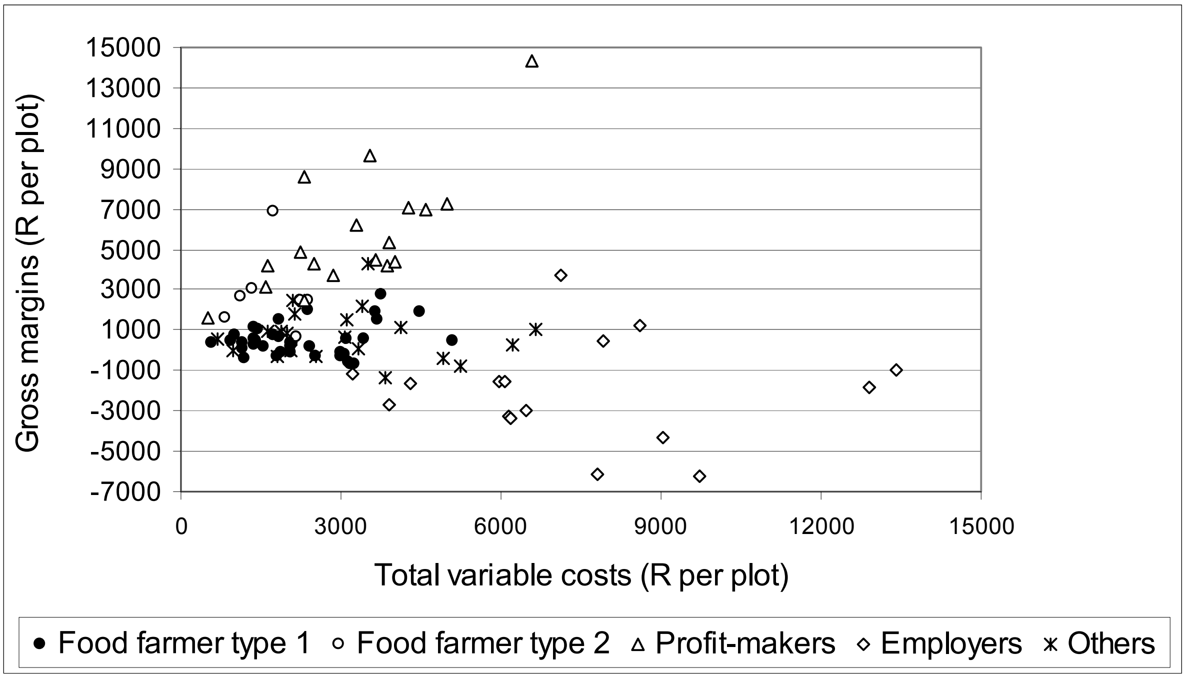

FIGURE 4.6: Farming styles identified at Dzindi

In Table 4.8 the mean values of selected social and economic characteristics of plot holder households in the different farming styles identified at Dzindi are shown. On average, households in the different styles were comparable in terms of age of head of household, household size, total household income and adult equivalent income. In terms of sources of income and their relative contributions to total, households in the different farming styles were on average also fairly similar. However, households in the profit-maker style, which on average had agriculture contributing 60% to their total household income, differed statistically from all other farming styles. In the other styles agriculture contributed on average between 20% and 30% to mean total household income.

TABLE 4.8: Social and income characteristics of plot holder homesteads by farming style at Dzindi (2002/03; n = 96)

Characteristics	**Farmer categories***					
	Employers (n = 16)	Food farmers type-1 (n = 37)	Food farmers type-2 (n = 7)	Profit-makers (n = 16)	Others (n = 20)	All (n = 96)
Age of plot holder (years)	62_a	58_a	59_a	53_a	61_a	58
Homestead size	5.4_a	7.0_a	7.0_a	5.4_a	5.3_a	6.0
Proportional contribution of different sources of income to mean total homestead income of plot holders (%)						
▪ Salaries and wages	20.5_a	21.3_a	11.8_a	15.7_a	14.8_a	18.2
▪ Remittances	5.2_a	3.4_a	0.0_a	0.1_a	1.6_a	2.5
▪ Welfare grants	37.0_a	39.0_a	35.2_a	21.6_a	41.8_a	36.0
▪ Agriculture	25.0_b	21.3_b	23.3_b	60.2_a	28.5_b	30.0
▪ Other sources	12.3_{ab}	15.0_{ab}	29.7_a	2.4_b	13.3_{ab}	13.2
Total homestead income (R)	$27\ 290.63_a$	$25\ 198.19_a$	$28\ 847.86_a$	$22\ 002.50_a$	$23\ 200.00_a$	24 864.15
Adult equivalent income (R/ month)	617.20_a	430.75_a	553.40_a	553.90_a	599.50_a	526.46

The ANOVAS were done using farming styles as factors. Differences between means are differences between farming styles for a particular variable (row). Statistically, means followed by different sub-scripted letters differed significantly ($p \leq 0.05$).

Table 4.9 shows the mean values of selected production-related variables for the farming styles identified at Dzindi. Farming in the different styles was similar in terms of mean total area planted during the year of study and also in terms of mean area planted during summer. It differed in terms of mean area planted during winter, with farmers in the employers and profit-makers styles planting twice as much land as food farmers. Plots in the food farmer type-2 style had the highest mean gross income per ha from summer production, followed by profit-makers whose plots produced the highest mean gross income per ha in winter. The high mean gross income per plot achieved by profit-makers during the winter season was associated with relatively high mean expenditure on farm inputs other than labour. In the study of the winter-vegetable commodity chain at Dzindi, presented in Chapter 3, it was shown that gross income from vegetable production was associated with choice of crop. White cabbages produced the highest gross income per unit area followed by Swiss chard, nightshade and Chinese cabbage.

Table 4.10 summarises selected themes that elaborate qualitative differences among the different farming styles at Dzindi. Among type-1 food farmers the key objective of farming was household food security through production for home consumption. They pursued this objective using a strategy aimed at minimizing the risk of losing money. One component of their strategy was to plant crops that featured prominently in the local diet, with maize occupying centre stage. Food farmers typically aimed at producing enough maize grain to supply their households for the entire year and only considered selling grain after the entire maize crop had been harvested, shelled and put into bags, enabling them to identify any surplus to their household requirements (Figure 4.7).

FIGURE 4.7: One of the food farmers at Dzindi threshing maize grain for storage at home

TABLE 4.9: Selected production-related variables by farming style at Dzindi (2002/03; n = 99)

Characteristics on the basis of single plots	*Farming styles**					
		Food farmers (n = 44)				
	Employers (n = 16)	Food farmer type-1 (n = 37)	Food farmer type-2 (n = 7)	Profit-maker (n = 18)	Others (n = 21)	All (n = 99)
Mean total area planted during the period July 2002 to June 2003 (ha)	1.28	0.99	0.85	1.13	1.11	1.08
Mean total area planted to summer crops (ha)	0.68	0.71	0.57	0.53	0.61	0.64
Mean total area planted to winter crops (ha)	0.60_{a}	0.28_{c}	0.28_{bc}	0.60_{a}	0.49_{ab}	0.44
Mean total gross farm income per ha for summer crops (R ha^{-1})	$4\ 236_{a}$	$3\ 307_{a}$	$8\ 739_{c}$	$6\ 195_{b}$	$3\ 748_{a}$	4 460
Mean total gross farm income per ha for winter crops (R ha^{-1})	$4\ 357_{a}$	$2\ 924_{a}$	$3\ 378_{a}$	$10\ 370_{b}$	$3\ 215_{a}$	4 603
Mean total cost of seeds used in winter (R)	254_{bc}	36_{a}	65_{ab}	338_{c}	141_{ab}	150
Mean total cost of pesticides used in winter (R)	190_{b}	88_{a}	89_{ab}	189_{b}	145_{ab}	135
Mean total cost of seeds per ha used in winter (R ha^{-1})	142_{a}	34_{a}	110_{a}	305_{b}	138_{a}	128
Mean total cost of pesticides per ha used in winter (R ha^{-1})	133_{ab}	88_{a}	119_{ab}	194_{b}	158_{ab}	131
Mean total cost of hired farm labour (R $annum^{-1}$)	4163_{a}	127_{b}	57_{b}	229_{b}	267_{b}	822
Mean expenditure on labour as a proportion of total variable costs (%)	56.8_{b}	5.3_{a}	3.0_{a}	6.0_{a}	6.8_{a}	13.9
Mean total variable costs (R $annum^{-1}$)	$7\ 422_{c}$	$2\ 304_{a}$	$1\ 684_{a}$	$3\ 256_{b}$	$3\ 101_{ab}$	3 429
Mean total gross farm income (R $annum^{-1}$)	$5\ 402_{b}$	$2\ 784_{c}$	$4\ 654_{bc}$	$8\ 966_{a}$	$3\ 861_{bc}$	4 692
Ratio of mean total gross farm income to mean total variable costs	0.7_{a}	1.2_{b}	2.7_{bc}	2.9_{c}	1.3_{ab}	1.6
Proportion of gross farm income realised as food consumed at home (%)	43_{c}	76_{d}	82_{d}	21_{a}	32_{b}	52
Proportion gross farm income realised as sales (%)	57_{b}	24_{a}	18_{a}	79_{d}	68_{c}	48

*The ANOVAS were done using farming styles as factors. Differences between means are differences between farming styles for a particular variable (row). Statistically, means followed by different sub-scripted letters differed significantly ($p \leq 0.05$).

TABLE 4.10: Qualitative differences among farming styles at Dzindi

Themes	**Farming styles**			
	Food farmer type-1 (n = 37)	**Food farmer type-2 (n = 7)**	**Profit-makers (n = 18)**	**Employers (n = 16)**
Farmer objectives and attitudes towards risk				
Farmer objective	Supply household with enough food.	Supply household with enough food and recover cost.	Generate cash income.	Supply household with food and recover costs.
Attitude towards risk	Avoid risk.	Accept low risk levels.	Accept high risk levels.	Accept low risk levels.
Farmer strategy				
Type of tractor service	Collectively-owned tractor because it is cheap.	Collectively owned tractor during winter; occasionally private tractor services during summer, when the waiting list threatens to delay date of planting.	Use private tractors or own tractor to plant all crops at the optimum time.	Collectively owned tractor, occasionally private tractor services when waiting list is too long.
Choice of crops	In summer maize and pumpkins. In winter nightshade and Chinese cabbage.	In summer maize and white cabbages. In winter small amounts of a wide range of different vegetables.	In summer green maize and white cabbages. In winter white cabbages and Swiss chard.	In summer mainly maize. In winte mainly nightshade and Chinese cabbage and some white cabbages and Swiss chard.
Planting date	Late in both seasons.	In summer on time. In winter late.	On time in both seasons.	Usually late in both seasons.
Plot use intensity	In summer ½ of the plot. In winter ¼ of the plot.	In summer ½ of the plot. In winter ¼ of the plot.	In summer ½ of the plot. In winter ½ of the plot.	In summer ½ of the plot. In winter ½ of the plot.
Approach to marketing	Passive.	Mainly passive.	Active.	Mainly passive.
Key constraints				
Expressed constraints	High cost of inputs. Too little water.	High cost of inputs. Too little water.	Lack of market. Small plot size. Too little water.	High cost of inputs. Too little water

During winter, type-1 food farmers mainly planted Chinese cabbage and nightshade, which are widely used as a relish by local people, creating a market for both (see chapter 3). Relative to the exotic vegetables that were grown at Dzindi, such as white cabbages and Swiss chard, Chinese cabbage and nightshade represented low risk options for two main reasons. Firstly, their total variable cost of production excluding labour was lower than that of white cabbages and Swiss chard, because the seed was produced on-farm and expenditure on chemicals to control pests was limited, especially when compared to white cabbages. Secondly, marketing of Chinese cabbages and nightshade was controlled by hawkers. Daily, these hawkers, invariably women, visited the scheme in search of Chinese cabbage and nightshade, walking from plot to plot in search of produce. Part of the produce that remained on the plots found a use as food for home consumption. Another part was given away to relatives and neighbours to nurture social relationships. Therefore, production of these two vegetables fitted both the farm objective and the risk-avoiding approach of the food farmer type 1 farming style. A second risk-avoiding component of the strategy of type-1 food farmers was the consistent use of the cheapest tractor service that was available, even when this implied delayed planting. The third component of the risk-avoiding strategy was to cultivate only small parts of their plots, especially during winter. By preparing and planting only a fraction of their plot, they limited their expenditure on total variable costs of production, eliminating the risk of losing more money than they could afford without placing strain on their livelihood. Relative to their farming objective, type-1 food farmers tended to store surplus grain at home or, in the case of good-quality white maize grain, deposited it at Magnifisan, the commercial milling company located nearby (Figure 3.5). Key constraints in farming raised by type-1 food farmers included the high cost of inputs and too little water for irrigation.

For type-2 food farmers, the key objectives of farming were household food security through production for home consumption and to recover costs. Relative to type-1 food farmers, who had the most conservative approach to farming, type-2 food farmers tolerated slightly higher levels of exposure to risk. They introduced small areas of white cabbages in both summer and winter in an attempt to better recover total variable costs of production. During summer they recovered expenditure on variable costs by offering part of their maize crop for sale as green maize. As was shown in chapter 3, at Dzindi, the gross margin in maize production was shown to be positively correlated with the proportion of the crop that was sold as green cobs. Typically, type-2 food farmers set aside a few beds of maize for this purpose and assigned the rest of their maize lands to grain production, to ensure that their household requirements for grain were met. Contrary to type-1 food farmers, type-2 food farmers were more inclined to sell surplus grain, in an attempt to generate cash income. Another low risk-acceptance component of the strategy of type-2 food farmers was the occasional use of privately owned tractor services during summer, when the waiting list threatened to delay the date of planting. Key concerns in farming for type-2 food farmers were the high cost of inputs and limited water for irrigation.

Employers also had household food security through production for home consumption as their main objective, but in addition they attempted to recover as much as possible their variable costs of production, which were particularly high as a result of the employment of a full-time farm worker. Their attitude to risk was similar to that of type-2 food farmers and they employed a similar strategy. However, the availability of a full-time farm worker enabled them to plant larger areas than type-2 food farmers. Generating cash income through the selling of crops, particularly in winter, was another strategy used by farmers in the employer style to pay for their farm workers. Key concerns of farmers practising the employer style were the high cost of inputs and insufficient water for irrigation.

The objective of profit-makers was to earn cash income from farming. In pursuit of this objective they adopted a strategy characterized by relatively high levels of risk. Generally, they did not grow the two indigenous vegetables produced by farmers in the other styles. Instead they produced mainly white cabbages during both summer and winter. As was shown in chapter 3, of the four important vegetables grown at Dzindi, white cabbages provided not only the highest gross income, but also the highest gross margin per unit area. However, cabbages were not an easy crop to produce in this sub-tropical environment, where success was highly dependent on effective plant protection. Relative to the large numbers of hawkers who purchased and retailed Chinese cabbage and nightshade, retailers who handled cabbages were few. To ensure a market for their white cabbages, profit makers engaged in actively marketing their produce. This process commenced well before the crop was ready for harvest. Farmers contacted potential clients using their personal cell phones and negotiated the details of the transaction. When the time of harvest arrived, the clients proceeded to the plot and harvested the cabbages that met their quality standards. All produce that did not make the grade was left behind. Consequently, relative to the production of the two indigenous vegetables production of white cabbages exposed farmers to a higher level of risk, because of the higher variable cost of production, the higher degree of market uncertainty and the more demanding quality concerns. To cope with higher levels of risk, profit makers elected to use superior services and goods, such as private tractor services, which were expensive but available when wanted, high quality commercial seed, including hybrid varieties and chemicals aimed specifically at the control of particular pests affecting white cabbages at the scheme. When growing maize, profit makers were mainly interested in selling the crop as green cobs. The same group of hawkers who were responsible for the trading of Chinese cabbage and nightshade handled the green maize trade, using the same process as for vegetables. They selected and harvested the maize cobs themselves and left any cob that did not meet their quality criteria on the plant. Typically, profit makers made their entire maize crop available for harvest as green cobs and only kept those cobs that were not harvested green for grain. Profit-makers' main concerns were the lack of reliable output markets, the small size of their plots and insufficient water for irrigation.

4.7 Relationships between livelihood type and farming style at Dzindi

To determine whether the identified livelihood types and farming styles were associated statistically, the Fisher's Exact Test was used. This test is used to examine the significance of the association between two categorical variables (Steyn *et al*., 1994; Hatcher, Stepanski and Edward, 1994). The test showed that overall, there was a statistically highly significant association between the livelihood type and the farming style ($p < 0.0001$).

The relationships between individual livelihood types and farming styles were examined by constructing a contingency table in which the observed frequencies were compared with the expected frequencies (Table 4.11). To be statistically valid this comparison required the use of the chi-square test, but because in many of the fields the observed frequency was less than 5, the use of the chi-square test was not recommended (Steyn *et al*., 1994). In Table 4.11 actual frequencies that are higher than expected frequencies indicate that the particular combinations of livelihood type and farming style are more common than expected. Conversely, actual frequencies that are lower than the expected frequencies indicate that the particular combinations of livelihood type and farming style are less common than expected.

Pensioner households were more likely to have the employer farming style than was expected (actual frequency of 9 and expected frequency of 6) and were less likely to have a profit-maker farming style than was expected (actual frequency of 1 and expected frequency of 6). The apparent association between the pensioner household and the employer farming style was somewhat surprising, because the mean labour force ratio was 56% among two-generation pensioner households and 55% among three-generation pensioner households (Table 4.3), suggesting ample availability of labour, and, therefore, a limited need to hire labour, let alone a permanent worker. The lack of interest in farming as a livelihood option among the second and third generation in these households was identified as the most plausible explanation for this phenomenon.

Farmer households were more likely to have the profit-maker farming style than expected (actual frequency of 11 and expected frequency of 3) and less likely to have the food farmer style (actual frequency of 4 and expected frequency of 9) or the employer farming style (actual frequency of 2 and expected frequency of 3).

Households active in the informal sector were more likely to have the food farmer style than expected (actual frequency of 8 and expected frequency of 4), but were less likely than expected to have the profit-maker farming style (actual frequency of 0 and expected frequency of 2), the employer farming style (actual frequency of 1 and expected frequency of 2) or the *other* farming style (actual frequency of 1 and expected frequency of 2).

Diversified-income households were more likely than expected to have the *others* farming style (actual frequency of 4 and expected frequency of 2) or the employer farming style (actual frequency of 0 and expected frequency of 2).

Among wage-earner households, the distribution of the different farming styles was more or less similar to that of the overall population.

TABLE 4.11: Relationships between livelihood type and farming style among plot holder households at Dzindi (n = 96, 2003)

Farming style	Livelihood type										Total
	Pensioner		**Wage-earner**		**Farmer**		**Informal sector**		**Diversified-income**		
	------------Frequency-----------										
	Actual	Expected	Actual	Expected	Actual	Expected	Actual	Expected	Actual	Expected	
Employer	9	6	4	4	2	3	1	2	0	2	16
Food farmer	17	16	11	10	4	9	8	4	4	4	44
Profit-maker	1	6	3	3	11	4	0	2	1	1	16
Others	9	8	3	4	3	4	1	2	4	2	20
Total	36	36	21	21	20	20	10	10	9	9	96

4.8 Dynamics in livelihood and farming at Dzindi

Change in livelihood and farming was investigated by comparing the 2003 census data with the 2005 survey data for the 48 households that were sampled for the 2005 survey. To guide the analysis, the households that were sampled were grouped in the five main livelihood types on the basis of the 2003 census results. Within these five categories, the livelihood type of each household was determined based on the 2005 survey data, using exactly the same procedures as those used to categorise livelihood type of households based on the 2003 census data. Change from one livelihood type to another was interpreted as evidence of change in the livelihood of the household concerned. The reasons for the change in livelihood type that had occurred were then determined for each case. Lastly, for each case 2005 adult equivalent income (AEI) expressed in 2003 Rand value was compared with the 2003 AEI to assess the impact of the change in livelihood type on livelihood outcome using AEI as the indicator.

4.8.1 Livelihood dynamics

4.8.1.1 Pensioner households: Table 4.12 presents the 2005 livelihood type of a sample of households that had a pensioner livelihood type in 2003.

Six of the 20 households had maintained the pensioner livelihood type, five had become wage-earner households, two had become farmer households and seven had become diversified-income households (Table 4.12). Among the households that had changed from the pensioner to the wage-earner livelihood type, the common feature was that one of the second or third generation members of these households had found formal employment. As a result, the reliance on welfare grants, particularly old-age pensions, for livelihood was reduced by the addition of employment as a source of income. The addition of this new livelihood activity caused the mean AEI of these five households to increase from R544.72 per month in 2003 to R1 153.30 in 2005 (2003 Rand value).

Generally, change from the pensioner livelihood type to the diversified-income livelihood type was not the result of important adjustments to the livelihood structure of the seven households concerned. For example, in one case the death of one of the two pensioners in the household was responsible for the shift in livelihood type. In others, there had been an increase in the contribution of sources other than welfare grants to total household income, reducing the contribution of these grants to less than 50% of total household income. Generally, the changes that had occurred had a positive impact on livelihood outcomes, because the mean AEI of these households was increased from R294.27 per month in 2003 to R414.46 per month in 2005. In both of the two households that changed from the pensioner to the farmer livelihood type, change was brought about by the passing away of the member that received an old-age pension. As a result, the household intensified its farming to compensate for the loss of this source of income. In both cases, the restructuring appeared successful because relative to their 2003 AEI their 2005 AEI was higher.

TABLE 4.12: The 2005 livelihood type categorisation of a sample of plot holder households at Dzindi that had the pensioner livelihood type in 2003 (n = 20)

Households that had the pensioner livelihood type in 2003			
Household	**AEI in 2003**	**Livelihood type in 2005**	**AEI in 2005[1]**
1	377.37	Pensioner	327.97
2	334.99	Pensioner	359.15
3	106.85	Pensioner	185.23
4	430.05	Pensioner	211.75
5	101.79	Pensioner	364.08
6	265.37	Pensioner	597.47
Mean	265.40		340.94
7	331.45	Wage-earner	896.69
8	643.63	Wage-earner	1 654.73
9	1065.00	Wage-earner	1 088.25
10	326.66	Wage-earner	1 240.46
11	358.12	Wage-earner	886.37
Mean	544.72		1153.30
12	156.91	Farmer	354.02
13	377.16	Farmer	725.31
Mean	267.04		539.67
14	228.50	Diversified-income	459.75
15	238.70	Diversified-income	221.18
16	271.42	Diversified-income	524.01
17	245.72	Diversified-income	467.73
18	634.29	Diversified-income	352.46
19	215.65	Diversified-income	366.18
20	225.62	Diversified-income	509.91
Mean	294.27		414.46
Overall mean	346.70		589.64

[1]2005 AEI was converted to 2003 Rand value

4.8.1.2 Wage-earner households: The 2005 survey contained nine households that were categorised as wage-earners in 2003. Six had retained the wage-earner livelihood type, one had become a pensioner household and two had become diversified-income households (Table 4.13). In the one household that had changed to the pensioner livelihood type, the wage earner in the household had retired and had become a pensioner (Table 4.13, household 7). This change resulted in a substantial reduction in the AEI of that household. In one of the two households that had changed into a diversified-income household, the wage earner in the household had been retrenched (Table 4.13, household 8). In the other petty trade had been added to the basket of livelihood activities, making income from wages relatively less important.

TABLE 4.13: The 2005 livelihood type categorisation of a sample of households at Dzindi that had the wage-earner livelihood type in 2003 (n = 9)

Households that had the wage-earner livelihood type in 2003			
Household	**AEI in 2003**	**Livelihood type in 2005**	**AEI in 2005[1]**
1	847.56	Wage-earner	594.77
2	725.80	Wage-earner	882.78
3	490.22	Wage-earner	770.13
4	515.36	Wage-earner	628.07
5	701.27	Wage-earner	958.06
6	699.70	Wage-earner	1 010.21
Mean	658.18		807.34
7	652.89	Pensioner	270.06
8	775.35	Diversified-income	676.54
9	322.29	Diversified-income	993.27
Mean	548.82		834.91
Overall mean	633.29		753.77

[1]2005 AEI was converted to 2003 Rand value

4.8.1.3 Farmer households: The 2005 survey contained 11 households that were categorised as farmer households in 2003. Three had retained the farmer livelihood type, five had changed to the pensioner livelihood type, one had become a household active in the informal sector and two had become diversified-income households (Table 4.14).

TABLE 4.14: The 2005 livelihood type categorisation of a sample of plot holder households at Dzindi that had the farmer livelihood type in 2003 (n = 9)

Households that had the farmer livelihood type in 2003			
Household	**AEI in 2003**	**Livelihood type in 2005**	**AEI in 2005[1]**
1	346.52	Farmer	745.09
2	351.67	Farmer	699.00
3	457.43	Farmer	386.51
Mean	385.21		610.20
4	334.99	Pensioner	359.16
5	101.79	Pensioner	364.08
6	182.16	Pensioner	412.54
7	117.51	Pensioner	232.60
8	787.31	Pensioner	529.56
Mean	304.75		379.59
9	394.02	Active in the informal sector	562.54
10	189.38	Diversified-income	530.34
11	204.48	Diversified-income	1 285.40
Mean	196.93		907.87
Overall mean	315.21		555.17

[1]2005 AEI was converted to 2003 Rand value

Two of the three households that retained the farmer livelihood type substantially increased their AEI between 2003 and 2005, suggesting that they had implemented farming system improvements. In four of the five households that changed from the farmer to the pensioner livelihood, the change came about as a result of the plot holder or the spouse reaching the age that qualified them to claim an old-age pension. In the fifth household there was no fundamental change to the structure of the livelihood. These five households had a mean AEI of R304.75 per month in 2003 and R379.59 per month in 2005, an increase of 25%.

The farmer households that changed into households active in the informal sector or diversified-income households added petty trade or the provision of services to their existing livelihood portfolios. In all three cases the diversification of their livelihood improved livelihood outcomes, as indicated by the substantial increase in AEI between 2003 and 2005.

4.8.1.4 Households active in the informal sector: Five households that were categorised as being active in the informal sector households in 2003 were included in the sample covered by the 2005 household survey. Only one maintained the same livelihood type, one changed to the wage-earner livelihood type, one to the farmer livelihood type and two to the diversified-income livelihood type (Table 4.15).

TABLE 4.15: The 2005 livelihood type categorisation of a sample of plot holder households at Dzindi that were categorised as being active in the informal sector in 2003 (n = 5)

Households that were categorised as being active in the informal sector in 2003			
Household	**AEI in 2003**	**Livelihood type in 2005**	**AEI in 2005[1]**
1	414.36	Active in the informal sector	385.32
2	494.28	Wage-earner	769.02
3	161.92	Farmer	95.99
4	262.17	Diversified-income	683.91
5	458.72	Diversified-income	690.91
Overall mean	358.29		525.03

[1]2005 AEI was converted to 2003 Rand value

Of the five sampled households that were categorised as active in the informal sector, only one had retained this particular livelihood type. In the household that changed into a wage earner household, one member of the household became employed. In the household that became a farmer household, the change in livelihood type was due to a lack of income from providing services during 2005. In 2003, this household derived most of its income from building-related services. During the period covered by the 2005 survey, little of this type of work had been secured, leaving the household to rely mainly on farming for its livelihood. In the two households that became diversified-income households change was brought about by the addition of livelihood activities to the existing portfolios. In three of the five cases, AEI increased as a result of the changes that occurred between 2003 and 2005.

4.8.1.5 Diversified-income households: Three households that were categorised as diversified-income households in 2003 were included in the sample covered by the 2005 household survey. Only one had retained that particular livelihood type (Table 4.16).

TABLE 4.16: The 2005 livelihood type categorisation of a sample of plot holder households at Dzindi that had the diversified-income livelihood type in 2003 (n = 3)

Households that had the diversified-income livelihood type in 2003			
Household	**AEI in 2003**	**Livelihood type in 2005**	**AEI in 2005[1]**
1	184.73	Diversified-income	337.36
2	106.85	Active in the informal sector	185.23
3	112.41	Child support grant	622.19
Overall mean	134.66		381.47

[1]2005 AEI was converted to 2003 Rand value

In the household that became active in the informal sector, there was no structural change in the livelihood portfolio. The observed change was merely due to the relative contribution of income sourced from engagement in informal sector activities rising to more than 50%. Change in the third household required the creation of a new livelihood type, namely the 'child support grant' livelihood type. This livelihood type emerged because of change in the legislation governing state grants in support of children of poor people. This change broadened access to this type of grant and raised its monetary value. In 2005, the household concerned obtained in excess of 50% of its income from claiming child support from the state, which improved its AEI considerably.

4.8.2 Farming style dynamics

In this section change in farming style during the period 2003 to 2005 is investigated. The approach that was followed was identical to the analysis of change in livelihood type.

4.8.2.1 Food farmers: Seventeen plot enterprises in which the food farmer farming style was practised in 2003 were contained in the sample covered by the 2005 household survey. Six of the 17 had retained the food farmer style, two had adopted the employer farming style, three the profit-maker farming style and six were categorised as *others* (Table 4.17).

TABLE 4.17: The 2005 farming style of a sample of plot enterprises at Dzindi that had the food farmer farming style in 2003 (n = 17)

Food farmer farming style in 2003	Farming style in 2005
--------Number of plot enterprises--------	
17	Food farmer: 6 Employer: 2 Profit-maker: 3 *Others*: 6

The two enterprises that changed from the food farmer to the employer farming style were brought about by the plot holders hiring a full-time farm worker. One of them hired a full-time farm worker because he had found employment and no longer had sufficient time to farm, whilst the other was a pensioner who hired a worker because he was no longer strong and fit enough to farm on his own. In the three enterprises which changed from the food farmer to the profit maker farming style, there was a re-orientation of the objective of production, from mainly subsistence to mainly market-oriented. In one of the cases this change was brought about by a young member of the household engaging in farming full-time after unsuccessfully trying to earn a living off-farm. In the six enterprises that changed from the food farming style to the *others* category no fundamental modifications to the way farming was conducted were identified.

4.8.2.2 Employers: Seven plot enterprises in which the employer farming style was practised in 2003 were contained in the sample covered by the 2005 household survey. In 2005, three of them had retained the employer farming style, two had changed to the food farmer farming style and two to the profit-maker farming style (Table 4.18).

TABLE 4.18: The 2005 farming style of a sample of plot enterprises at Dzindi that had the employer farming style in 2003 (n = 7)

Employer farming style in 2003	Farming style in 2005
--------Number of enterprises--------	
7	Employer: 3 Food farmer: 2 Profit-maker: 2

In all four cases where a farming style other than the employer farming style was adopted, the change came about by the retrenchment of the full-time farm worker. In the two cases where the food farmer style was adopted, the change was the direct result of the passing away of the plot holders, who were both pensioners. Losing the pension income, the two households concerned could no longer afford to keep their full-time farm workers, who were both retrenched. In the two cases where the profit-maker farming style was adopted, the households concerned retrenched their workers to increase the net returns from farming, increasing the allocation of family labour to agriculture.

4.8.2.3 Profit-makers: Nine plot enterprises in which the profit-maker farming style was practised in 2003 were contained in the sample covered by the 2005 household survey. In 2005, five had retained this farming style, one had adopted the employer farming style and the remaining three were categorised as *others* (Table 4.19). In the enterprise where the employer farming style was adopted, change was brought about by the plot holder finding off-farm employment. He substituted his own labour by that of a full-time worker, which caused the contribution of expenditure on labour to total variable costs of production to increase from 0% in 2003 to 12% in 2005 and the ratio of gross farm income to total variable costs of production to decline from 4.2 in 2003 to 1.0 in 2005. Similarly, in two of the three plot enterprises that changed to the *others* category, the change was due to the plot holder finding off-farm employment, bringing about a reduction in the intensity of farming. In the other case the plot holder qualified for a pension, which also brought about a reduction in the intensity of farming. In this particular household, the contribution of farming to household income decreased from 52% in 2003 to only 13% in 2005.

TABLE 4.19: The 2005 farming style of a sample of plot enterprises at Dzindi that had the profit-maker farming style in 2003 (n = 9)

Profit-maker farming style in 2003	Farming style in 2005
--------Number of enterprises--------	
9	Profit-maker: 5 Employer: 1 *Others*: 3

4.8.2.4 Others: Thirteen plot enterprises that were categorised as *others* in 2003 were contained in the sample covered by the 2005 household survey. Six remained in this category, four adopted the food farmer farming style, two the profit-maker farming style and one the employer farming style (Table 4.20).

TABLE 4.20: The 2005 farming style of a sample of plot enterprises at Dzindi that were categorised as *others* in 2003 (n = 13)

***Others* in 2003**	**Farming style in 2005**
--------Number of enterprises--------	
13	*Others*: 6 Food farmer: 4 Profit-maker: 2 Employer: 1

The *others* category of farm enterprises represented a transitional farming style, because it had characteristics of both the food farmer and the profit-maker farming styles. Change from the *others* category to either the food farmer or the profit-maker farming style is, therefore, not necessarily due to important alterations to the way in which farming is conducted. This argument was supported by the data. In all four cases, change to the food farmer style was brought about by an increase in the value proportion of the produce allocated to home consumption (on average it increased from 43% in 2005 to57 % in 2005). In the two enterprises that changed to the profit-maker style, change was caused by an increase in the ratio of gross farm income to total variable costs of production from slightly less than 2 to slightly more than 2. In the enterprise that changed to the employer farming style, the plot holder qualified for a pension and decided to employ a full-time farm worker to assist him on his plot.

The comparison between livelihood type based on principal source of income in 2003 and again in 2005 among a sample of 48 households revealed that the livelihoods of plot holders at Dzindi were highly dynamic. Of the 48 households covered by the analysis, 31 (65%) had changed their livelihood type during this two-year period. In the majority of the cases (26 of 31) the change in livelihood type was brought about by change in the livelihood portfolio of the households concerned. Examples of portfolio changes were household members finding employment or being retrenched, household members becoming eligible to claim an old-age pension or pensioners passing away, households gaining access to child support grants and new activities being added to existing livelihood portfolios.

What applied to the livelihood of plot holder households at Dzindi also applied to their farming styles. The approach to farming at Dzindi was shown to be subject to considerable change as evident from changes in the farming style of 28 (58%) of the 48 households that were surveyed in both 2003 and 2005. In several cases, change in farming style was clearly in response to change in the structure and content of the livelihood portfolio. As a result, change in farming style occurred in all directions. Important also was that change occurred very rapidly, indicating that circumstances on smallholder irrigation schemes allowed for the transformation of a subsistence enterprise to a market-oriented enterprise (and *vice versa*) in a matter of one or two years.

4.9 Livelihood and farming of plot holders at Khumbe and Rabali

4.9.1 Methods

To investigate livelihood and farming at Khumbe use was made of the focus group method. A survey of a selection of individual farmers using a structured questionnaire was also conducted.

Khumbe counted 118 plots of 0.65 ha each. These plots were clustered in four irrigation blocks referred to as A, B, C and D. Block B, the largest of the four, had 65 plots. Block A had 31 plots, and Block C and D 11 plots each. Three focus group studies were conducted. The first involved five farmers from block A, the second ten farmers from block B, and the third five farmers from blocks C and D combined.

At Rabali, using the advice of the chairperson of the Natural Resource Committee, Mr Mudau, the scheme was subdivided into three sections, namely blocks 1 to 3, blocks 4 to 6 and block 7 to 11. A separate focus group was created for each of these three subdivisions. Each focus group consisted of five plot holders whose plot was part of the subdivision they represented.

At the start of the focus group studies the objective was explained. Then participants were asked to identify differences among plot holders within their sub-section in terms of farming, and to describe the characteristics that differentiated the farmer categories that were identified. For each of the farmer categories that were identified a symbol was decided on, and this symbol was drawn on an index card. Then the name of each plot holder in the subsection was read out to the participants. As a name was read out, participants discussed among each other in which farmer category the plot holder belonged until consensus was achieved. Following the analysis of diversity among farmers, participants were asked which sources other farming plot holder households in their irrigation blocks obtained income from. All the sources that were identified were listed. Then for each farmer an individual index card was generated on which the information about sources of income provided by the participants was recorded.

4.9.2 Livelihood of plot holders at Khumbe and Rabali

Using the information provided during the focus groups the plot holder households at Khumbe and Rabali were categorised into the main livelihood types that were identified at Dzindi. The results of this categorisation are presented in Table 4.21. Data for Dzindi are included for the purpose of comparison.

TABLE 4.21: Livelihoods typology of plot holders at Dzindi, Khumbe and Rabali

Livelihood type	Dzindi (n=97)	Khumbe (n = 31)	Rabali (n=70)
		(%)	
Welfare dependent households	31	49	51
Skilled wage-earner households	8	16	10
Unskilled wage-earner households	13	19	4
Farmer households	21	0	7
Households active in the informal sector	11	16	24
Diversified households	9	0	4
Total	**100**	**100**	**100**

Although the data collection method used at Dzindi (detailed questionnaire survey) differed from that used at the other two schemes (focus groups), certain similarities among all three schemes did emerge. What was abundantly evident was that plot holders at the three schemes constructed their livelihoods in different ways. At Dzindi, pensioner households (welfare dependent households) were identified as the largest group. Relative to Dzindi, state transfers (old-age pensions and child support grants) played an even more important role in the livelihoods of households at Khumbe and Rabali. At Dzindi a relatively larger number of farmer households (21%) were identified than at Khumbe (0%) and Rabali (7%). This was probably partly due to the difference in data collection method used, but the overall impression was that farming at Rabali, where the plots were the same size as at Dzindi was less intensive than at Dzindi. At Khumbe the small size of the plots may be preventing plot holders from relying solely or mainly on farming for their livelihoods.

4.9.3 Farming at Khumbe and Rabali

4.9.3.1 Khumbe: The focus group representing Irrigation Block A was the only group that identified differences among farmers. These included differences in choice of crop, differences in the area planted to crops in summer and winter, differences in wealth, particularly with reference to being able to afford tractor services, and differences in access to water. After discussing these differences thoroughly, the farmers in Block A concluded that wealth was the key determinant of diversity in farming in their section of the Scheme. Consequently, they categorized farmers into two groups, namely farmers with money and farmers without money. Farmers with money (16 out of 31) planted large portions of their plots in both summer and winter. In winter they produced maize, cabbage, spinach, onions and Chinese cabbage. Winter production was primarily aimed at generating income. Maize that was planted in winter was usually aimed at sales on the green cob market. In summer farmers with money mainly planted maize, but now the crop was aimed primarily at satisfying the annual maize grain requirement of their households. Farmers without money (15 out of 31) focused mainly on summer production of maize to produce grain for their households. In winter they produced vegetables on a small part of their plots, leaving the rest fallow. Typically these vegetable plantings contained a range of species, including indigenous vegetables. As in summer, the objective was primarily to produce food for home consumption.

The focus groups involving representatives of irrigation blocks B, C and D were of the opinion that there were no differences among farmers in their blocks. All were poor, and they all had problems with accessing tractors and water.

4.9.3.2 Rabali: In the first focus group, which consisted of representatives of irrigation blocks 1 to 3, participants identified two farmer categories, namely 'farmers with money' (1) and 'farmers without money' (16). Participants described the single farmer with money as one who was able to prepare his land and purchase inputs whenever he wanted or needed to, because he had a lot of money. This, in turn, enabled him to achieve good quality crops and high yields. His production system was characterized by year-round use of most of his plot. In summer he planted mainly maize for the green cob market, with only the remainder of the cobs being kept for grain, and often the grain was sold also. In winter he planted a range of vegetables, including tomatoes, butternut, onions, cabbages, dry beans, Chinese cabbage and Nightshade. Again the main purpose was to market the harvests. Farmers without money were described as those who struggled to raise the funds required to prepare their land and to purchase the necessary inputs. Participants pointed out that a lack of cash to purchase the necessary services or products when these were needed prevented farmers without money to farm commercially and limited them to the production of food for home consumption mainly. Farmers without money were said to use their plots mostly during summer to produce maize grain for consumption by their households. Occasionally they also planted dry beans on a small part of their plot, again for food purposes. In winter they used a small section of their plot, typically 0.1 ha, to produce a range of vegetables for home consumption and the occasional sales or donations.

In the second focus group, which consisted of representatives of irrigation blocks 4 to 6, participants again identified two farmer categories, namely 'farmers who can afford to purchase inputs' (9) and 'farmers who cannot afford to purchase inputs' (8). Participants explained that 'farmers who can afford to purchase inputs' planted whenever they wanted to and applied fertilisers. During winter they planted a large portion of their plot to vegetables, including tomatoes, cabbages, onions, Chinese cabbage and dry beans. These vegetables were grown primarily for marketing purposes. In summer they produced maize and groundnuts, usually planting their entire plot. Maize was planted early and even though this crop was mainly grown for grain, some was also sold as green cobs. Groundnuts were sold to petty traders. 'Farmers who cannot afford to purchase inputs' planted only maize in summer and in winter they cultivated a small section of their plots to leafy vegetables, such as Chinese cabbage, Swiss chard and Nightshade. Typically summer maize was planted late. This group of farmers often engaged in share-cropping to reduce the cost of production.

In the focus group representing irrigation blocks 7 to 11 one member dominated the discussions and he forced the others to accept his views. When a participant pointed out that money was the key differentiating factor among farmers, he argued that the overriding factor affecting all farmers in blocks 7 to 11 was the lack of water, because their plots were situated at the tail end of the canal. On several occasions other participants indicated that despite the problem of water, there were still differences among plot holders, but such views were always suppressed with the argument that all farmers were lacking water. During a transect walk through the scheme there was no visible difference between land use in the first six blocks and that in blocks 7 to 11, suggesting that differences in access to water between sections of the scheme were exaggerated. This was confirmed by the Chairperson of the Natural Resources Committee, who is responsible for water distribution at Rabali, and who also holds a plot towards the tail end of the Scheme. The dynamics in this focus group prevented the development of a farmer categorization.

4.10 Synthesis of the findings on livelihood and farming on smallholder irrigation schemes

4.10.1 Livelihood activities

The analysis of plot holder livelihood at the three smallholder irrigation schemes showed that households engaged in a wide range of livelihood activities, both on-farm and off-farm. In addition, they obtained a substantial portion of their income from claiming against the state. Agriculture was an important livelihood activity among plot holders at the three schemes. At Dzindi, income derived from agriculture contributed 29.7% to mean total household income in 2003 and was by far the most important local economic activity.

4.10.2 Livelihood capabilities

The study of livelihood at Dzindi showed that livelihood capabilities had a quantitative and a qualitative dimension. The quantitative dimension was concerned with the number of members of a household who could engage in livelihood activities. In this study, this type of household members were defined on the basis of age and referred to as economically active members. They were persons aged between 15 and 64 years old. The labour force ratio, which expresses the number of economically active members relative to total household size, provided an indication whether or not the number of economically active members in a household was adequate to support the household. In 2003, the mean labour force ratio of plot holder households at Dzindi was 67%, which is high, suggesting that numerically and on average, plot holder households had adequate capability to engage in livelihood activities. The qualitative dimension of livelihood capabilities was concerned with skills, competencies and qualifications to perform different livelihood activities. The study provided evidence that educational qualifications of plot holders or members of their households were associated with household income. When household members with educational qualifications were able to find employment commensurate with their qualifications, the income of their households tended to be high. This is indicated by the income of skilled wage-earner households, which was by far the highest of all the livelihood types that were identified (Table 4.3). However, in several households there were members with educational qualifications who had not found work, particularly in the three-generation pensioner households, indicating that formal qualifications were not a guarantee for professional employment. Vocational training was also important in the development of livelihood capabilities, providing livelihood opportunities in the informal sector. Skills in farming were essential when seeking to transform a subsistence enterprise into a market-oriented enterprise. Within households basic farming skills were transferred from one generation to the next, but the portrait of one of the market-oriented farmers at Dzindi indicated that more advanced knowledge of farming was required to create a successful market-oriented plot enterprise. This portrait also indicated that the current information transfer system at Dzindi was inadequate to provide access to advanced farm knowledge and skills.

4.10.3 Livelihood stores

Among plot holder households at Dzindi two important categories of livelihood stores were identified, namely monetary stores and food stores. Households in all livelihood types had monetary savings. There were no clear differences among livelihood types in the amounts of money being saved, although, wage-earner households, especially skilled wage-earner households, tended to have the highest level of savings and one-generation pensioners the lowest (Table 4.3). Plot holder households used different institutions to save money, including stokvels (*mgalelo*), burial societies and formal financial service providers. Funeral policies were the most widespread means of saving money, indicating that plot holders placed a high priority on ensuring that they would receive a ‘decent burial’ without placing a financial burden on their families.

Maize grain was the most common form of food store among Dzindi households. Some also stored dry vegetables. Storing maize grain was particularly prevalent among food farmers. Typically the aim was to store enough maize to provide for the family for an entire year. Maize was either stored at home or was delivered to the Magnifisan Milling Company, where it was exchanged for a credit note, enabling plot holders to obtain maize meal at any time without having to worry about post-harvest damage to the grain. The different portraits indicated that the general level of food security among plot holder households at Dzindi was higher than that reported for selected dryland communities (Monde, 2003).

4.10.4 The role of farming in the livelihood of plot holder households

At Dzindi, farming was central in the livelihood of about one in five plot holder households. This statement was based on the observation that more than half of their income was derived from this irrigated farming. For the others the use of the plot was a supplementary or complementary livelihood activity. The portraits provided evidence that among many plot holder households at Dzindi there were occasions during their lives when farming had occupied central stage in their livelihood. In most cases the evidence indicated that constructing a livelihood that was entirely based on farming proved difficult. As a result, after relying on farming for a few years they once more engaged in off-farm employment. There were exceptions in the form of selected market-oriented farmers who were able to achieve reasonable livelihood outcomes from farming. Almost invariably they sought to expand their operation but the prevailing circumstances were not conducive for this to happen. They resorted to cultivating non-scheduled parcels of land and invested in other farm-related activities, such as the purchase of a tractor, which enabled them to earn money by providing land preparation services to others. Since inception of the Dzindi Scheme, market-oriented farmers have corresponded with the vision of policy makers because from an economic perspective they make most effective use of the available resources. However, this study indicates that among smallholder communities market-oriented farmers have always been a minority group, irrespective of the policy measures that prevailed.

The decision by plot holders to live from farming was in several cases made when other livelihood options were closed. This indicated that the irrigated plot and farming represented a fall-back option to be exercised during a livelihood crisis, such as the loss of a job or the passing away of a grant holder. As a result, it was not uncommon to find a plot at Dzindi not being cultivated for a year, because the plot holder household had become involved in other livelihood activities and to find the plot in full production the year after, because circumstances had changed. Many of the subsistence farmer households, which were the poorest group at Dzindi, were in a stage of livelihood transition. They used farming to survive, whilst exploring other livelihood options.

4.10.5 The irrigated plot as a livelihood asset

The empirical evidence indicated that the plot was an asset that allowed for flexibility in the way it was used. It could be left dormant when circumstances favoured mobilisation of the available household labour for off-farm livelihood activities; be partially activated when the structure of the livelihood of a household enabled multiple livelihood activities; and be fully activated when circumstances demanded farming to occupy central stage in the livelihood of the household. Consequently, from a livelihood perspective viewing the plot merely as a productive asset is a perspective that is too narrow.

As a productive asset the plot enabled households to achieve one or more of the following livelihood outcomes: (i) improved food security; (ii) increased household income through reduction in food expenditure and sale of crops; (iii) reduced vulnerability to livelihood stresses and shocks; (iv) poverty alleviation or avoidance; and (v) provision of full livelihoods. One other possible economic use of the plot as a livelihood asset was the renting out of the plot or part thereof against payment, or in return for certain services, such as land preparation. Demand for land existed at Dzindi, but up until 2005, renting out land was very rare among plot holders, because it was discouraged by the community and its leadership. However, towards the end of this project, selected plot holders had ventured into renting out of parts of their plots, but only to other plot holders and usually in return for the preparation of the rest of the plot free of charge. There were also indications that the future generation was more open to the idea of earning income from renting out their plot.

As indicated, plot holders did not only value their plots for its productive capacity. There were other reasons why the plot was important. The livelihood security that a plot could provide following a livelihood shock was an important factor that made plot holders to cherish ownership. Both their personal and their collective experiences, which stretched over more than 50 years, had taught plot holders at Dzindi that when all else failed there was always the plot that could be relied upon to provide, if not monetary income, at least food. Plot holders not only looked at the past when gauging the security value of their plots, they also considered the future generation.

4.10.6 Degree of poverty

In contemporary rural South Africa poverty is widespread. The study results indicated that the degree of poverty at Dzindi was less than in selected dryland settlements for which recent data were available (Table 4.22). For example, in Limpopo Province in 2001, the poverty rate among households

TABLE 4.22: Distribution of poverty in five rural settlements in South Africa

Poverty class	**Dzindi (Limpopo)[1]**	**Ga-Molekane (Limpopo)[2]**	**Sekuruwe (Limpopo)[2]**	**Koloni (Eastern Cape)[3]**	**Guquka Eastern Cape)[3]**
Year of survey	**2003 (n = 97)**	**2001 (n = 80)**	**2001 (n = 51)**	**1999 (n = 60)**	**1999 (n = 68)**
			----------(%)----------		
Non poor	40	20	28	25	4
Poor	34	41	29	30	37
Ultra poor	26	39	43	45	59
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

[1]Current study; [2]Khosa (2003); [3]Monde (2003)

in Sekuruwe was 71% and 80% in Ga-Molekane (Khosa, 2003). In 1999 in the Eastern Cape, the poverty rate among households in Koloni was 75% and 96% in Guquka (Monde, 2003). Among households at Dzindi, the poverty rate was only 60% in 2003 and the 2005 household survey suggested a further reduction, because a general increase in AEI was observed.

Among the different types of households at Dzindi subsistence farmer households were the poorest. In 2003, these households had a mean income of about R167 per adult equivalent per month, which was less than half of the poverty line (R230.72 per adult equivalent per month). Consequently, from an absolute poverty perspective they were considered ultra-poor. Household types that were on average categorized as poor included three-generation pensioner households (R322 per adult equivalent per month), diversified-income households (R351 per adult equivalent per month), households active in the informal sector (R353 per adult equivalent per month), market-oriented farmer households (R433 per adult equivalent per month) and two-generation pensioner households (R453 per adult equivalent per month). Three types of households had mean incomes above the poverty line. These were the unskilled wage earner households (R744 per adult equivalent per month), the one-generation pensioner households (R1038 per adult equivalent per month) and the skilled wage earner households (R1347 per adult equivalent per month).

4.10.7 Livelihood outlook of plot holders

In many cases the livelihoods of plot holder households at Dzindi, especially those based on off-farm activities, were vulnerable. One way of dealing with this vulnerability was to invest in the education of the next generation. Generally the hope of most plot holders was that through education their children would find good jobs. However, there was also the realization among many parents that if that scenario did not materialize, the other legacy they could leave behind for their children was the plot, which they knew from their own experiences and those of their parents, would offer their children a way to survive or even make a decent living. The portraits provided an outlook on what plot holders aspired to achieve in their livelihood. Investment in the development of capabilities among their children through formal education indicated the type of livelihood they wished their children to have. Monetary investment in the development of livelihood capabilities among children was almost exclusively oriented towards the construction of off-farm livelihoods. Investing in off-farm livelihood capabilities was probably influenced by the general perception among households that off-farm livelihoods, especially those based on professional capabilities, were the most successful. The validity of this perception that prevailed among people at Dzindi was supported by the survey results. On the other hand, investment in the farming capabilities of their children through informal processes of learning suggested that parents also prepared their children for land-based livelihoods. The concern of households to develop farming capabilities among their children, underlined the importance they assigned to agriculture. Generally parents believed that agricultural knowledge and skills were best transferred in an informal way. As a result, farming capabilities were passed on from parents to children through a process of 'learning by doing'. Several households were encountered where plot holders' children were being equipped with farming knowledge and skills by means of this process.

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5 SOCIAL AND INSTITUTIONAL DIMENSIONS OF SMALL-HOLDER IRRIGATION

5.1 Important concepts

Farming has many dimensions, including bio-physical, technical, economic, and social. In South African agricultural research, the social dimension of farming has received relatively little attention. Yet, interactions and relationships among people and groups feature prominently in farming activities and processes and they form an integral part of farm management. On smallholder irrigation schemes, examples of domains in which the social dimension of agriculture is important are the homestead as a social unit, the scheme and its resources and the markets for inputs, produce, labour and services.

Social behaviour is guided by norms. Norms are cultural phenomena that prescribe behaviour. Norms reflect shared beliefs and ideas about various facets of society. They include formal rules and laws, as well as informal social controls. They encourage or give permission to behave in certain ways and discourage other ways of behaviour. Norms also sanction undesirable behaviour (Ellickson, 1991).

A system of norms mimics a legal system. It explains the expected behaviour, including its procedural characteristics, and clarifies how aberrant behaviour is dealt with (Eggertsson, 2001). Hechter and Opp (2001) distinguish between (i) moral norms, which prescribe behaviour that most people would practise anyway, or proscribe behaviour which most people would not practise even in the absence of such norms and the associated threat of sanctions, and (ii) coercive norms, which prescribe behaviour that most people would not otherwise practise or proscribe behaviour that most people would practise in the absence of such norms.

Norms link social behaviour to institutions or rules. Rules are systems of expectations. They clarify the rights, responsibilities, and obligations of members of the group and nurture, protect and govern the operation of the group (Swift and Hamilton, 2001; Eicher, 1999; Hubbard, 1997).

Rules can be externally imposed or they can be formulated from within. Introduction of new technology is one of the circumstances in which rules are imposed from the outside. Although externally imposed rules often ignore the cultural orientations of recipients, they can be internalised. Internalisation is assisted when the rules are compatible with the recipients' way of life and when they govern the use of a new resource that is of benefit to recipients and for which there was a need in the community (Rogers, 1995). Rules created from within are the result of social dynamics within the group, whereby the focus is on matching group goals to the diversity of interests among group members. Generally, rules crafted through internal social processes are easily understood and well respected by members of the group, because members took part in the negotiations that lead to their formulation. \

To be effective rules need to be enforced. The intensity of enforcement needed to make rules effective depends on whether the rules are close to moral norms or not (Eggertsson, 2001). When rules are close to moral norms, less external enforcement is required because individuals sanction themselves through feelings of remorse and guilt.

Conversely, rules that are far removed from moral norms typically require a lot of enforcement.

This chapter is concerned with the social and institutional dimensions of farming on smallholder canal irrigation schemes. The social arenas that were investigated include (i) the sharing of water among smallholders; (ii) the maintenance of infrastructure; (iii) accessing markets; (iv) land tenure and exchange; and (v) land preparation.

5.2 Sharing of water at Dzindi

5.2.1 Introduction

On canal irrigation schemes the amount of water that enters the distribution system does not allow farmers to irrigate whenever they wish to. On the contrary the amount water is sufficient only to allow a limited number of farmers to draw irrigation water. In the absence of individual reservoirs in which water is stored for use at the discretion of farmers there is a need to have a system of water sharing in order to provide all farmers with water. Practically this means the adoption of a time schedule which stipulates when each of the plot holders have the right to draw water from the system. In this section the social and institutional system of water sharing among farmers at Dzindi is analysed.

5.2.2 Methods

Data were collected from different sources using a range of methods during the period January 2003 to September 2005. The first part of the study sought to document the content of the institutional and organisational system used to manage water at Dzindi and to analyse its underlying values. Historical information on the water management rules and associated organisational arrangements was obtained by constructing a time-line in which a collective of plot holders engaged in the participatory reconstruction of the history of the scheme with special attention to how irrigation water was managed. Additional detail was acquired by conducting focused interviews with individual participants, especially the five surviving plot holders who were present when Dzindi was established. The current situation was documented using written records held by the Scheme Management Committee and interviews with members of that Committee, the water bailiffs, the local extension officer and selected farmers in the different irrigation blocks.

During the subsequent phase of the study, the practical application of the water management system was investigated using consecutive cycles of data collection, analysis, and interpretation. Data collection methods involved participant observation of Scheme Management Committee meetings; field observations made during transect walks through the scheme, alone or in the presence of the bailiffs, and face-to-face interviews with a multitude of farmers and other participants.

Obtaining information about the rules and the organisational system that was used to manage water at Dzindi was relatively easy, because participants treated this information as public. For the same reason, recorded offences against the rules were discussed freely. However, the institutional and organisational water management system also had an informal part, which was particularly relevant to the way conflicts between plot holders over irrigation water were avoided or resolved. Collecting information on the informal, hidden part was tedious. Essentially participants were only prepared to discuss a particular element of the informal part when presented with evidence that the authors had uncovered that element, and even then some elements were just not talked about except in the most vague and general of terms. Consequently, although considerable progress was made towards achieving the objectives of the study, the findings presented here remain the result of work in progress.

5.2.3 Content of the institutional and organisational system used to manage water at Dzindi

When Dzindi started operating in 1954, the extension officer appointed to the Scheme verbally introduced three rules to manage the use of irrigation water, namely (i) farmers were to irrigate in accordance with a time table; (ii) obstructing the flow in the main canal was not allowed; and (iii) washing of one's body or laundry in the canal was forbidden. Two bailiffs in civil service employ policed these rules and reported offences to the Scheme Management Committee (SMC), which consisted entirely of elected plot holders, but the extension officer attended its meetings. The SMC judged the cases brought before it and imposed monetary fines. Money collected from fines was banked in a scheme account and were used for public good. When the SMC was unable to bring a case to its conclusion it referred the matter to the Chief, who, without exception, endorsed SMC recommendations. Involvement of the Chief resulted in the fine being doubled in order to compensate him for his contribution. Over the past 50 years, these institutional and organisational arrangements have changed little. The values of the fines were raised in line with inflation, farmers obtained permission to exchange irrigation slots, and selected plot holders were given authorisation to cultivate parcels of land falling outside the scheduled irrigation area, as long as irrigating these parcels occurred during their allocated time slots. As the state withdrew from the Scheme, the bailiffs were progressively less involved in policing duties and the moral authority of the extension officer declined. More detailed discussion of the water rules and their evolvement at Dzindi is given by Letsoalo and Van Averbeke (2005).

Equity, equality, and cleanliness were the values on which the water rules at Dzindi were based. Cleanliness is a normative value among the Venda people. In the traditional Venda belief system, illness is caused by spiritual or personal agencies, such as the ancestors and sorcerers (witchcraft), or by being in a state of pollution, which occurs at birth, after illness, after a crime and after a burial. Pollution is thought of as dirt, explaining why rituals of washing feature prominently in the purification process (Hammond-Tooke, 1993). Washing bodies or laundry directly in the canal causes body dirt to pollute the water. During their daily activities, plot holders regularly come into contact with canal water, and they also use it to wash harvests of leafy vegetables. Consequently, they experience the idea of working with water that has been polluted with body dirt as repulsive.

Equity is also a value to which local people subscribe. In traditional African society it is accepted that human beings need access to resources, such as land and water, to survive. Therefore, it is customary to share these resources among members of the group (Shapera *et al*., 1959; Okoth-Ogendo, 2002). Equality, on the other hand is not a value which the local African society upholds. On the contrary, there is general acceptance that individuals differ in terms of their position in society based on descent, age and gender (Hammond-Tooke, 1993; Magubane, 2000). Associated with position is the expectation of being shown respect, including material expressions. Consequently, social pressure encouraging group members to equally share a resource, such as water, tends to be weak. Individuals seeking personal gain take advantage of this to break the rules and acquire more than their fair share of a resource, thereby planting the seed of conflict.

5.2.4 Practical application of the institutional and organisational system

The demand for irrigation water at Dzindi is function of many variables, but climate is principal. During or immediately after a period of heavy rain, demand for irrigation water is low, whilst supply is high, because of a strongly flowing river. Demand for irrigation water rises during winter and tends to peak during spring up to about October (see also Laker 2005), when preparations are made to plant maize. This rise in demand is caused by the absence of rain during these two seasons. For the same reason supply of irrigation water during winter and spring is low. Therefore, winter and spring are the seasons when most offences against the water sharing rules occur. Obstructing the main canal immediately below the distribution furrow turnout and irrigating during time slots allocated to other plot holders are the two main offences against the water sharing rules. Obstructing the main canal below the distribution turnout is done to increase the flow of water reaching one's plot. The higher the flow the less time it takes farmers to complete the irrigation of their fields. When for some or other reason farmers are prevented from irrigating their plots during the slot they were allocated, they use a time slot that belongs to someone else. Another reason for stealing another plot holder's water is when crop water use is very high, and weekly irrigations are inadequate to fully meet crop demand.

Part of the formal institutional and organisational arrangements at Dzindi is that the two bailiffs are responsible for policing the water rules. In practice, the bailiffs no longer do their daily rounds of the Scheme. Theft of water is usually discovered by plot holders themselves. Plot holders becoming aware that the quantity of water reaching their plot is less than expected go in search of the cause, which in nearly all cases is another plot holder breaking the rules. When an offence is discovered the aggrieved farmer confronts the offender. Usually, the offender immediately discontinues the offending action and pleads for forgiveness. If the apology is accepted, the conflict has been settled.

In cases where the aggrieved plot holder refuses to forgive the offender, the offender seeks assistance from a mediator to resolve the conflict. Old grudges between aggrieved and offending plot holders are typical circumstances for an offence not being settled amicably and immediately. People requested to mediate are usually elderly members of the Scheme. Mediators are peacemakers. Their role is to listen to the accounts of the conflict by the affected parties without taking side, and to create the necessary conditions to restore the peace between them. Mediators help detect the underlying reason why the conflict was not settled immediately, and in this way steer the two parties towards reconciliation. Throughout the negotiations, mediators avoid the use of harsh language. Instead, they make use of reconciliatory idiomatic expressions and proverbs aimed at building the personalities of the affected persons. In this way, the mediator creates opportunities for the offender to help him or herself out of the situation by being humble, co-operative, and showing remorse. The conflict is resolved when the mediator succeeds in calming down the aggrieved, and gets him or her to forgive the offender.

When mediation fails to bring about a resolution of the conflict, the matter is reported to the block leader. Each of the four blocks has an elected leader, which is an informal position of authority of indefinite duration, to be discontinued only for reasons of incompetence. The main task of the block leader is exercising authority to help resolve conflicts over the sharing of irrigation water. The competence of the block leader is judged accordingly. When an aggrieved plot holder reports a conflict to the block leader, the block leader calls the offender to order, and urges for a resolution.

In some cases aggrieved plot holders by-pass block leadership and report the problem directly to one of the bailiffs. Although the bailiffs are expected to report offences directly to the SMC, their first action is to enquire whether the parties involved have attempted to resolve the matter in amicable ways, using mediation or the intervention of the block leader. In instances where these avenues have not been explored, the bailiffs encourage the affected parties to do so. The bailiffs only report cases to the SMC when all other avenues of achieving reconciliation have been exhausted. When an offence is brought before the SMC, it enters the formal institutional level, which was described earlier.

Structured interviews with a sample of 10 randomly selected farmers using the list of Dzindi plot holders as the sampling frame provided an indication of the relative importance of formal and informal levels in the resolution of conflicts among plot holders over water. Considering the sensitivity of the matter, the interviews avoided referral to conflicts in which respondents were personally involved. Instead participants were asked to identify the different levels at which conflicts over irrigation water were resolved in their neighbourhood. The results of this assessment are presented in Table 5.1. The data presented in Table 5.1 indicate that the majority of conflicts (97%) remain hidden, being settled before they enter the formal level. This suggests that the institutional and organisational arrangements at Dzindi are sufficiently flexible to provide plot holders with the necessary room for manoeuvre. The system accommodates rule breaking without this necessarily causing serious conflict among plot holders, indicating that plot holders interpret the water sharing rules in relative terms. Conflict resolution is not centralised at Dzindi. All plot holders have the authority and ability to resolve conflicts related to the use of water. This contributes to the social sustainability of farming in this community.

TABLE 5.1: Relative importance of the different domains and levels at which conflicts between plot holders over irrigation water are resolved at Dzindi

Domain	**Level**	**Proportion of conflicts settled** (%)
Formal	Chief	1
	SMC	2
Informal	Bailiff	6
	Block leader	10
	Mediator	18
	Plot holder	63

Population growth accompanied by the settlement of large numbers of people on land surrounding the Scheme has made it increasingly difficult for Dzindi farmers to keep the water in the canal clean. Just below the weir, where the water emerges from the tunnel under the main road between Makhado and Thohoyandou, a carwash has been established. This enterprise extracts its water from the canal, which is not a problem, but the concrete surface on which the cars are washed drains into the canal, adding large amounts of soap to the water. Further, down the canal where it proceeds through residential areas, washing laundry in the canal, especially soiled baby napkins, has become common practice. These offences are not checked, because the Dzindi community, scheme management, and the bailiffs lack both the authority and the power to force outsiders to abide by the cleanliness rule.

When summer rains fail the flow in Dzindi River drops to very low levels during the subsequent winter and spring. This causes competition for water among farmers to peak. The history of Dzindi presented in section 2.1.2 of this report shows that drought and lack of irrigation water is not uncommon at Dzindi. Such circumstances again arose during the winter and spring of 2005, following a very dry summer. The frequency with which water rules were broken increased rapidly, and a crisis developed. Especially farmers in the two blocks at the end of the canal were badly affected. The SMC, expected to intervene and restore order, remained inert.

In terms of behaviour, farmers responded differently to the water crisis. Five behavioural categories were identified. The first, referred to as the "bullies" openly broke the rules, thereby disregarding the norms of good behaviour. The second group, referred to as the "opportunists", sneakily sought out opportunities to obtain water in excess of their legitimate share. By operating on the sly they tried to avoid social repercussions for their actions. Ostrom (2002) refers to irrigators who actively pursue disproportionate advantages as "rent seekers", and both the bullies and opportunists at Dzindi fitted this description. The third group, referred to as the "righteous", abided by the rules, irrespective of the severity of the water crisis. They followed the irrigation time-table to the letter, and irrigated at night, which is permitted, whenever they ran out of time during their allocated slot. The fourth group, referred to as the "evaders", fundamentally changed their farming activities in response to the crisis. They either reverted to dryland farming or suspended farming completely, focusing on alternative livelihood activities instead. This enabled them to evade being drawn into conflicts over water. The last group referred to as the "marginalised", was the group of plot holders that "bullies" and "opportunists" took most advantage of. When the right to water of the marginalised was compromised, and they confronted the offenders, or complained to the bailiffs, the SMC, or the extension officer, their pleas were completely ignored. Typically, the marginalised were female plot holders whose husbands had either passed away or had been incapacitated by illness.

Early in October 2005, as the water crisis worsened, plot holders started to voice opinions on how the problem needed to be resolved. One opinion was that the SMC needed to exercise its authority. It called for strict application of the rules and the systematic punishment of all offenders until such time that order was restored. The second was that the farmers in the block nearest to the weir needed to have their times reduced, because they were extracting a disproportionately large share of the water entering the Scheme. The third, which was ultimately adopted, drew on experiences of the previous extreme drought in 1982-83. During that drought a bi-weekly irrigation time table, which provided farmers with a full day of irrigation every second week instead of half a day every week, was introduced and adopted (see also section 2.1.2). This particular solution was most probably preferred, because it did not seek to punish individuals, nor did it accentuate differences among groups of plot holders. Instead, it focused on how the group as a whole could deal with the crisis in a harmonious way, until the rain brought relief.

5.2.5 The social dynamics of water sharing at Dzindi

The findings of this study show that the smallholder community of the Dzindi continues to be influenced by traditional values when given the opportunity to craft or modify institutional and organisational systems to manage shared resources. The content of the institutional and organisational system that was imposed at establishment was largely kept intact even when farmers had the power to make changes but its application was modified in line with the social norms of the community. The new interpretation of the content of the system tended to emphasize the social objectives of peace and harmony of the group, even when from an economic perspective this made the system less effective than before.

The social objectives of the water management system were pursued by creating a sense of belonging among members of the group. This was achieved by encouraging generosity, compassion towards others and forgiveness towards those that had done wrong. When all members of the group subscribe to the values of such a system, both social and economic objectives can be realised effectively but at Dzindi this was not the case. There were several role deviants in the form of rent-seekers, whose value systems differed from that of the group. They took advantage of the system to persistently grab a disproportionately large share of the water, thereby creating a state of dissonance. Proponents of the system had to expend considerable amounts of time and effort to maintain concord, making it an expensive system to maintain. According Ostrom (1995), social systems need to be cheap to be sustainable, suggesting that the system at Dzindi is under strain. At Dzindi the 2005 drought triggered an increase in the breaking of the water rules, preparing the ground for enhanced dissonance and conflict. This experience indicated that scheme designs that generously allocate water to plot holders are less likely to experience conflicts over water than those that allocate water sparingly.

The study showed that a democratic, community-based water management system is empowering for the group, because it enables different members to obtain experience in management. At Dzindi, scheme management, in the form of the SMC, was elected regularly from among the plot holder community for a term of three years, resulting in new people joining the management team, including women, although in practice their portfolio was limited to that of secretary. Through their involvement in scheme management members of the group built and sustained a reservoir of empirical knowledge. This reservoir was tapped for precedence whenever the group had to find solutions to new challenges. However, the results of the study indicated that the democratic, community-based resource management system that was in place suffered from indecisiveness. When elected or appointed to management positions in an organisation, people are expected to make decisions in accordance with their mandate. At Dzindi, SMC members were generally reluctant to execute their management mandates. Instead, they readily referred matters to general meetings for a decision in an attempt to achieve consensus. Delayed progress and inconclusiveness were key weaknesses of their management style. Their tendency to vacillate was most probably due to the prevailing value system that discourages people from offending others. Moreover, they appeared unable to distinguish between their role as member of the group and that of elected and mandated managers of the organisation. As a result, they preferred indecisiveness to the likelihood of slighting members of the group by ruling or deciding on matters.

The results showed that inequality rather than equality featured in the indigenous value system. Descent, seniority, gender and professional status were attributes used to distinguish among members of the group. In Venda, society women have traditionally been on the bottom rung of the social ladder, and at Dzindi single female plot holders tended to be the group that was being marginalised by the way the water management system was applied.

The water management system at Dzindi struggled to find suitable ways of dealing with rent seekers who took more than their share of water, especially the bully type. For example, for the past two years a farmer who purchased a pump has been extracting water directly from the main canal to irrigate a non-scheduled parcel of land he was permitted to cultivate. His pumping significantly reduces the stream of water that reaches lower-lying blocks. Plot holders farming in these blocks have complained repeatedly to the SMC about this practice, but to no avail.

The water management system at Dzindi was also incapable of enforcing the water cleanliness rule. This was mainly due to the arrival of outsiders into the area, over which the SMC had little or no moral authority. In the absence of a broader institutional system and authority to enforce the cleanliness rule, the quality and safety of the canal water at Dzindi is bound to deteriorate further.

Removing equality as an absolute value from the management system at Dzindi has constrained scheme productivity. Firstly, allowing farmers to take non-scheduled land into cultivation, created inequality in terms of plot size, resulting in less water being available per unit area, which had adverse productivity implications. Secondly, by not dealing decisively with rent seekers, other plot holders in the scheme received less water than was due to them, reducing the productivity of their farms.

During the 2005 crisis, there was a group of farmers who called for a return to the initial management system, which interpreted the values of equity, equality, and cleanliness in absolute terms. This group consisted primarily of young market-oriented farmers operating in the blocks at the end of the canal. They were annoyed with the lack of decisiveness by the SMC, which caused their enterprises to suffer, because they obtained less water than they were entitled to because of plot holders higher up the canal taking more. However, in the past, the rules were policed by the bailiffs, and the presence of the extension officer at SMC meetings encouraged the SMC to be strict on offenders. In the current system, the bailiffs no longer police the rules, and the moral authority of the extension officer has weakened. As a result, the SMC carries full responsibility for its decisions, and as was pointed out earlier SMC members are reluctant to act severely.

5.2.6 Conclusions

At Dzindi an institutional and organisational system to manage water was imposed on plot holders at establishment of the Scheme. Based on the values of equity, equality and cleanliness, this system has prevailed for 50 years, indicating a high degree of sustainability.

Farmers wielded considerable executive power in the application of the system from the start, but over the years, their power increased as the state progressively withdrew. Accompanying the gradual increase in farmer power was a process of indigenisation of the system. Interpretation of the rules governing the management of water changed from predominantly absolute to mainly relative. The change provided individual plot holders with more room to manoeuvre than before, because the rules were now negotiable. Getting away with the occasional breaking of the water management rules became easier, especially when one followed the required protocol to admit guilt and show remorse when caught, in line with long-established custom.

Traditional values such as respect, generosity, and recognition of the importance of the group guided the revised interpretation of the system, but this was not necessary extended to all. Particularly single female plot holders were treated unfairly. Not everyone subscribed to the traditional values. There were also members of the group who actively pursued personal material gain at the expense of the community, bringing about increasing degrees of inequality in terms of access to water. Their selfish behaviour put strain on the system, demanding large amounts of time and effort from proponents of the system to keep it operational.

The most obvious alternative to the prevailing water management system is a return to the original system, which involved the absolute interpretation of the rules that applied, and their strict enforcement to ensure maintenance of its underlying values. However, without an external agency to police and enforce the rules a return to the original system is unlikely to occur.

The findings of this case study emphasize the importance of institutions and organisations in water management on smallholder irrigation schemes. The study shows that systems that Black smallholders appear to prefer are not necessarily the most efficient from an economic perspective. Social concerns take preference, even when this brings about economic inefficiencies. The advantage of these systems for society is that they are maintained by participants themselves, seemingly even when the opportunity cost to achieve maintenance is high.

5.3 Maintenance of irrigation infrastructure

5.3.1 Introduction

For optimum functioning, the different components of canal systems need to be regularly inspected, cleaned and maintained (Stern, 1988). Maintenance activities are subdivided into three categories, namely routine, special and deferred (FAO, 1986). On canal schemes, deferred maintenance refers to large modifications to the canal system and normally arises when these schemes are in need of a complete overhaul. Special maintenance refers to repairs or replacement of sections of the primary or secondary canals (FAO, 1986). Activities that form part of special maintenance include the straightening or realignment of canal sections, the application of a new canal lining when the old lining has been damaged by corrosion or mechanical forces, and the repair or replacement of regulation devices, such as control gates and valves. Special and deferred maintenance require the availability of expertise, equipment, and financial resources and on South African smallholder irrigation schemes these have historically been a public responsibility (Letsoalo and Van Averbeke, 2006).

Routine maintenance refers to all work necessary to keep the irrigation system functioning satisfactorily. In canal systems routine maintenance involves regular removal of plants and sediments from the canals, application of antirust treatment and paint to control gates, grease to the valves, repairing of minor cracks in the concrete lining of canals and removal of sediments from the overnight storage dams, if present (FAO, 1986). When plants root in the canal or hang in the water, they obstruct the flow, causing a reduction in the flow rate. Roots and decomposing plant material produce organic acids, which react with the calcium in the concrete of the canals, causing corrosion (Laker, 2005; Stern, 1988). Corrosion of the concrete weakens its structure and renders it vulnerable to mechanical damage, for example by tractors crossing the canals to get to the plots (Laker, 2005). Cracks in the concrete, especially at the joints, need to be filled to avoid seepage and to prevent plants from finding foothold in the canals (International Commission on Irrigation and Drainage, 1989). When the water entering the canals carries silt, the regular removal of the sediments deposited in the canals and silt traps is critical. Deposits reduce the cross-sectional area of the canal and increase the Manning roughness coefficient (Withers and Vipond, 1974). Both effects cause a reduction in the flow rate, reducing the stream size that reaches the individual plots. The size of the stream that enters the supply furrow of the strips is a key factor determining the distribution uniformity in short-furrow irrigation, which is commonly practised on smallholder canal schemes in the north of South Africa (Crosby *et al*., 2000). Inadequate flow rates are a regular problem on these schemes, especially at the tail ends of the main canal and the concrete furrows (Lahiff, 2000; Letsoalo and Van Averbeke, 2005; Van Averbeke and Mohamed, 2006). It is, therefore, in the interest of farmers to ensure that routine maintenance of the conveyance system is effective. The objective of this study was to analyse the history of community-based routine maintenance at Dzindi and to use the results of this analysis to identify how this form of collective action can be supported under contemporary circumstances.

5.3.2 Methods

To reconstruct the history of infrastructural maintenance Dzindi plot holders participated in the construction of a time line (Matata *et al*., 2001). The time line was complemented by conducting interviews with individual plot holders, bailiffs, and extension staff. Records kept at the scheme office were also used. These records consisted of two books. One book contained the monetary fines that had been issued to plot holders since 1989, but the specific reasons why the fines had been issued were only recorded during the period 1997 to 2003. The other book contained the minutes of the Dzindi Scheme Management Committee meetings since 1984.

During the period 2003 to 2006, routine maintenance practices and decisions were documented by means of transect walks along the canals, participant observation during maintenance events and interviews with plot holders, members of the Scheme Management Committee, the resident extension officer and the bailiffs. Interviews were recorded in shorthand and transcribed in full as soon as possible after the events. The data were first categorised into themes and then checked for consistency. Any information that was subject to controversy or ambiguity was investigated further during follow-up visits to the scheme, and data collection was sustained until all ambiguities or controversies were resolved.

5.3.3 History of infrastructural maintenance at Dzindi

During the first two decades after establishment (1954-1972), the resident extension officer was formally in charge of routine maintenance processes at Dzindi. Assisted by two water bailiffs he monitored the state of the main canal and decided when it needed to be cleaned. Typically, the main canal was cleaned twice annually. In consultation with the Scheme Management Committee (SMC), an elected body of farmer representatives, the extension officer decided on the date for the cleaning operation. Routine maintenance during the Native Commissioner era was governed by rules. All plot holders were obliged to participate in the cleaning of the main canal, which typically happened twice per year. On the day of a cleaning operation, the extension officers divided the canal into segments of equal length, assigning one segment of about 150 m in length to each plot holder. During that day, each plot holder had to complete the cleaning of the inside of the canal, because this activity required the supply of water to the main canal to be closed off at the weir. In addition to cleaning the inside of the canal, plot holders also had to clear the vegetation along both sides of the canal. This involved the cutting of grass, weeds and shrubs to ground level along a one-metre wide strip on both sides of the canal. Farmers were given two weeks to complete this part of the work, but most plot holders attempted to complete all the tasks in a single day, mobilizing their entire homestead to achieve this goal. Plot holders were allowed to send substitutes to the cleaning sessions, but absconding was subject to punishment in the form of a monetary fine. These fines accrued to the farmer collective for use in scheme projects.

Individual plot holders were responsible for keeping the concrete furrows clean. Each of them was accountable for the cleanliness of the section of the furrow that bordered their plot and from which they drew their water. The bailiffs regularly inspected the condition of the furrows and reported any problems to the extension officer, who then instructed the relevant plot holder to start cleaning immediately. Monetary fines were imposed in cases of non-compliance with these instructions.

Cleaning of the dam above Block 1 consisted of removing debris, plant material, and rubbish that had collected near the outlet. On occasion farmers also removed sediments from the bottom of the dam. Cleaning of the dam occurred separately from routine canal maintenance and was also done by the full collective of plot holders. A specific day was announced, three to four times per year, usually on a Wednesday. The day before it was to be cleaned, the outlet was left open to allow the dam to empty, whilst the inlet gate to the canal that fed the dam was closed. For plot holders cleaning the dam was joyous occasion, because emptying the dam enabled them to collect the fish that lived there. *"Cleaning the dam was enjoyable. Everybody liked it, because we* *got lots of fish"* recalled one plot holder. The promise of fish helped to ensure that dam cleaning days were well attended.

Maintenance of the flow control devices was done by the extension officer or the bailiffs that assisted him. This consisted of greasing the valves, and applying antirust treatment to the gates, for which the material was supplied by the state.

As was pointed out in section 2.1.2, during the period 1954-1972, Dzindi formed part of a "Native Area", which later became the Venda homeland. This Native Area was administered by a Commissioner. The Commissioner regularly inspected Dzindi and other similar schemes. Surviving plot holders who were on the Scheme during that period remember the Commissioner as an authoritarian. They all said that he was feared by both plot holders and civil servants alike.

The commissioner had the power to expel plot holders who failed to use their plots in accordance with the prescriptions contained in the "Permission to Occupy" certificate with which they held their plots. Expulsion from the Scheme not only meant the loss of the irrigation plot, but also of the residential site and the dwelling on it, because these were linked to the irrigation plot. An elderly plot holder who had been at Dzindi since its inception recalled, "*The commissioner kept us all on our toes. We had to perform in order to keep our farms and our residential plots. Canals had to be kept clean and none of us wanted to be reported to this man for not abiding by the rules including those related to the cleaning of the canals. People never absented themselves without sending a representative.*"

All the available evidence indicated that during the Commissioner's era, plot holders complied with the routine maintenance rules. No one could recall an incident of a plot holder being expelled for not obeying these particular rules.

In 1972, it was announced that the Commissioner would no longer inspect Dzindi. This function would be performed by a new official to be appointed by the government of the Venda homeland. Functionally, the arrangements pertaining to the routine maintenance of the canals established during the Commissioner's era remained in place. Plot holders adhered to these arrangements even though inspection by a Venda official never materialised. Between 1978 and 1980, the extension officer transferred responsibility for management of routine maintenance of scheme infrastructure to the SMC. From that time onwards, bailiffs reported directly to plot holders, whose leadership decided on when to clean.

Over time, new behavioural patterns in relation to routine maintenance emerged among some of the plot holders at Dzindi. Plot holders who employed full-time farm workers started to send their workers instead of attending personally with their families. Oral evidence suggests that farm workers were less industrious than plot holders. Over time, some plot holders also started to occasionally abscond from taking part in the cleaning sessions, paying the fine instead. Indications are that absconding was usually done in response to personal emergencies but all sources agreed that there was a gradual decline in the thoroughness, with which the canal was cleaned and maintained during the Venda homeland era.

Following the first democratic election in 1994, the declining trend in the quality of routine canal maintenance continued. Among a group of plot holders paying the fine instead of attending the cleaning sessions became increasingly common practice (Figure 5.1). Scrutinising the 1997-2003 record of fines, three groups of plot holders were identified, namely a group that attended every session, a group that never attended any of the sessions and a group that attended occasionally. The flood that affected Limpopo Province in 2000 halted farming at Dzindi for a long time. During that year there was also a major conflict among plot holders pertaining to the Scheme Co-operative. These two events further reduced farmer participation in routine maintenance activities. By 2001, the decline in attendance had worsened to the extent that less than half of the plot holders presented themselves for the routine maintenance of the canal. As a result, removal of sediments from the canal could no longer be completed in a single day.

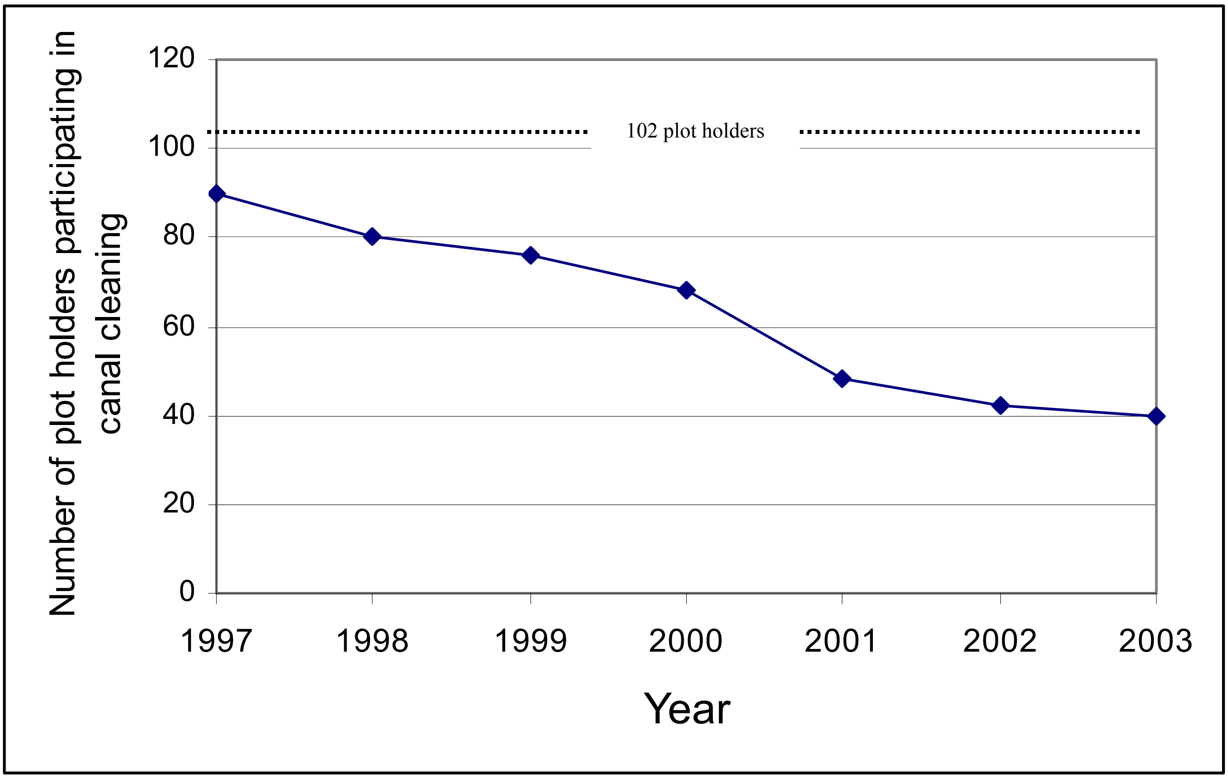

FIGURE 5.1: Number of plot holders that took part in the cleaning sessions of the main canal during the period 1997 to 2003

In 2003, when only 40 plot holders turned up for the two cleaning sessions, the SMC concluded that the existing arrangements were no longer working. Since the majority of plot holders preferred paying to cleaning, the decision was made to establish a system of fees payable by every plot holder. These fees were to be used to hire private contractors to do the routine maintenance of the canal. The yearly fee was set at R100 per plot holder. In 2004, four contractors were employed to clean the canal. The work was done well and plot holders praised the contractors, but the cost of the operation exceeded the amount that had been collected by means of the fees. Moreover, not all plot holders had paid their dues. Reserve funds had to be used to cover the deficit.

In 2005, a less expensive alternative was looked for. The SMC decided to hire a single contractor, who was prepared to do the work at a lower cost than the four contractors used previously did. However, the workload was too much for the single contractor, and although he later sub-contracted some of the work to others, he failed to complete the task. Under pressure from the sub-contractors, he requested the SMC to pay him for that part of the work that had been completed, but the SMC refused to hand over any money before the contract had been honoured in full. A dispute was declared and the contractor lodged a claim with the Small Claims Court. By October 2006 the case had not yet been concluded, whilst in the mean time no routine maintenance had been performed. After more than a year of neglect, a substantial layer of sediment had accumulated in the canals and plants were overgrowing many of its parts.

In 2007, plot holders in Block 2, which is at the tail end of the canal, decided to re-introduce the routine maintenance arrangement of the past. They came together and jointly cleaned the section of the main canal between the diversion sluice to Block 1 and the last off-take in Block 2. Although not followed by plot holders in the other irrigation blocks, this initiative did underline that collective action for routine maintenance of the irrigation system has retained a degree of resilience, suggesting opportunities for its revitalisation.

5.3.4 Social dynamics of routine infrastructural maintenance at Dzindi

At establishment of Dzindi, rules on routine maintenance were formally codified by the state. Canal irrigation was new to the plot holders of Dzindi and not linked directly to their norm system. Imposing rules, geared towards the application of best practice in canal maintenance was the obvious option available to the state at that time. The rules had to be coercive as they prescribed behaviour (cleaning of the canals), which plot holders would not otherwise do, and proscribed behaviour (absconding from participating in the cleaning), which most plot holders would do in the absence of the rules. The system that was established during the Native Commissioner era was effective in terms of its outcomes, because of vigorous monitoring and enforcement by the authorities.

The Venda homeland era can be regarded as a period of transition. Active enforcement of the rules by the state organs was discontinued, but the collective action persisted much in the same way as before, even when decision making was transferred to plot holders. This suggests that the system of routine maintenance had been internalised by the community. This did not mean that plot holders had come to understand why routine maintenance of the conveyance system was important, on the contrary. When one of the plot holders, who complained about the limited size of the stream that reached his plot, was asked why the canals needed regular cleaning, he responded, "*The scheme must be kept clean and beautiful. If plants are left to grow we will have a problem in accessing our plots and snakes will find a hiding place."* Questioned on the relationship between sediments and plants in the canal and the size of the stream reaching his plot, he argued that, '*Even when the canal is dirty the water still flows. Dirty or clean, the canal never fills up with water*". Confronted with questions about the relationship between plant growth in the canal and the many cracks and perforation in the lining, he pointed out that, *"The canals are just too old! The government should rebuild them*." Similar responses were obtained from other plot holders that were interviewed.

In the absence of an external authority that enforced the rules, selected plot holders started challenging the institutional system by electing to pay the fine instead of actively participating in the routine maintenance proceedings. Several possible reasons for this change in behaviour were identified. Natural attrition and succession changed the composition of the group of plot holders, bringing in new members who lacked the institutional memory of the original generation. Another reason was that the livelihood of plot holders had been allowed to diversify. As indicated in section 2.1.2, during the Native Commissioner's era plot holders at Dzindi were forced to engage in farming on a full-time basis, because those who paid insufficient attention to their farms were expelled from the scheme. From 1972 onwards, this requirement was no longer strictly enforced, resulting in selected plot holders openly exploring additional livelihood opportunities. Engagement in and commitment to other activities clashed with the routine maintenance sessions, resulting in plot holders preferring to pay the fine to actively participating in the cleaning activities. For example, when asked when he started to pay the fine instead of actively participating in the routine maintenance activities, a plot holder with a livelihood based on participation in the informal economic sector, responded, '*In the past I had no money to pay the fine, forcing me to come to the cleaning sessions. When I started earning money by painting houses in the village I no longer cleaned the canals, because I earned more from a day of painting than the value of the fine and my clients wanted me to complete the work as soon as possible.*

Challenges to the routine maintenance institution that existed at Dzindi increased during the post democratisation era and this caused it to collapse and being replaced with a new system. At the forefront of the social change process were individuals who could be referred to as norm entrepreneurs. They sought personal benefit from exploring new ways of working within the rules, ignoring the fact that the consequences of their actions threatened the desired outcome of the collective action. Their behaviour defied the social order that existed in the collective action of routine maintenance and ultimately this brought about social change. Social order refers to the set of linked institutions, structures and practices which conserve, maintain and enforce established ways of relating and behaving. Challenges to social order are natural and unavoidable processes, which are responsible for social change (Eggertsson, 2001). They result in new institutional arrangements being adopted, but often the social truces that are reached are uneasy, because proponents of change are seen as winners and defenders of the existing social order as losers (Ellickson, 1991).

At Dzindi, norm entrepreneurs challenged the social order, but social change only came about when others copied their behaviour after seeing the alternative and realising the opportunity for personal benefit by paying the fine instead of being physically involved in the collective canal cleaning sessions. There was also a group of plot holders who always attended the cleaning sessions. They tended to be elderly farmers and invariably they placed group success before personal gain, defending the social order. A third group consisted of plot holders who absconded occasionally. This group speculated and experimented. Each time they carefully considered their options before deciding to participate in the maintenance activities or not. In this way, they avoided being perceived as not supporting the group goals, whilst still exercising the option of paying the fine instead of active participation when personal circumstances demanded this particular course of action. Similar differences in behaviour among plot holders were identified in relation to the water sharing institution described in section 5.1.

At Dzindi, social change brought about the transformation of the content of the routine maintenance collective action from physical engagement to monetary contributions enabling the hiring of an agency to do the work on behalf of the collective. When social struggle leads to transformation, the new institutional arrangements are not beyond challenge. New conflicts arise and these lead to further change (Ellickson, 1991). At Dzindi, the new routine maintenance institution was challenged almost immediately after it had been adopted. Not all plot holders paid their dues, forcing the collective to use reserve funds to honour the routine maintenance contract. A cheaper alternative failed to yield the desired outcomes and caused the collective to become entangled in a legal dispute. This, in turn, caused a suspension of all routine maintenance, and by 2006 plants along the canal had been allowed to grow unchecked and sediments had been accumulating in the canal for more than a year. These events exposed the weakness of the new arrangement and new conflicts and initiatives were expected to develop as a result. In 2007, plot holders in Block 2 reverted to the old system of collective action and voluntarily cleaned their section of the canal. There is little doubt that the future of farming at the Scheme is dependent on the entire collective of plot holders finding a workable solution to the routine maintenance crisis that has arisen.

5.3.5 Conclusions

In canal irrigation, effective routine maintenance of the conveyance system is critical for optimal functioning. At establishment, an institutional system of collective action was imposed, monitored, and enforced by the state to ensure that routine maintenance was taken care of. Over time, the routine maintenance institution was internalised by the group and when external monitoring and enforcement was removed, the institution persisted. Natural change in the composition of the group and change in the structure of the livelihoods of plot holders provided the context for the institution to be challenged, initially by norm entrepreneurs and later on by the majority of plot holders. This forced the group to fundamentally modify the routine maintenance institution from a system that relied on plot holders to voluntarily supply their labour to a system that demanded plot holders to make financial contributions to pay for labour. The new institution showed its weaknesses almost immediately and for the practical purpose of ensuring that the conveyance system is maintained, it has already collapsed, threatening the sustainability of irrigation at the Scheme. However, the 2007 initiative of plot holders in Block 2 to revert to the old system of collective action to get their section of the canal cleaned up suggests that the Dzindi community will find a solution to the problem.

The empirical evidence that was collected suggests that the current group of plot holders lacks understanding of the relationship between routine maintenance, flow rate in the canals, and stream size at plot edge. Educating plot holders about this relationship is considered a critical element to the internal debate that is necessary to craft a new and effective routine maintenance institution.

Although sustainability of any routine maintenance institution depends on the closeness of the rules to the moral norms, irrigation scheme infrastructure at Dzindi came about because of public investment. Possible rehabilitation of the scheme infrastructure will also be implemented using public resources. As a result, the state has the obligation that these public investments are properly cared for. Re-introducing the public function of monitoring, assessment and feedback to farmers is, therefore, recommended, and this may require a degree of rule enforcement.

At Dzindi, enforcement of the rules pertaining to the functioning of the scheme is the responsibility of the elected leadership. Analysis of different domains pertaining to resource management, including routine maintenance of the canal system, showed that this leadership struggled to effectively enforce the rules, even when these rules had been fully sanctioned by the group. One weakness of the existing institutional structure was the absence of a higher authority which scheme leadership could call upon to deal with persistent deviants.

5.4 Access to input and output markets

5.4.1 Introduction

The major constraints that affect access to input and output markets by black smallholder farmers in South Africa are lack of transport, the absence of storage facilities, remoteness, poor roads, lack of market information, lack of organised bargaining power, the absence of dedicated governmental support, and discrimination in the market place (Makhura and Mokoena, 2003). The severity of several of these constraints arises from the limited scale of smallholder production. Sustainable commercialisation of smallholder farming is heavily dependent on access to markets (Madikizela, 1997; Hasnip, 2001). Typically, smallholders seek to purchase farm requisites in small quantities when accessing input markets, and the same applies when they participate in output markets. Effective collective action in the domain of market access holds the promise to reduce transaction costs to individual farmers. Smallholder irrigation schemes are particularly well suited for collective action in relation to markets, because they represent concentrations of farmers, usually involved in fairly homogeneous production systems, yielding a limited variety of commodities.

Co-operatives are one of the models that may be used to organise and institutionalise collective action in relation to markets. A co-operative consists of members who voluntarily strive to meet their mutual economic and social needs, in such a way that the economic advantages they derive from being a member are greater than they could achieve on their own. Co-operatives have manifested themselves worldwide and do not conform to any particular political system (Weitz, 1993). Agricultural co-operatives are co-operatives that are concerned with the needs of farmers. Typically, farmer co-operatives operate as agents for their members when purchasing farm inputs and selling produce. They may also become involved in grading, storage, and processing activities and provide financial services, such as advance and deferred payments and insurance.

In South Africa the functioning and regulation of agricultural co-operatives has been influenced by social segregation of the farming sector. Nationally, this sector is dominated by about 50 000 large-scale, predominantly white, commercial farmers (Ortmann and Machethe, 2003). The country also counts about 240 000 black smallholders who regularly participate in produce markets, and between one and three million black rural and urban households that engage in one or more agricultural activities primarily for own consumption. Segregation of the South African farming sector resulted from gradual but sustained disempowerment of African farmers, which commenced when the state started to interfere in African society (Bundy, 1988; Bernstein, 1996). Using various policy instruments white farmers were assisted in their development, whilst most black farmers were gradually reduced to sub-subsistence producers, partly because their access to land was limited to designated areas.

One of the measures in support of the commercial development of white farmers was legislation that improved access to input supply and marketing services in the form of the Co-operative Societies Acts of 1922 and 1939. Although this legislation did not prevent black farmers from becoming members, the separation of South Africa into white and black territories effectively excluded black farmers from joining these new ventures (Vink and Van Zyl, 1998; Bernstein, 1996). Regulations governing agricultural co-operatives were amended several times by Acts No. 44 of 1960, No. 65 of 1964, No. 44 of 1975, No. 69 of 1979 and the Co-operative Act No 91 of 1981, which applied to the content of this study. This Act governed three kinds of co-operatives, viz. agricultural co-operatives, special farmer's co-operatives and trading co-operatives.

Black South African smallholders became involved in collective action in relation to markets after WWII. This occurred through the establishment of farmers' associations, a government initiative. At that time the state had started to invest in the establishment of irrigation schemes in the Native Areas (also called Bantu Areas) and it was at these newly established projects that farmers' associations were introduced. Farmers' associations were not governed by legislation. They had two main objectives, i.e. to facilitate access to agricultural inputs and to assemble products produced on small plots to create sufficient quantity to enable supply to large markets. The Commission for the Socio-economic Development of the Bantu Areas within the Union of South Africa (1955) identified collective action by smallholders in relation to markets as the main reason for the large differences in farm income between organised and non-organised groups. In a few selected cases, black farmers' associations were transformed into co-operative societies. One example was the co-operative established by smallholders at the Olifants River Irrigation Scheme (Commission for the Socio-economic Development of the Bantu Areas within the Union of South Africa, 1955). Machethe (1990) reports that between 1935 and 1965 there were only four registered smallholder co-operatives in South Africa, clearly indicating that formalisation of smallholder collectives was rare before 1965.

From 1971 onwards, following the passing of the National States Constitution Act (Act no. 21 of 1971), the different Bantu Areas of South Africa gradually progressed towards self-governing homelands, as envisaged by the Grand Apartheid policy. Self-governing status allowed for the formulation, amendment and passing of legislation. With specific reference to collective action by smallholders in relation to markets, the seven homelands that were created adopted the South African legislation governing co-operatives, in some cases with limited amendments (Van Rooyen, 1998). Homeland governments initiated campaigns to promote the smallholder co-operative movement, because co-operatives were viewed as suitable instruments for agricultural development. The campaigns were directed at establishing new smallholder co-operatives and at converting existing farmers' associations into registered co-operatives. When South Africa was again unified in 1994, smallholder co-operatives established in the homelands became part of the national register of co-operatives.

According to Machethe (1990), smallholder co-operatives that were established in the homelands were largely unsuccessful for a range of reasons. Among these alienation between membership and management of co-operatives and the lack of real economic advantages derived from membership in terms of access to both input and output markets were key. Despite the apparent failure of smallholder co-operatives to bring about smallholder development, researchers and government have continued to recommend co-operatives as the most a suitable model to improve smallholder access to markets (Groenewald and Nieuwoudt, 2003). However, generally the co-operative movement in South Africa has failed to show substantial growth, as is evident from Table 5.2.

TABLE 5.2: Number of registered agricultural co-operatives during the period 1997 to 2001 (extracted from the South Black National Co-operatives Registry, 2003).

Year	1997	1998	1999	2000	2001
Registered co-operatives	243	233	222	220	256
New co-operatives	28	15	11	16	49
Cancellations	26	25	22	18	13
Amalgamations	3	2	2	4	2
Conversions to companies	12	19	11	-	9
Conversions to other	1	1	1	-	-
Liquidation	10	3	8	10	2

The data in Table 5.2 refer to all registered agricultural co-operatives in South Africa, including those historically belonging to white commercial farmers. An average of 24 new co-operatives was registered every year during the period 1997 to 2001. However, this gain was almost completely offset by an annual average of 21 cancellations, for reasons of amalgamation, conversion to other legal entities or liquidation. When seen in the context of sustained government efforts to get African smallholders organised, the observed lack of growth in the number of registered co-operatives suggests that the South African co-operative model has inherent weaknesses that limit its application in the smallholder sector.

5.4.2 Methods

Historical data on the farmers' association (FA) and registered co-operative that existed at Dzindi were collected through the construction of a time-line (Matata *et al.*, 2001), in which 98 farmers were engaged in a participatory reconstruction of the history of the collective action. In addition semi-structured interviews were used to collect data. People who were interviewed included plot holders who were present when the FA was established at Dzindi, agricultural extension officers, plot holders who had served on the Scheme Management Committee (SMC), plot holders who had served on the Farmers' Association and Co-operative committees and state officials who served in the office of the Registrar of Co-operatives.

Data collection strived towards capturing the full diversity of views and practices, and was sustained until all ambiguities had been clarified, and no additional information was forthcoming (Bernheimer, 1986). Depending on circumstances, the interviews were recorded, written down in shorthand, or put to memory, when the sensitivity of the occasion demanded. In all cases, transcription occurred as soon as possible after the interview was held. Trained, Venda-speaking research assistants interpreted and translated the interviews from Venda to English.

Data analysis was by means of multiple coding and memo writing aimed at developing coherent and integrated accounts of the observed phenomena. Feedback to the interviewees was carried out in order to verify the findings.

The two essential questions that this study sought to answer were what benefits do smallholders seek from collective action to access markets and what are the attributes that contribute to the sustainability of this type of collective action. Dzindi was a suitable case for this type of study because over the years the scheme had experienced two models of collective action in relation to markets, namely the farmers' association and the registered co-operative. The aim was to contribute to lessons for the establishment and planning of collective action by smallholders in relation to markets, especially since various government departments have been involved in developing rehabilitation and management transfer programmes to revitalise moribund irrigation projects (Perret, 2002).

5.4.3 History of collective action in relation to markets at Dzindi

The idea of starting a farmers' association at Dzindi was introduced by the resident extension officer in 1958 and obtained the support of the Scheme Management Committee (SMC) during the same year. The SMC presented the idea to the farmers in a mass meeting at which it was accepted. The meeting decided that only plot holders of the scheme would qualify as members of the collective and that each plot holder had to contribute 5 pennies as membership fee. All 105-plot holders paid the membership fee within a week, indicating acceptance and embracing of the idea by Dzindi farmers. The collective was named the Dzindi Farmers' Association (DFA). A decision was made to form a committee to oversee the functioning of the DFA because the SMC felt that DFA has specialised functions that required a dedicated structure. A committee of nine members with a term of three years was elected by plot holders in a mass meeting in 1958 to form the Dzindi Farmers' Association Committee (DFAC). Every third year a new committee was elected to office.

The first committee planned and figured out the manner in which the DFA should function. At that time the need for access to chemical fertilisers and pesticides by plot holders was not urgent, because farmers were not yet using these materials. As a result, the committee stopped meeting and became dormant. The office period (three years) of the committee expired and the committee was replaced entirely by a new committee in 1960.

The start of DFA activity coincided with the time when Dzindi farmers started using chemical fertilisers in their fields, which occurred in 1961. The DFAC collected information from farmers on their chemical fertiliser needs, obtained quotations and requested funds from the SMC to purchase the fertilisers from the Luvhubu Co-operative, which was the only outlet where agricultural inputs could be obtained in the Thohoyandou region during that time. The Luvhubu Co-operative delivered the stock to Dzindi. DFA membership fees and money collected from fines (see sections 5.1 and

5.2) were used to make the initial purchase. Thereafter the income from sales was used for this purpose. The DFAC was also responsible for overseeing the sales of the fertilisers. Bags of fertiliser were stored in a room next to the extension officer's office and sales were conducted from that room. The store was open for business on Tuesdays and Thursdays. Two elected plot holders were responsible for store maintenance and the sales of fertilisers. They were exempted from the chore of cleaning the canals, which was compulsory to all farmers. Since the cleaning of canals was only done occasionally, the SMC in consultation with plot holders decided to pay the two farmers each five pennies per week. One of the advantages of the DFA initiative was that farmers were able to purchase farm inputs in small quantities. Bags of 50 kg fertiliser were opened and fertiliser was sold per kg. Typically between 50 and 100 bags of fertiliser were purchased and these lasted about two to three months. No records were kept of purchased stock or sales.

An important change in the status of the farmers' association was brought about when the Venda Department of Agriculture adopted the Co-operative Act of the Republic of South Africa (Act 17 of 1980) in 1984. As was the case in the other homelands, the Venda Department of Agriculture launched campaigns promoting the smallholder co-operative movement, because co-operatives were viewed to be suitable instruments for agricultural development. At Dzindi, the extension officer explained to the SMC that the Co-operative Act required the DFA to be transformed into a registered co-operative. He also stated that the government would only provide assistance to farmer groups when these were organised in registered co-operatives. In 1985, an official from the government who dealt with co-operatives was invited by the DFA to explain the registration procedures and the benefits of being a registered co-operative. Plot holders were informed that the registration of a co-operative required a statute and a business plan. The newly elected DFAC sought outside help to draw up the statute and the constitution leading to the registration of the Dzindi Farmers' Co-operative Ltd. (DFC) in 1985. The DFAC was renamed accordingly and became known as the Dzindi Farmers' Co-operative Committee (DFCC). Joining fees applied but only 62 of the 102 plot holders at Dzindi paid and became members. Subsequently, membership was extended to people outside the scheme. As a collective plot holders had incurred costs to have the statute and business plans compiled by a consultant and as individuals they had incurred the cost of the joining fees but basically the only change that occurred was in the name of the organisation. Practically, the co-operative operated in exactly the same way as the farmers' association. Financial reports demanded by legislation were never submitted to the Venda Department of Agriculture or to the newly established Department of Agriculture of the Northern Province (later renamed Limpopo Province).

During the second half of the nineteen nineties, the Department of Agriculture, not only nationally but also at provincial level, made the strategic decision that support to smallholders would be channelled through their organisations. Consequently the Department encouraged farmers to get organised. Smallholder co-operatives were identified as suitable organisations for the receipt of state support.

In 1998, the Department of Agriculture constructed a shed to be rented to the Dzindi Farmers' Co-operative. This shed was erected on land donated by the local chief, but Dzindi plot holders refused to take occupation because the rent was an extra cost to them and considered not affordable. As part of its strategy to support smallholder organisations, the Department of Agriculture started a campaign to ensure that registered co-operatives met their legal obligations. In 1999, the election of the new DFCC was heavily influenced by the extension officer who advised plot holders that members of the new committee needed to be literate since registered co-operatives had to keep records and submit written reports to the government as required by law. Illiteracy prevented most of the farmers from being elected to office. Five plot holders who were teachers were nominated and four additional farmers, who also could read and write, were co-opted. The members of the newly constituted DFCC took the stance that the co-operative was a business which was too complicated for ordinary scheme farmers to understand. They managed the affairs of the DFCC independently of the SMC and communicated directly with the Department. As a result, plot holders came to see the co-operative as a government structure over which they no longer had control. Members of the co-operative still received discounts on purchases but the way in which discounts were allocated was no longer transparent. Soon after coming to office, the new DFCC decided to take occupation of the shed, which had been standing empty for about a year. *"The government had forgotten about the shed,"* said the chairperson of the DFCC of that time. No rent was ever paid.

As soon as the co-operative store moved to the shed, the DFCC employed two people on a full-time basis for daily administration and sales of goods from the co-operative store at monthly wages of R350 each. This decision created an overhead cost of R700 per month, whilst at that time the co-operative on average only made a profit of about R150 per month. During interviews, members of the DFCC defended their decision to employ these workers by pointing out that there were prospects for growth and increased profits. However, these prospects were never realised and month after month the co-operative store ran at a loss. The DFCC became worried about the persistent financial deficit and requested the SMC to convene a mass meeting with farmers with the intention of discussing the financial problems of the co-operative. The SMC refused to call farmers to a meeting stating that since 1999 it had no longer been involved in co-operative matters. Subsequently the DFCC attempted several times to call a mass meeting with farmers directly but each time only a handful of farmers pitched up, not enough to form a quorum. The poor attendance of these meetings reflected the rift between plot holders and the DFCC brought about by deepening suspicions and lack of trust in the DFCC among plot holders. When the financial reserves of the co-operative had been depleted the DFCC made a short-term loan amounting to R5 000 with a local micro-lender at an interest rate of 30% per month. The loan was necessary to pay the wages of the two permanent workers at the co-operative store and to purchase new stock.

In 2000, floods struck the north of South Africa causing crop production at Dzindi to come to a halt. Reportedly farmers missed out on two planting seasons. As a result, the co-operative did not sell anything for several months but still had to pay its two full-time employees. When sales resumed in 2001, the existing stock was sold but the DFCC had no funds to purchase new stock and took the decision to close down the co-operative store and retrench the two workers. All sources confirm that during the period 1999 to 2001, no reports were ever sent to the Department as required by the Co-operative Act.

In 2003, farmers decided to reconstitute an organisation that would operate just like the original farmers' association with the store run by farmers themselves. They agreed to contribute a membership fee of R150 per plot holder to provide the starting capital. A committee of nine plot holders was elected. However, the defunct DFCC objected strongly to the formation of a new co-operative stating that the Committee was never dissolved and therefore still in existence. The SMC resolved in a meeting to demand records and files of the co-operative from the old DFCC so that these records could be handed over to the new Committee. The old DFCC approached the Department of Agriculture and reported their discontent.

As the SMC was preparing to take up the matter with the Chief, an official from the government was dispatched to intervene. After three long meetings between the DFCC, the SMC and the official, the DFCC agreed to dissolve and hand over the records on condition that farmers paid back the money the DFCC had borrowed from the micro lender. Unknown to farmers, the members of the DFCC had used their personal funds to pay back the micro lender and now they wanted their money back. The government official presented the matter to farmers in a mass meeting and announced that farmers had to contribute towards the payment of the debt. Farmers did not respond to the announcement but records indicate that farmers did not pay the money. Informants explained that they were not keen on repaying the loan because in their eyes the DFCC was responsible for incurring the debt. In 2007 this stalemate still had not been resolved and plot holders continued to purchase inputs individually, or as small groups.

5.4.4 Social dynamics of collective action in relation to markets at Dzindi

The farmers' association (FA) created in 1958 functioned well. Activities were organised and managed using local arrangements. Plot holders gradually internalised the FA system, which was compatible with their way of life, incorporating the principles of cooperation and mutual aid. The farmers' association resembled contemporary forms of traditional collectivism aimed at helping members to achieve self-fulfilment as individuals in terms of participation, initiative, decision-making and exercising influence in their communities. Examples of contemporary expressions of traditional collectivism in African communities are burial societies and saving clubs. Burial societies perform the role of insurance. Members contribute money to the burial society on a monthly basis and when a member has a death in the family the burial society contributes towards the cost of the funeral. As in the case of burial societies, members of saving clubs make monthly financial contribution to the collective. Some clubs pay out every month, whereby on a rotational basis one of the members receives all the contributions that have been collected that month. Others save the monthly contributions and pay out members at the end of the year. The main aim is to once a year raise the household income of members to enable them to afford some discretionary spending. These traditional collective organisations are self-regulating and generally function well, seemingly because they are based on the existing and entrenched mutual trust among members.

The prevalence of collectivism and mutual aid initiatives in African society does not necessarily make this society adapted to collective action of a modern kind, involving formal registration and regulation. The state viewed registered co-operatives as a modernised form of traditional co-operation and pursued their legislation and regulation to consolidate the traditional system and to provide protection to members. The South African co-operative model ignored the content and practice of indigenous collectivism in black communities in which both the explicit and the tacit are included (Wegner, 1999). The tacit, such as the culture of empathy and altruism among African people, was poorly articulated in the co-operative model. The co-operative model took the tacit for granted and allowed it to fade to the background. However, the essence of indigenous African co-operation is contained in the logic of mutual aid. A host of scholars, such as Craig and Saxen (1986), and Weitz (1993), concur that characteristic of co-operation is the free and voluntary association of people to create an organisation which they democratically control to provide themselves with goods and services, rather than profiting from others, with an equitable contribution of capital and accepting a fair share of risks and benefits generated by the joint activity. The implicit relations of members in the choice of leadership of traditional collectives, such as the Dzindi Farmers' Association, were not based on academic qualifications of people. The South African co-operative model, on the other hand, required board members to be able to read and write because they had to be able to compile reports for annual submission. The Co-operative Act imposed new demands on plot holders. The Act required the development of a business plan and a statute. It prescribed the establishment of a board of directors and a minimum number of board meetings per year. It required the submission of minutes of board meetings and audited financial records to government offices. These prescriptions and requirements demanded expert knowledge and resources, which the majority of plot holders at Dzindi did not possess. The long and seemingly untroubled history of the farmers' association at Dzindi which was dominated by tacit conventions and embedded understanding of the functioning of this organisation did not require complex recording systems. Members of the indigenous collective action agreed on roles that rotated such as the duties in the co-operative store at minimal costs to the collective. Introduction of the new system of the registered and regulated co-operative at Dzindi occurred without signs of short-falls in the existing farmers' association and, therefore, could not be justified. The introduction of regulated co-operatives encouraged social stratification by placing a small privileged group in charge of managing the co-operative. At Dzindi, this group offered itself a variety of privileges. The committee members were paid for attending meetings. They claimed refunds for transport from the coffers of the co-operative after attending meetings with government officials even when the government had provided the transport. They also employed store keepers. The FA, on the other hand relied entirely on volunteer services by members, which enhanced the sense of ownership. All these changes were strange occurrences to the majority of plot holders. They made no sense and ultimately they brought about estrangement and alienation between leadership and membership and the destruction of a seemingly sustainable form of smallholder collective action in relation to the market for inputs.

The promise of protection of members against mal-administration of board members of the registered co-operative, as implied by the Co-operative Act never materialised in the case of Dzindi. Responsible officials explained that since the Dzindi Co-operative never submitted reports, the state was officially not aware of the problems and could, therefore, not intervene. The legacy of this failed social experiment continues to prevent the reconstruction of the collective action to access inputs at Dzindi, which the majority of plot holders desire. The unresolved issue of the repayment of the loan to members of the last DFCC by plot holders blocks progress towards the re-establishment of this collective in the form of an organisation that mimics the farmers' association of old.

5.4.5 Conclusions

At Dzindi voluntary cooperation among farmers for improved access to markets has been limited to input markets. No evidence of voluntary cooperation was found in relation to output markets and this also applied to Khumbe and Rabali. The institutional arrangements that applied to the farmers' association suited the plot holder community at Dzindi. Although the concept was introduced by the state, farmers were given the opportunity to reflect on what the role of the farmers' association should be, how it should be structured and managed and what its functions should be. Three years went by to develop and negotiate these issues without any real practical activities taking place. The institutional arrangements plot holders arrived at were based on the value of mutual aid in line with traditional forms of collectivism. Structurally, power and authority in the organisation was held by the collective of plot holders and its elected leadership. The function of the organisation evolved in response to changing circumstances. The initial function was the bulk purchase of chemical fertilisers and the retailing of these to farmers in convenient ways, which followed the gradual adoption of this innovation by plot holders. Later on the bulk purchase and retailing of other inputs, such as insecticides and seed were added as the demand for these products developed. The management practices of the organisation were based on volunteerism and mutual trust. Despite the absence of any book keeping procedures there were no complaints of misappropriation of funds during the long history of the Dzindi Farmers' Association.

The state, probably influenced by the expert system that informed it, felt it necessary to intervene and insisted that the small holder farmers' associations be converted into registered co-operatives. It imposed the co-operative model that applied to the white commercial farming sector seemingly with complete disregard for the differences between that sector and the African smallholder sector. The outcome was not successful because the imposed model did not suit smallholder communities. The lesson learnt from this experience is that state intervention in arenas where smallholders successfully operate their own organisations should either be avoided completely or be done in ways that allow smallholders sufficient time to internalise the new concepts and to adapt them to suit their own circumstances.

5.5 Access to land on smallholder irrigation schemes

5.5.1 Access to land and land tenure

Access to land is affected by land tenure, which refers to the way individuals or groups hold land. A particular type of tenure is defined by the rights it allocates to individuals or groups in relation to land. According to Feder and Feeny (1991), four main categories of rights are identified, namely,

1. *Use rights*, which stipulate the privileges a holder has to utilize the land for the growing of crops or trees, to make permanent improvements to, and to harvest products from;
2. *Transfer rights*, which stipulate the privileges a holder has to transfer his or her rights to someone else by means of sales, donations, mortgaging, leasing, renting or bequeaths;

3. *Exclusion rights,* which stipulate the privileges a holder has to exclude others from claiming use rights or transfer rights in relation to a particular piece of land;
4. *Enforcement rights,* which refer to the legal, institutional and administrative provisions that are available to guarantee rights related to land.

In the context of smallholder farming, land tenure is usually raised as a concern because it affects the ability of land right holders to use their land as collateral when seeking access to finance (Ortmann and Machethe, 2003), probably because the use of farm land as collateral when accessing loans is common practice among white commercial farmers in South Africa. Van Averbeke *et al*. (1998) and Bembridge (2000), on the other hand, identified ineffective land exchange, which prevented farmers from expanding their holdings, as the most important constraint associated with land tenure and access to land on smallholder irrigation schemes. International experience has identified secure and flexible land tenure as a condition for successful implementation of irrigation management transfer (IMT) (Vermillion, 1997; Shah *et al*., 2001).

5.5.2 Trust tenure on smallholder irrigation schemes

At many of the irrigation schemes established during the 1950s in the northern parts of South Africa, including Dzindi, Khumbe and Rabali, land was de-tribalised before construction of the scheme commenced. Land earmarked for irrigation development was transferred from the tribe to the Bantu Development Trust, a state agency. This transfer usually followed negotiations between the state and the tribal leadership, as was evident from the results obtained in this study. Typically, the Chief and the homesteads that held land within the boundaries of the proposed scheme were offered compensation for making way to the development by being offered a plot on the scheme.

The division of land on schemes followed the principles of betterment planning, which involved the spatial separation of the three categories of land, i.e. irrigated plots, residential plots and commonage. Trust tenure applied and land rights were issued by means of Permission to Occupy (PTO). The imposition of Trust tenure on irrigation schemes that were established during the 1950s in the north of South Africa supported the objectives of the South African government of that time. During that era, smallholder irrigation development was aimed at providing black households with the means of deriving full livelihoods from farming (The Commission for the Socio-Economic Development of the Bantu Areas within the Union of South Africa, 1955). Detribalisation of the land and the imposition of Trust tenure which stipulated how the land was to be used by land right holders, were considered important to enable efficient use of the land and the irrigation infrastructure.

Among the different tenure systems with which black people held land in South Africa during the 20th century, Trust tenure is considered one of the most insecure, because the state had the power to withdraw land rights by recalling the PTO when right-holders failed to comply with the conditions of the Permission (De Wet, 1987, Cokwana, 1988; Cross, 1991). In an overview of different tenure systems that applied to the Ciskei region of the Eastern Cape, Kruger (1995) concluded that ‘in practice Trust tenure is the least secure of any of the tenure systems applying in the Ciskei. Communities living in Trust tenure areas are effectively tenants on state land on conditional leases. Legally, it is a very rigid form of tenure, allowing for very little innovation and flexibility to respond to social and economic threats and opportunities'.

Several of the conditions of the PTO related to the method of farming and the intensity with which the plot was used. A transcription of the PTO conditions that applied at Rabali is presented in Box 5.1. The text in Box 2.1 was extracted from the register of PTO certificates kept at the Office of the Department of Agriculture at Rabali Irrigation Scheme. The particular PTO certificate that was used to extract the text had been issued on the 30th of January 2003.

BOX 5.1: Conditions governing Trust tenure (PTO) at Rabali issued in accordance with Proclamation R.5 of 1963

Conditions for land occupation (Permission To Occupy)

1. The probationer lesser shall not remove, burn or be allowed to remove or destroy any kraal manure or plant material suitable for making compost from the irrigation scheme without the prior approval of the Superintendent.

2. The probationer lesser shall in regard to irrigation allotments, comply with the provisions of the general farming system as prescribed by the Superintendent or any person acting under his written authority, which provides for the correct methods of cultivating and irrigation, application of manure and fertilizer, the most suitable crops, their rotation, time of sowing and disposal, the planting of approved kinds of shrubs and trees, the eradication of weeds and noxious weeds and the control of pests and plant diseases, the number, kind and breed of livestock and poultry which may be kept, their care, manner of depasturing, disposal, the disposal of their products and the control of animal diseases; observation of correct irrigation practice as to requirement, diversion, application, wasteful use and drainage of irrigation water; the proper maintenance of roadways, furrows, drains, banks and any irrigation structures and the construction of any new road, furrow, bank or structure.

3. The probationer lesser shall not absent himself from his allotment for longer than a continuous period of 14 days without the prior approval of the Superintendent.

4. The probationer lesser shall observe the limits of his holding when cultivating his land and shall not disturb any beacons.

5. The probationer lesser shall pay on due date the rental determined from time by the Secretary for Bantu Administration and Development.

6. The rights conferred by this Permission to Occupy shall not be transferable.

7. The probationer lesser shall further observe and abide by the provision of the above mentioned Proclamation (Proclamation R.5 of 1963) or any instruction lawfully issued there under.

At Dzindi, enforcement of the conditions of the PTO occurred primarily during the period when the Department of Bantu Administration and Development, established by the Bantu Administration Act of 1927 (Holdt, 1971), had direct control over the homelands, then called Native Areas. The Act provided for the Governor-General, later on the State

President, to be the “Supreme Chief of the “Bantu” in the homelands. It further provided for the appointment of Bantu Affairs Commissioners and their courts and also for Chief Bantu Affairs Commissioners for specified homeland areas. A very important provision in relation to land and its use in the homelands was that the Act gave the Supreme Chief, i.e. the State president of South Africa, the power to legislate by proclamation, subject to the condition that each proclamation had to be published in the Government Gazette at least one month prior to promulgation, and that each proclamation was laid upon the Tables of both Houses of Parliament (Holdt, 1971).

On irrigation schemes that were established during the 1950s and where Trust tenure applied, the local Bantu Affairs Commissioner was in control over what happened on the schemes. Oral evidence indicates that the Commissioner visited Dzindi regularly, assessing land use on each of the plots. When in his opinion a plot holder was not performing in accordance with the conditions of the PTO, he instructed its withdrawal. At Dzindi there were several homesteads that lost their land rights, because their use of the land failed to live up to the standard of the Commissioner. For a homestead the consequences of having their permission to occupy withdrawn must have been traumatic, because not only did they lose their right to the use of the irrigation plot and commonage, they also had to vacate their home, because each residential plot and dwelling erected on it formed an integral part of the bundle of rights covered by the PTO at Dzindi.

From about 1960 onwards, the South African Government steered the homelands on the road towards self-determination (Holdt, 1971). The establishment of a black civil service in the different homeland areas brought with it a relaxation of the implementation of the PTO conditions on the smallholder schemes. According to witnesses at Dzindi, initially the new authorities still withdrew the PTO of plot holders who failed to comply with its conditions, but they no longer forced them to vacate their dwellings. Later on enforcement of the PTO conditions in terms of farming system and land use intensity by threat of withdrawing the permission was abandoned entirely, to be replaced by a less coercive approach of encouragement.

At Khumbe and Rabali, farmers hold their plots by means of permission to occupy (PTO) as is the case at Dzindi. At Khumbe plot holders were issued with PTO certificates that were signed by Chief Tshikhovo-khovo and the extension officer. The number of the plot that was allocated to a particular household appeared on the PTO certificate. When a plot holder passed away, the family of the deceased was requested to identify the family member to whom the rights to the plot should be transferred. Usually these rights were transferred to the eldest son of the deceased plot holder. It was not permitted to subdivide the plot and transfer the PTO to multiple family members. Transferring a plot to a person who was not part of the household of the deceased was also not allowed. If nobody in the homestead of the deceased was interested in taking over the plot, it reverted back to the Chief for re-allocation to a landless family or to a plot holder in search of additional land. Most of the Khumbe farmers who held multiple plots obtained their additional plot(s) during the Venda homeland era, when Tsonga speaking plot holders (Shangaan) were evicted from the Scheme and forced to move to Gazankulu, the designated homeland for the Shangaan. A similar event with similar consequences occurred at Dzindi but at Dzindi, the community later on decided against farmers holding multiple plots. All plot holders who had obtained additional land following the forced removal of the Shangaan had to return their additions for redistribution among the landless. At Khumbe, households who acquired additional plots during that era were allowed to hold on to these additions. As a result, some farmers at Khumbe hold three plots, which is equivalent to 1.92 ha (2.25 morgen). In the focus groups Khumbe farmers expressed the wish to own their plots by means of title deed. They pointed out that holding the plots by means of PTO no longer had any advantages, because the rentals (R12 per annum per plot) paid to the state were no longer used to maintain the Scheme.

When Rabali Irrigation Scheme was established, each household living in the Rabali settlement was allocated a plot. Plots were issued by means of PTO. During the focus groups no mention was made of instances where plot holders had their PTO withdrawn because they did not comply with the condition contained in the PTO, suggesting a history of limited state interference. This was in sharp contrast to Dzindi, where loss of land rights for such reasons had been common (see section 2.1.2). It needs pointing out that the situation at Rabali differed from that at Dzindi. At Rabali, Trust tenure applied to the irrigation plots only, whilst residential plots and commonage remained under tribal control. At Dzindi, Trust tenure applied to all three types of land. This meant that in cases where Rabali plot holders would have had their PTO to the irrigation plot withdrawn, this would not have affected their rights over their residential site and use of the commonage.

Land held by PTO is not transferable (see also Box 5.1) but in practice when the holder of a plot passes away, the right to the plot usually remains in the hands of his or her immediate family. At Rabali, the immediate family of the deceased right holder was tasked to appoint the person to take over the right to the plot and supply the name of that person to the resident extension officer. The family was expected to reach full consensus on this issue before they approached the extension officer. The content of the will of the deceased, pertaining to who should take over the plot, was not considered by the extension officer. The decision had to be reached by the living. Only one name could be brought forward, meaning that officially the right to the plot remained indivisible. However, internally the family was permitted to subdivide the use of the plot among several members. At Rabali at least one case of a plot was encountered where internally the family had subdivided the plot into three parcels, each used by a different family member. Subsequent fieldwork at Dzindi, reported on in section 6.5.1, showed that the process of transferring plots following the death of a plot holder was very similar to that at Rabali.

During the fieldwork at Rabali in 2005, new PTO certificates continued to be issued. These certificates were filled out in fourfold by the resident extension officer. One copy was handed to the new right holder, one remained at the extension office, one was sent to the District Municipality and one to the Regional Director of the Department of Agriculture. However, Sibanda (2004) pointed out that the power of the former homelands and former South African Development Trust to issue PTO certificates was not delegated to the Provinces when the Interim Constitution of the Republic of South Africa came into effect in 1994. The only exception was KwaZulu-Natal, where the delegation of this power was issued in September 1998. Legally, therefore, PTO certificates issued after 27 April 1994 in provinces other than KwaZulu-Natal are invalid.

Although plot holders at Rabali did not express particular concerns about the way in which they held their land, they did indicate that they would prefer title deed, but only because they thought that this would release them from the obligation of paying an annual fee of R12.00, which applied to the current system of tenure.

5.5.3 Land exchanges on smallholder irrigation schemes

Tenure is thought of as an important factor in smallholder irrigation, particularly with reference to productivity at scheme level. Chapter 4 of this report provided ample evidence of diversity in the livelihood of plot holder households at Dzindi. Irrigated cropping played different roles in their livelihood and a degree of congruence between the way livelihoods were constructed and the role of irrigated cropping in these livelihoods was demonstrated. For example, pensioner households, who received an old-age grant from the state on a monthly basis, were more likely to orient their agriculture towards producing food for home consumption with market oriented production playing a secondary role. Often such households matched investment in total variable costs to their monthly expenditure patterns as determined by the size of their old-age pension grants and the cost of the essential goods and services they required. As a result, they often cropped only a portion of their plots, especially during winter. The availability of unutilized land offered opportunities to earn income from renting out land, but until recently this opportunity was seldom if ever exercised at Dzindi, despite the considerable demand for land both within the scheme (see Chapter 4) and in the surrounding communities (see Chapter 6).

The focus groups at Khumbe pointed out that it was the rule that when a plot holder was no longer interested in farming, he or she had to return the plot to the Chief, so that it could be allocated to another person who was in need of land. Renting out land against payment was not permitted, and anyone caught renting out land in this way was severely punished. The fine imposed on transgressors was one or even two cattle (R3000 per animal in 2005). The focus group pointed out that renting out land against payment was against the rules of the PTO certificate. The group claimed that this was the reason why severe punishment was meted out to transgressors.

Sharecropping was the only form of land exchange that was allowed at Khumbe. This particular practice occurred throughout the year and exchanges applied to single seasons only. Central to the exchange was the cost of land preparation. Share cropping agreements were based on the person in search of land paying for the preparation of a specified number of beds in return for the right to cultivate a proportion of these beds. All agreements to sharecrop had to be communicated to the extension officer in the presence of the Chief and the scheme management committee first, before they could be implemented. The agreements were also communicated to the community, but they were not written down. Only households who formed part of the Khumbe Irrigation Scheme community were allowed to engage in sharecropping. Arrangements with outsiders were forbidden.

Contrary to Dzindi and to an extent Khumbe, land exchanges at Rabali were very common and involved both exchanges among members of the scheme and among plot holders and outsiders. As at Khumbe, exchanges were invariably for a single production season. Two forms of exchange occurred. One form of land exchange involved sharecropping. In return for preparing a specified number of beds, the lessee was usually granted the use of half the number of beds that had been prepared. At Rabali, and other schemes where short furrow irrigation is practised, cultivation consisted of three operations, namely ploughing, disking and ridging. In July 2005 at Rabali, the cost of these three operations varied between R120 and R140 per bed when a tractor service was hired to execute the work. By removing the cost of land preparation for the plot holder, sharecropping significantly reduced the variable cost of production, making irrigated cropping more affordable. This theme is revisited in section 5.5 of this chapter. The second form of land exchange involved an exchange of money in the form of rent. To the plot holder the advantage of this system was that the reward for making available land did not necessarily have to be invested in agriculture. Instead it could be used to pay for projects that were considered more urgent, including the purchase of food.

5.5.4 Discussion and conclusions

Trust tenure applied to all three irrigation schemes that were included in this study. The issue of new permission to occupy (PTO) certificates by the authorities to register transfer of ownership of plots continues, even though from a legal perspective these issues are no longer valid. Historically plot holders have experienced Trust tenure as highly insecure, especially at Dzindi. During the era when the Department of Bantu Administration and Development had authority over the homelands, several plot holders lost their holding for non-compliance with the conditions of the PTO which stipulated how the plot had to be utilized. During the era of the Venda homeland administration another wave of expulsions occurred at both Dzindi and Khumbe based on ethnicity. Evidence collected during this study showed that enforcement of PTO conditions pertaining to the use of the plot is largely a thing of the past but other conditions remain in force. In terms of holding rights, plots remain indivisible, but subdivision of the user rights is being allowed. The authorities maintain control over the transfer of the rights over a plot following the death of a plot holder or when a plot is vacated, but the composition of what constituted the authorities differed among the schemes.

The contemporary irrigator communities at the three schemes each interpreted the Trust tenure system differently and enforced selected elements of the historical PTO conditions that applied, whilst ignoring others. This phenomenon had important implications for land exchange at the three schemes. At Dzindi, exchanges of land have been discouraged completely by the community and its leadership until very recently. The main reason for this appeared to be the history of evictions for non-compliance with PTO conditions during the first two decades after the establishment of the scheme. Some evidence of change in attitudes has occurred since about 2006 (see chapter 6). At Khumbe, land exchanges were allowed by means of sharecropping arrangements involving members of the Khumbe community only. Strictly forbidden at Khumbe were the renting out of land against payment and exchanges of land involving 'outsiders', with severe fines being imposed on transgressors. At Rabali, both sharecropping and renting out of land were common practice and both members of the irrigation community and 'outsiders' were allowed to engage in these types of land exchanges. Among plot holders at Rabali poverty was the main motivation to engage in exchanges of land. Sharecropping which involved the lessee paying for the cost of land preparation of all or part of the plot in exchange for about half of the land that had been prepared substantially reduced the total variable costs of production for the lessor. Renting out land against payment enabled the lessor to derive monetary income from his land holding that was not directly linked to production.

The apparently efficient market for land that existed at Rabali was expected to increase land use, but the comparison of land use at the three schemes during 2005 shown in Table 3.1, did not provide evidence of this expectation. It needs pointing out that other factors, such as differences in climate and water availability among the three schemes might be responsible for the apparent lack of impact of the efficient land exchange market on land use at Rabali.

The evidence that was obtained in this study indicates that land tenure on smallholder irrigation schemes similar in structure, scale and plot size as Dzindi, Khumbe and Rabali, impacts primarily on transfer rights, with particular reference to renting out land. No evidence was found of the wish to use the plot as collateral to access finance among plot holders at the three schemes. Whereas the same Trust tenure system applied at all three schemes, the different irrigation communities interpreted the rights and conditions of the system in their own particular way. They each invoked different conditions to prevent the broadening of certain transfer rights, because as a group they did not favour the possible outcomes of these rights. All three ignored other conditions of the system, because these no longer suited their collective or personal interests. Resistance against the broadening of transfer rights that would enable plot holders to rent out part or all of their plots was strongest at Dzindi, but since the start of this project attitudes have started to change as is explained in section 6.5.1. At Khumbe sharecropping was allowed, but only among members of the group. This indicates reluctance to allow the entry of outsiders, possibly because this would further complicate the system of water management at these schemes, which at all three schemes was under strain as a result of unresolved conflicts (see section 5.2). However, at Rabali conditions pertaining to Trust tenure were not invoked to prevent land exchanges with outsiders, because plot holders had learnt to benefit from such arrangements. At all three schemes, the particular conditions of Trust tenure that pertained to the productive use of the plot were being ignored, because the community understood that farming was influenced by the overall livelihood situation of individual plot holder households.

At all three schemes plot holders expressed a desire to obtain title deed to their plots, but this was not necessarily motivated by the perception that the current tenure system offered too little security. At Rabali and Khumbe, the main reason plot holders preferred title deed was because they thought this would end the annual rental demanded by the Department of Agriculture. Clearly, Trust tenure is an anachronism, and the issue of PTO certificates in Limpopo Province is legally no longer valid. However, the replacement of the current tenure system with an improved system that offers a higher degree of security will not necessarily free the market for land exchanges. This study has shown that factors other than land tenure appear to influence the particular stance plot holder communities adopt towards land exchanges, especially those involving outsiders.

5.6 Land preparation on smallholder irrigation schemes

5.6.1 History of land preparation technology

Smallholder irrigation schemes established after WWII were projects of modernization with the state as agency. In these projects the state introduced African farmers to technology that enabled improved crop water availability. Irrigation also enabled year-round production, whereas in the traditional cropping system production was limited to the summer period when it rained. Extending production into winter required the introduction of new crops into the repertoire of smallholders. The schemes were also the sites where African farmers were first exposed to other technological innovations, such as chemical fertilisers, hybrid seed, chemical pest control and mechanized land preparation.

South African large-scale commercial agriculture switched from animal to mechanical draught for the cultivation of land after WWII. The country counted 230 tractors in 1918, 6000 in 1937, 20 000 in 1948 and more than 100 000 in 1960 (Starkey *et al*., 1995). The earliest record of the use of tractors in African farming that was retrieved dates back to 1949, when the St Marks District Council (Eastern Cape Province) requested the state to assist African smallholders by making available tractors to prepare the land for the planting of summer grains, because the number of cattle (oxen) for draught were hopelessly too few for the task (St. Marks District Council, 1949).

Before 1850 Africans practised hoe agriculture, but during the second half of the 19^{th} century and the early decades of the 20^{th} century they converted to animal draught and the use of the plough for cultivation (Bundy, 1988; Starkey *et al*., 1995). In the southern homelands of Ciskei, Transkei and KwaZulu, cattle were the principal animal draught species, whilst in the other homelands donkeys also played an important role. During the 20^{th} century, African people in the homelands increasingly ran out of space, especially after WWII, when the human population in these territories increased rapidly. Many families lacked the number of draught animals required to pull a plough and their inability to timely prepare cropping land reduced their capacity to provide in their own food requirements. As a result, hunger and malnutrition regularly affected the homeland populations, motivating the state to make available a subsidized public tractor service in these territories (Starkey *et al*., 1995). From about 1950 to 1980 this service rapidly grew in size and impact, but from about 1980 onwards the cost of this service to the public raised concern, first resulting in stagnation and later on in the dismantling of the service in the various homeland areas. Limpopo Province withdrew its public land preparation service shortly after re-incorporation of the homelands in South Africa in 1994.

Smallholder irrigation schemes were focal points for mechanization. Public tractors were used during the initial preparation of the plots at establishment of the schemes and subsequently they were made available, often on a permanent basis, to scheme farmers. In some cases the provision of tractor services for cultivation to farmers free of charge formed part of the conditions of establishment of the scheme (Van Averbeke *et al*., 1998). The result was a rapid and often total abandonment of animal draught on these projects, a process that was less explicit in dryland communities (Starkey *et al*, 1995; Lahiff, 2000). However, when the subsidized public land preparation service on smallholder irrigation schemes was withdrawn, farmers were faced with a serious constraint.

5.6.2 Withdrawal of public land preparation services from smallholder irrigation schemes

Common to Dzindi, Khumbe and Rabali was that cultivation of land in preparation for planting involved three operations. The first consisted of ploughing to turn over the sod of the previous crop and to break up the surface layer of the soil. The second consisted of disking to loosen the topsoil further and to reduce the size of the clods. The third consisted of ridging to construct the furrows through which water flows when irrigation is applied.

In 1995, when the public cultivation service were still available, Lahiff (2000) compared the cost of preparing land at Tshiombo Irrigation Scheme using the public service with that when a private supplier was used. Using the public service the cost of cultivation contributed 19.8% to the total variable cost (excluding labour) of maize production, and 8.3% to that of vegetable production. Using the private supplier this contribution increased to 26.9% in maize and 12.3% in vegetables.

At Dzindi the proportional contribution of the cost of land preparation to total variable costs (excluding labour) was determined on three occasions (n = 175) during the period 2001 to 2005. On average, it was found to be 33.9% in maize and 28.4% in vegetables. When compared to what it was at Tshiombo in 1995 at a time when the public land preparation service was still available, the significance of the impact of the withdrawal of this public service on the total variable costs of irrigated cropping is clear.

When the public land preparation service was withdrawn from Rabali in 1994 and from Khumbe and Dzindi in 1995, the Province did not exercise the options of transferring the tractors and implements to the farmer communities or offering farmers the opportunity to purchase this equipment. Instead the equipment was transported to Polokwane, the provincial capital, for disposal. Since then plot holders at the different schemes have had about a decade to develop strategies to cope with the withdrawal of the public service.

5.6.3 Coping with the withdrawal of public land preparation services

5.6.3.1 Dzindi: In 1995 at Dzindi, when farmers were informed that the Province intended to withdraw the public land preparation service, and that farmers would not be offered the option to purchase the equipment, they decided to collectively purchase a tractor and the necessary implements. Using money earned from fines and joint production projects, which were held in a savings account, they paid R44 000 in cash for a second-hand tractor and ridger. They also entered into a hire-purchase agreement of R11 000 to acquire a plough and a disk. An experienced tractor driver was appointed to operate the tractor, and a system of booking and waiting lists was implemented to manage service delivery. Rates were set in relation to those charged by private operators. Relative to private rates, the rates per strip for ploughing and disking of the collective service were R5 less, and the rate for ridging R10 less. There after, whenever the rates charged by private operators increased, the rates of the collective service were raised by the same amount.

In 2005 the cost of a full set of operations provided by the collectively owned tractor was R55 per strip and R75 when a private supplier was used. Considering that on average a plot at Dzindi contains 18 strips, the cost of cultivating a complete plot in 2005 was R1350 using a private operator, and R990 using the collective service, a saving of R360 or 27%. Disadvantages associated with the collective service were long waiting times and long down times following mechanical failures. As a result, the service was used mainly by farmers who produced food for own consumption. Market-oriented farmers almost exclusively used private services, or had acquired their own tractors. There was evidence that financially the collective service was not sustainable. Over the 10-year period income had been sufficient to pay for operation and maintenance, but capital redemption had been ignored. In 2005, the collectively owned tractor was starting to show its age. However, no money had been set aside to purchase a new tractor, because over the entire period, the income from providing the service had not been adequate to generate a reserve. Any reserves that were built up at one or other stage were consumed to pay for major repairs. The second strategy at Dzindi, employed only by the poor, who mainly farmed for food, was to leave part of their plots fallow, especially during winter.

5.6.3.2 Khumbe and Rabali: At Khumbe and Rabali no collective action was taken to lessen the impact of the withdrawal of the public land preparation service on the farmer community. As a result, at both schemes the only mechanized services available to plot holders were in private hands.

As at Dzindi, one of the strategies plot holders at Khumbe and Rabali used to cope with the high cost of land preparation was to cultivate only parts of their plots. Another strategy was to enter into sharecropping arrangements with others (see also section 5.5). At Khumbe, sharecropping involved members of the plot holder community only, but at Rabali outsiders were also involved. Two types of sharecropping were identified. The first type required the seeker of land to pay for the preparation of the plot in return for the use of part of the plot. The second was more of a land rental agreement, whereby the plot holder rented out a number of strips for a single season at about R100 per strip. The plot holder then used at least part of the rental income to hire a private contractor to prepare the remainder of the plot. A third strategy was to use animal draught for cultivation. This strategy was employed by two plot holders at Rabali, who made use of donkeys and one plot holder at Dzindi, who used cattle to disk and ridge. The potential for a more widespread use of animal draught was limited at the three schemes because of a lack of rangeland. A fourth strategy was to resort to cultivation by hand. At Dzindi and Khumbe this was limited to the ridging operation, but at Rabali one farmer was identified who conducted all operations by hand. Cultivating two strips covering an area of 1100 m^2, took him seven full days to complete (Figure 5.2).

5.6.4 Discussion and conclusions

The withdrawal of the subsidized public land preparation service on the three smallholder irrigation schemes that were investigated resulted in a substantial increase in the cost of cultivation to farmers. Five different strategies developed by farmers to cope with the high cost of land preparation were identified. They included establishing a collective cultivation service that offered discounts, leaving part of the plot fallow, share cropping, converting to animal draught and resorting to manual labour. The different strategies enabled farmers to continue producing crops, which was particularly important for the attainment of food security at the level of their households. For the poor the withdrawal of the subsidized public land preparation service has made life more difficult than before, and at scheme level the withdrawal has most probably reduced the use intensity of the land.

Bembridge (2000) and Laker (2005) drew attention to the option of re-introducing animal draught on smallholder irrigation schemes as a way to reduce variable costs and possibly limiting the problem of soil compaction associated with the use of tractors. Whether or not this is a viable option warrants investigation.

FIGURE 5.2: At Rabali, this farmer rented two strips covering 1100 m^2 and prepared them entirely by hand, which took him seven days of work

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6 RELATIONSHIPS BETWEEN SMALLHOLDER IRRIGATION SCHEMES AND THEIR SURROUNDS

6.1 Introduction

When the Water WRC conceived this project and formulated its terms of reference, it identified the importance of relationships between smallholder canal irrigation schemes and their surrounds. Of particular concern to the responsible WRC manager at the time, Dr S Mkhize, was the establishment history of smallholder irrigation schemes, which, according to him, was in several instances accompanied by dispossession. He was of the opinion that dispossession had a long-lasting effect on the social relationships between irrigation communities and their surrounds and the team was instructed to investigate this issue at Dzindi, the primary research site of the study. The title of the project also implied the inclusion of the areas surrounding smallholder irrigation schemes in terms of the main aim of the project, which was to develop best management practices for small-scale subsistence farmers. Practically, the available time and budget did not allow the team to engage in comprehensive parallel studies of both an irrigation scheme and a surrounding dryland community. For this reason, the team decided to focus on an analysis of land, water and agriculture in selected communities surrounding Dzindi and on the social relationships between the scheme and these surrounding communities. Attention was also awarded to potential ways in which the resources available at the scheme could be shared with people living in its surrounds. This was in line with the ideas of the Limpopo Department of Agriculture at the time of inception of the project. The Department referred to the impact of an irrigation scheme on development in and around them as its sphere of influence and sought to expand the spheres of influence of smallholder irrigation schemes in an attempt to justify state expenditure on their revitalization as part of the Revitalization of Smallholder Irrigation Schemes (RESIS) programme of the Province. The main objectives of the study were to find out to what extent differences in access to land and water affected relationships between irrigation communities and their surrounds and to develop ideas on how these relationships could be improved.

6.2 Methods

A single case study approach was employed to conduct the study using Dzindi Irrigation Scheme as the case. The study investigated access to and use of land and water and perceptions about ownership of these resources amongst households on the scheme and among those living in its surrounds. Dzindi is located in an area of rapid urbanization. It borders urban settlements in the north and rural settlements in the south (Figure 6.1). Itsani, the settlement that contains Dzindi, is bounded by the settlements of Manamani, Muledane, Shayandima and Tshisahulu. The majority of Dzindi plot holders reside in Itsani and most of the others live in Shayandima.

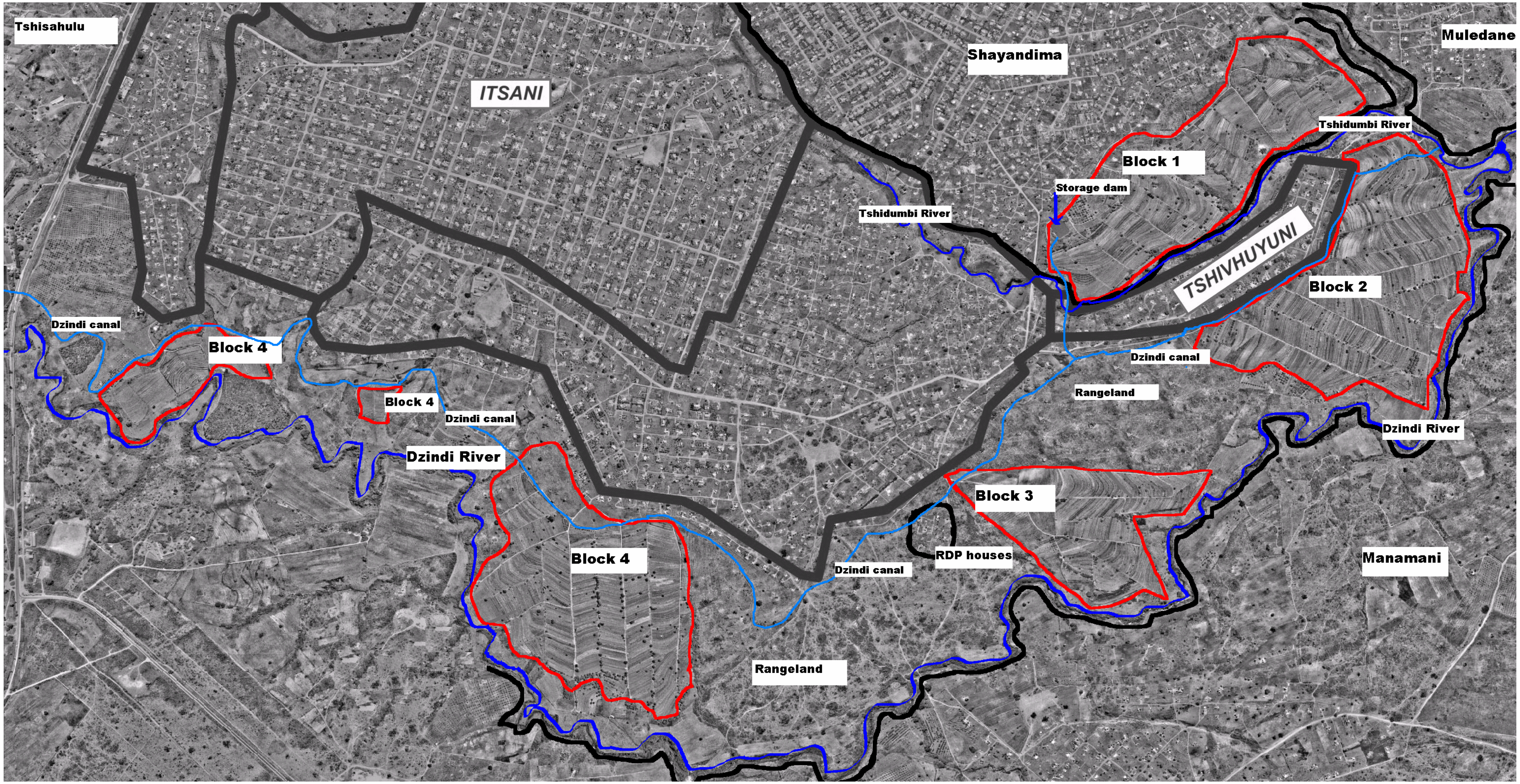

FIGURE 6.1: Dzindi, Itsani and surrounding settlements

Itsani is a peri-urban settlement that features a few privately held fruit orchards and an area assigned for use as rangeland. Residents of Itsani practise home gardening on their residential plots. Manamani is a rural village characterized by large residential plots, parts of which are used for vegetable gardening and fruit production. Livestock is reared on communal rangeland. Shayandima is a fairly affluent township inhabited mostly by middle-income households who often practise ornamental gardening. Some residents of Shayandima use a small portion of their residential sites land for home gardening. Muledane is a township inhabited mainly by poor people. Here residential sites tend to be larger than in Shayandima. Some residents of Muledane practise stream bank cultivation of maize in summer and vegetables in winter. Sugar cane is also planted. Tshisahulu has the characteristics of a peri-urban settlement and is similar to Itsani. Residents of Tshisahulu use parts of their residential plots for vegetable production and other parts for ornamental gardening.

The study involved a series of surveys that were conducted in the five settlements surrounding the scheme, namely Itsani, Shayandima, Muledane, Manamani and Tshisahulu and at Dzindi. In addition a transect walk was done along the Dzindi River up stream of the irrigation scheme to document extraction and use of water along this river above the weir that supplies water to the scheme.

The interview schedule used to conduct the surveys in the settlements surrounding Dzindi sought data on access to land and water and on the perceptions of respondents on ownership of these resources among homesteads in these settlements. Questions enquiring about existing relationships between these households and the scheme were also included. In each settlement 35 households were selected using a probability sampling procedure. The primary sampling units were residential plots, whereby it was assumed that each residential site was occupied by a single household. The sampling frame was a list of all residential sites obtained from the local civic organization of each settlement. Residential sites occupied by households owning plots at Dzindi, vacant residential plots and plots used for purposes other than residential were removed from the list. Systematic sampling (De Vos, 2002) was used to draw the sample. The surveys in the different settlements were conducted during the period January 2005 to May 2006. The interviews were targeted at the heads of households and their spouses. Face-to-face interviews were conducted in *Tshivenda*, the mother tongue of the respondents and the researcher, Mr MM Netshitomboni. According to Babbie *et al*. (2001), face-to-face interviews are the preferred method to collect data in surveys where literacy levels are low. The interview schedule was drawn up in English and translated to *Tshivenda*. It was pre-tested using a sample of ten households in Itsani. All interviews took place in the house of the respondents and they were conducted during daylight hours. The majority of interviews were conducted during the first visit to participating households. When the head of households or spouse were not found at home during the first visit, an appointment was arranged for a second visit. In instances where participation of a household in the sample could not be secured, the household occupying the site to the right of the sampled site when facing the front door was selected as the replacement. Replacements were necessary when head of households or spouse were not found, when they refused participation or when the house was not occupied. This was necessary for 31 of the 175 households that were contained in the samples that were drawn. Size of the residential sites was measured by counting calibrated steps enabling conversion to units of length. Before commencing the interviews, respondents were informed about the purpose of the study and their consent to participate was requested. Data were collected using face-to-face interviews, whereby the questions appearing on the interview schedule were read to the respondents. Closed and open-ended questions appearing in the interview schedule were read to the respondents in their mother tongue. The responses were recorded on the interview schedule. After completing the fieldwork, the data were edited and coded, before being captured on a spreadsheet using MS Office Excel software. After capturing, data was subjected to descriptive statistical analysis to calculate group means.

At Dzindi a survey was used to investigate the perceptions on ownership of land and water amongst plot holders. The sample of 45 plot holders participating in the study was obtained using systematic sampling with the list of all plot holders serving as the sampling frame. This ensured representation of all four irrigation blocks. Following the completion of the survey three additional plot holders were interviewed, because they were identified as the only three plot holders at Dzindi that were involved in land exchanges and they were not included in the sample. The field work of the survey at Dzindi was done during August 2006.

The investigation of water extraction from the Dzindi River above the weir was motivated by a statement made by one of the Dzindi plot holders to Prof MC Laker, who made a study visit to Dzindi (15-17 August 2005). The farmer claimed that seasonal water shortages at Dzindi were due to the extraction of water from the river above the weir (Laker, 2005). Data were collected during a transect walk from the weir to Mapate during May 2006. Data collection involved visual observations and enquiries made from local residents about water extraction along the River. Where possible, pictures were made of the systems that were used to extract water. The topographic maps 2330AB (Chief Directorate: Surveys and Land Information 1993) and 2230CD (Chief Directorate: Surveys and Land Information 1994), both on a scale of 1:50 000 were used to locate the points of extraction. Once a point of extraction was identified, the person responsible for the extraction was identified and interviewed. The purpose of the interview was to find out the purpose of the extraction of water, whether extraction was seasonal or perennial and how much water was being extracted.

6.3 Land and water in the surrounds of Dzindi

6.3.1 Land in the settlements surrounding Dzindi

Land is a natural resource that is used for a variety of purposes. In this study three types of land namely, residential, arable and rangeland, were considered. Residential land refers to land that is meant for housing purposes. In South Africa, residential sites in rural areas are typically smaller than 0.5 ha in size and the size of new allocations has declined over time. In urban areas residential sites are usually smaller than in rural areas. The residential sites in the five study sites varied in size between 600 and 5040 m^2 (Table 6.1). To an extent, differences in the size of the residential plots within particular settlements were associated with the period of plot demarcation. For example, in Itsani sites allocated prior to 2002 were larger than sites that were demarcated in 2002.

TABLE 6.1: Size of residential plots in settlements surrounding Dzindi Irrigation Scheme

Settlement	Range (m^2)	Mean (m^2)
Itsani (n = 35)	1050-5040	1751
Shayandima (n = 35)	600-1435	1115
Muledane (n = 35)	750-1800	1152
Manamani (n = 35)	950-2000	1578
Tshisahulu (n = 35)	1050-1800	1521
All (n = 175)	**600-5040**	**1423**

The overall mean size of a residential plot was 1423 m^2. Comparatively, sites in rural Manamani were on average the largest and those in the formal urban township of Shayandima the smallest. In Itsani selected households held two residential sites, whilst others had extended their sites onto unused land bordering their sites. The majority of respondents (88%) were satisfied with the size of their residential sites. The few (12%) who felt that their sites were too small indicated that they were keen to access more residential land. They identified purchasing or renting from others as possible ways to access additional residential land as there were no vacant plots available in the vicinity of their homes. Residential sites were sold in all settlements but prices were higher in urban areas (R500 - R3000) than in rural areas (R150 - R2000). Selling of residential sites involved the civic association or the chief of the settlements involved.

Residential sites in the study area were used for a variety of purposes depending on the preferences of the owner. The different uses are presented in Table 6.2. Besides using their residential plots for housing purposes, the majority of households also used their residential sites for agricultural purposes. Typically, they allocated a portion of their sites to the production of food. The most important form of agriculture was vegetable production practised by 85% of the respondents. The vegetables that were grown included Chinese cabbage, Swiss chard, white cabbages, sweet potatoes and onions. Fruit trees, including mangoes, paw paws, litchis, avocados, oranges and lemons were grown by 78% of respondents. Crops, mainly maize and pumpkins, were also important and were grown by more than half (64%) of the respondents.

In urban and peri-urban areas the rearing of livestock was less common than in rural Manamani, where about half of the respondents raised poultry. Lawns and ornamental plants were commonly found (89%) in urban areas, but less so in rural areas (34%). Agricultural production on residential sites was mostly for own consumption.

TABLE 6.2: Uses of residential plots by households in settlements surrounding Dzindi Irrigation Scheme

Uses	Proportion of households (%)					
	Urban		Peri-urban		Rural	All (n=175)
	Shayandima (n=35)	Muledane (n=35)	Itsani (n=35)	Tshisahulu (n=35)	Manamani (n=35)	
Housing	100	100	100	100	100	100
Grow vegetables	86	80	91	80	89	85
Grow fruit trees	60	69	74	91	94	78
Grow lawns or ornamental plants	89	80	74	71	34	70
Grow crops	43	52	66	94	66	64
Produce micro-livestock	6	15	37	31	51	28
Conduct trade	3	6	11	9	9	8

The prevalence of crop production on the residential sites of settlements surrounding Dzindi indicates that agriculture remains important among local people, even those living in the formal urban settlements of Shayandima and Muledane. Selected households in these townships did not hesitate to grow crops along the road sides. In Itsani much of the land alongside the road was cultivated and planted to maize during the summer of 2005. In the winter of 2005 some parts were planted to vegetables, which were irrigated. The practice of ornamental gardening dominated in urban settlements but was rare in rural Manamani. In all the settlements residential land was owned by the occupants and none of the respondents was renting the residential land they occupied.

Arable land refers to land specifically designated for crop production. This type of land is usually located away from the residential plots. Access to arable land among households residing in the settlements surrounding Dzindi was extremely limited (Table 6.3). In the rural settlements of Manamani, the proportion of households with arable land was higher than in the townships of Shayandima and Muledane.

TABLE 6.3: Households that held arable land in settlements surrounding Dzindi Irrigation Scheme

Settlement	Proportion of households (%)
Manamani (n=35)	14
Itsani (n=35)	6
Muledane (n=35)	6
Tshisahulu (n=35)	6
Shayandima (n=35)	3
All (n=175)	**7**

With the exception of rural Muledane, the arable land held by respondents was located outside the settlements where they resided. Distances between the residence and the locations where the arable land was situated ranged between 8 km and 40 km. The respondents who held arable land had either inherited or purchased their plots. Arable land was mostly planted to food crops, such as maize, groundnuts, vegetables, and pumpkins. Some was planted to fruit trees. In Manamani, Muledane and Tshisahulu, selected households used vacant land in the settlement for cropping. Residents of settlements surrounding Dzindi accepted that plot holders at the scheme were the legitimate owners of their plots and during the interviews none of the respondents challenged this right.

Rangeland refers to areas of natural veld (Scogings, De Bruyn and Vetter, 1999). In South Africa communal rangeland belongs to entire communities whose members have equal access (Scogings, De Bruyn and Vetter, 1999). In the study area all respondents confirmed that rangeland belonged to the entire community and could be accessed freely by all its members but the survey results indicated that very few respondents utilized this land (Table 6.4).

TABLE 6.4: Use of rangeland by households in settlements surrounding Dzindi Irrigation Scheme

Uses	**Proportion of households**					
	Urban		**Peri-urban**		**Rural**	
	Shayandima (n=35) (%)	Muledane (n=35) (%)	Itsani (n=35) (%)	Tshisahulu (n=35) (%)	Manamani (n=35) (%)	All (n=175) (%)
Collect firewood	3	11	14	3	51	16
Collect medicinal plants	0	3	3	0	14	4
Collect wild fruit	0	6	3	0	6	3
Collect timber	0	9	6	0	14	6

Use of the rangeland was most prevalent among households in rural Manamani and virtually non existent among households in Shayandima and Tshisahulu. The low utilization of the available rangeland was related to distance between residence and rangeland and to the process of urbanization, such as electricity replacing the use of firewood. The results of the survey indicated that collection of firewood and to a lesser extent the collection of timber for building purposes were the most prevalent uses of the available rangeland. None of the 175 respondents held small or large livestock, explaining the absence of the use of the rangeland for the purpose of grazing by livestock.

Demand for additional land was identified among residents of the settlements surrounding Dzindi, primarily for arable land. The majority of respondents indicated that they were satisfied with the size of their residential plots but many of the respondents who did not hold arable land expressed an interest in gaining access to such land. The demand for arable land has led to selected members of Itsani growing crops on land along the canal.

Respondents from Itsani and Shayandima identified Dzindi as the only potential source of arable land in the vicinity and indicated renting or purchasing land at Dzindi as possible ways to obtain access. None of these respondents was interested in sharecropping of land at Dzindi. The few respondents who had tried to rent land at Dzindi had been unsuccessful. There was no evidence of demand for additional rangeland.

6.3.2 Water in the settlements surrounding Dzindi

Water is a key resource. Access to sufficient and safe water is vital for human development. In the rural areas of South Africa water is derived from taps, dams, springs, boreholes, rivers, streams, canals and wells. Here, the chore of providing water is usually the responsibility of women and children, who often cover long distances in order to collect sufficient water for the daily requirements of their families.

In the settlements surrounding Dzindi sources of water included taps, roof harvesting, the canal that supplied water to Dzindi, private boreholes, one spring and two rivers. The proportion of households collecting water from these different sources is presented in Table 6.5.

TABLE 6.5: Use of different sources of water by households in settlements surrounding Dzindi Irrigation Scheme

Sources of water	Proportion of households (%)					
	Urban		Peri-urban		Rural	All (n=175)
	Shayandima (n=35)	Muledane (n=35)	Itsani (n=35)	Tshisahulu (n=35)	Manamani (n=35)	
Taps	100	100	100	100	100	100
Roof harvesting	60	57	86	51	60	63
Boreholes	6	14	14	11	14	12
Canal	17	0	23	0	0	8
Rivers	0	14	3	3	20	8
Spring	3	0	3	0	0	1

Table 6.5 indicates that all households had access to tap water. Most of them (71%) had taps on their residential sites. In the different settlements access to tap water on the residential site varied and was higher in urban settlements than in rural settlements. In the urban settlement of Shayandima almost all respondents (86%) had taps on their sites. Respondents without taps on their sites obtained water from street taps at a distance less than 300 m from their place of residence. The reliability of tap water availability varied among the settlements. In Itsani tap water was sometimes not available for a week, whereas in Shayandima tap water was usually available. In rural Manamani the availability of water in street taps was reportedly poor. Typically tap water was available four to five days per week. Residents of Shayandima, Tshisahulu and Muledane with taps installed on their residential sites were expected to pay R20 a month but most respondents did not make these payments. Residents of Itsani and Manamani that had taps of their residential sites did not have to pay for water. In all settlements water from street taps was available free of charge but households had to pay for the repair of broken pipes and taps. They collectively purchased the materials required to execute the repair which was done free of charge by staff of the Department of Public Works.

Harvesting of water from rooftops was practised in all settlements but was most common in Itsani. A minority of households in Shayandima and Itsani used canal water because the canal flows through these two settlements. In all settlements there were households that had private boreholes. They sold water to others during periods of water shortage. Use of water extracted from the Dzindi and Tshidumbi Rivers and the spring located in Itsani was rare. The few households that used spring or river water lived close to these sources. In all cases the distance between the residence and the source was less than 500 m. Respondents indicated that water obtained from the two rivers was unhealthy.

Water obtained from the various sources in the study area was used for a variety of purposes, including drinking, cooking, bathing, laundry, watering of micro-livestock and watering of plants and home gardens. The majority of respondents indicated that they were satisfied with the amount of water they had access to. The different uses recorded in the study area during the survey are presented in Table 6.6.

TABLE 6.6: Uses of water obtained from different sources by households in settlements surrounding Dzindi Irrigation Scheme

Source	**Uses**			
	Drinking and cooking	Bathing and laundry	Watering of micro-livestock	Watering of plants in home gardens
Taps	x	x	x	X
Roof tops	x	x	x	X
Boreholes	x	x	x	X
Canal		x	x	X
Rivers		x	x	X
Spring	x	x		

Water from taps, roof tops and boreholes was used for all the different purposes that were identified. Water from the canal and the rivers was not used for drinking and cooking, because respondents rated it as unsafe. Selected households from Itsani and Shayandima extracted water from the canal supplying Dzindi; but the amounts involved were not expected to greatly affect water availability at Dzindi. Uses included washing, bathing, laundry and agriculture. In some instances canal water was used to irrigate crops planted on vacant land along the canal. Besides the relatively small extractions by these residents large extractions from the canal were also reported. These involved the filling of big water tankers but who exactly was responsible for this was not determined.

Perceptions on ownership of water varied among respondents. All respondents agreed that spring and river water were owned publicly and could be freely accessed by everyone. The majority of respondents (86%) were of the opinion that canal water belonged to plot holders, whilst the remaining 14% thought that it belonged to the public and should be shared accordingly. All respondents indicated that water harvested from roof tops belonged to the owner of the house concerned. They were also unanimous that water extracted from a borehole sunk on a residential site belonged to the owner of the site and borehole.

The majority of respondents were satisfied with the amount of water they accessed from the various sources. The few who were not satisfied wanted more water for the irrigation of crops in home gardens, washing and doing laundry.

6.4 River extraction of water from the Dzindi River above the weir

As was indicated earlier, up-stream extraction of water was identified by one of the Dzindi farmers as a cause for reduced flow reaching the weir (Laker, 2005). This section documents the cases that were encountered during a transect walk along the Dzindi River upstream of the weir. Most of the arable land found along the Dzindi River was planted to dryland maize. However, five extractors of water from the Dzindi River were identified. The sites where these extractions occurred are indicated in Figure 6.2.

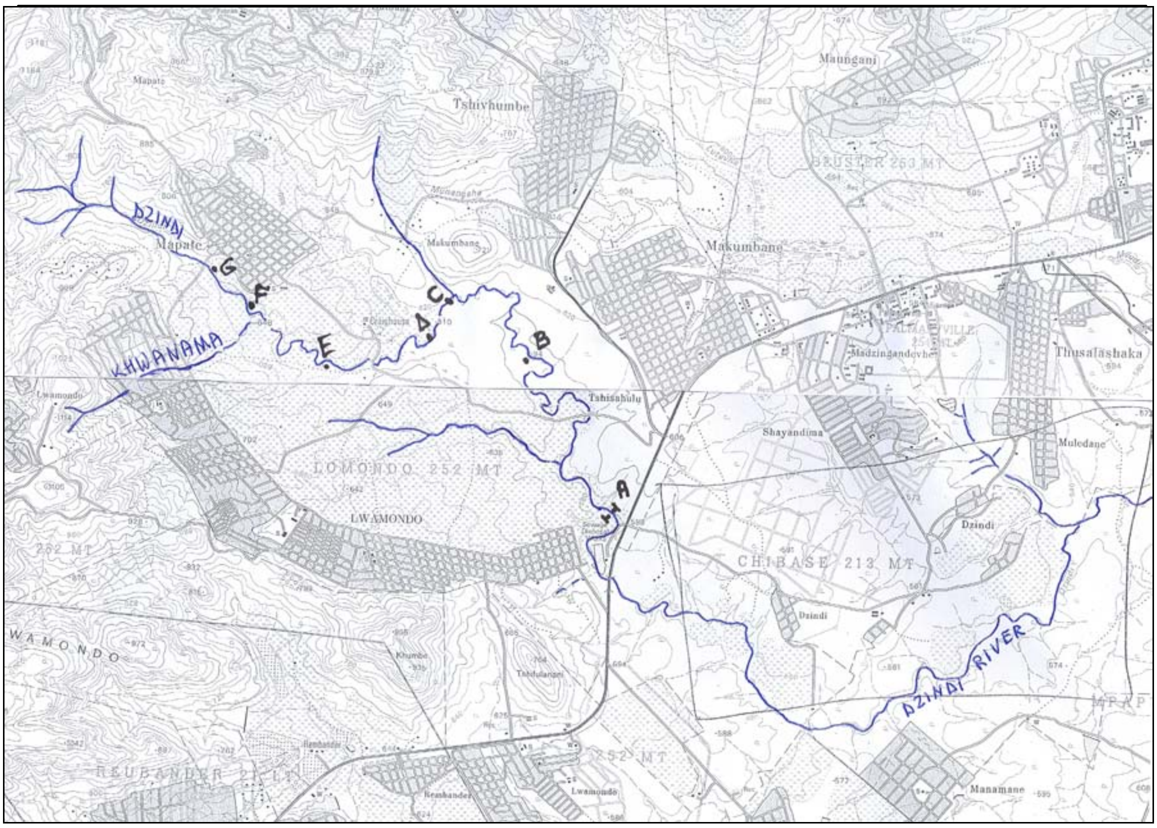

FIGURE 6.2: Extraction from Dzindi River upstream of the Irrigation Scheme weir (A)

A privately held farm (site B in Figure 6.2) located in Lwamondo extracted water from the Dzindi River during winter only for the production of irrigated vegetables using a moveable diesel pump. The pump was brought to the farm once per week for irrigation. During summer the land was used to produce dryland maize. Part of the farm was planted to mangoes and avocados but the trees were not irrigated. Irrigation of the trees did occur during 2002 when they were still small. The orchard part was about 3 ha in size and the vegetable part about 1 ha. The diesel pump was not at the farm at the time of the survey having been sent to Makhado for repairs.

Until 2004, the Tshisahulu Community Garden (site C in Figure 6.2) extracted water from the Dzindi River for the production of irrigated vegetables, initially using a diesel pump and later on using an electric pump. This 2 ha project was funded by the state and was equipped with a greenhouse in which vegetable transplants were grown for use in the project and to sell to the general public. Financial management problems and non-payment of debt lead to the closure of the project in 2004. At present the land is used to grow dryland maize during summer.

Brico (site D in Figure 6.2) was a brick making company that occasionally extracted water from Dzindi River using a pump driven by an old tractor engine. Most of the time, the company made use of borehole water but during the dry season they also used river water. To extract the river water the company blocked the river using sand bags to construct a weir, which remained in place until the end of the dry season. At the time of the survey, the weir had been removed, because there was sufficient borehole water, but from the description given, the Brico weir was similar in construction to the sandbag weir shown in Figure 6.3. The company had three large plastic tanks and a concrete reservoir with a combined capacity of about 200 m^3 to store water. According to the company this amount of water was sufficient to enable about 45 days of brick production.

From 2000 until 2003, the Lwamondo Community Project (site E in Figure 6.2) extracted water from Dzindi River using an electric pump. This project produced vegetables and intended to plant bananas and macadamia nuts but it collapsed as a result of financial problems. Since the collapse of the project the land has been used to grow dryland maize during summer.

Two privately held farms (sites F and G in Figure 6.2) both had a history of extracting water from Dzindi River. All available evidence indicated that only one of the two farms (site F) was still actively extracting water from the River at the time of the survey. To obtain water the owner of the farm built a weir using sand bags and wooden poles (Figure 6.3).

FIGURE 6.3: The weir made of sandbags and wooden poles by a private farmer to extract water from the Dzindi River

Each summer the weir was destroyed and had to be rebuilt when the rainy season had come to an end. Water collecting in the weir was diverted in an earthen furrow dug by the farmer. This furrow conveyed the water to his farm, which was planted to vegetables, macadamia nuts and litchis. The farm was about 3.5 in size with about 1.5 ha planted to vegetables. The farmer practised surface irrigation. He irrigated once per week and each irrigation event lasted for a day. The other privately held farm (site G) apparently made use of an electric pump to extract water from the

Dzindi River but according to local residents no irrigation had been taking place for some time.

The information collected during the transect walk provided evidence of water extraction from the Dzindi River above the weir but the scale of the extractions was limited and probably of little consequence to the quantity of water reaching the scheme except perhaps during periods of exceptionally low flow.

6.5 Land and water at Dzindi

6.5.1 Land at Dzindi

The investigation of land and water in settlements surrounding Dzindi identified a demand for arable land among households residing in these settlements. Dzindi Irrigation Scheme was identified as the only potential local source of this type of land. A survey among a sample of Dzindi plot holders was done to explore to what extent the scheme could possibly serve as a supplier of arable land. Table 6.7 shows the perceptions plot holders had about the adequacy of the plot size at Dzindi.

TABLE 6.7: Perceptions of plot holders on the adequacy of the plot size at Dzindi (2006)

	Proportion of plot holders (%)			
	Block 1 (n=15)	**Block 2 & 3 (n=18)**	**Block 4 (n=15)**	**All (n=48)**
Too small	13	28	20	21
About right	87	72	80	79
Too large	0	0	0	0

The data presented in Table 6.7 indicate that most plot holders (79%) at Dzindi were satisfied with the size of their plots but none of them rated their plots as being too large. A minority of plot holders (21%) considered their plots too small and they were keen to access more land. They identified renting or borrowing land from farmers, who did not fully use their plots, as the two possible ways to obtain access to this land.

Sharing of plots among family members was common at Dzindi (Table 6.8) and in three cases sharing of land involved fellow farmers at the scheme but sharing of land with outsiders was not practiced.

TABLE 6.8: Sharing of plots at Dzindi (2006)

Sharing partners	Block 1 (n=15)	Block 2 & 3 (n =18)	Block 4 (n=15)	All (n=48)
Sharing with family members	5	11	6	22
Share with fellow farmers	0	3	0	3
Share with outsiders	0	0	0	0
No sharing	10	4	9	23

Of the 48 plots that were sampled, 23 (48%) were not shared, 22 (46%) were shared with family members and 3 (6%) were shared with fellow plot holders who were not related by kin.

When a plot holder passed away at Dzindi, the Scheme Management Committee (SMC) expected the family of the deceased plot holder to approach the SMC and propose the name of the person to whom the plot should be transferred. When transferring plots the SMC adhered to the Trust tenure regulation that plots at the scheme are indivisible and insisted on a single name being proposed. The SMC of Dzindi also insisted that the entire family supported the proposal. As a result, prior to making the proposal to the SMC, the family had to negotiate the transfer of the plot. Similar procedures applied at Rabali (see section 5.4.1). The data obtained at Dzindi (Table 6.8) indicate that in nearly half of the cases included in the sample, the family had decided that the plot should be shared among two or more family members, even though only one name was submitted to the SMC.

Table 6.9 presents the internal family arrangements in terms of how plots were shared in 18 cases. Plot 60, where the plot had *de facto* been transferred from parent to son but officially the parent was still the registered plot holder is not shown in Table 6.9. Plots 40, 44 and 45, which involved sharing with fellow plot holders who were not related by kin, are also not shown. The data in Table 6.9 show that the person who had been proposed by the family as the new plot holder was regarded as the main user of the plot because in each case the official plot holder controlled the lion share of the strips on the plot (about 70% on average). Family members with minor user rights to the plot did not always exercise their rights for reasons such as being employed far away from the scheme. The information that was collected indicated that in such cases the major plot holder refrained from using this land. When in need of additional land the registered plot holder preferred to cultivate parcels of non-scheduled land or to rent in land from other plot holders than to request the use of the fallow strips on his own plot, which the family had allocated to another family member. Although no research was done to identify the reasons for this phenomenon it would appear that this behaviour was aimed at avoiding potential conflict within the family. To what extent this social pattern contributed to the underutilization of land at Dzindi in quantitative terms was not determined but the data suggest that its contribution is most likely very modest.

TABLE 6.9: Internal family arrangements for the sharing of plots at Dzindi (n = 18; 2006)

Plot no	No of strips in the plot held by the						
	Holder	Brother	Sister	Mother	Half brother	Son	Total
4	15	-	-	-	-	6	21
8	20	7	-	-	-	-	27
12	8	-	-	-	-	3	11
16	12	4	-	-	-	4	20
25	15	5	-	-	-	2	22
26	13	-	3	5	-	-	21
29	6	-	-	4	-	-	10
30	16	-	2	-	-	-	18
34	14	5	-	-	-	-	19
54	16	5	-	-	-	-	21
63	8	-	-	-	-	4	12
70	4	3	3	-	-	-	10
80	11	4	-	-	-	-	15
86	15	-	3	-	3	-	21
94	13	-	-	3	-	-	16
96	9	4	-	-	-	-	13
100	8	5	-	-	-	-	13
104	12	-	-	-	-	6	18
All	215	42	11	12	3	25	308
%	69.8	13.6	3.6	3.9	0.1	8.1	100

When this research project started in 2003, plot holders at Dzindi were adamant that sharing of land among plot holders was strictly forbidden and was never done. In several mass meetings the research team had pointed out that renting out land was one of the ways in which plot holders could raise their income, particularly in cases where plot holders lacked the resources to utilize their plots fully. In 2005, the team rented land from a plot holder in Block 2 to conduct winter crop experiments when the water supply to Block 1, where the research plot is located, was interrupted. To what extent these events influenced the perceptions of plot holders is not known, but in 2006 there were three plot holders who rented out land to another plot holder who was not kin. All three plots holders involved (Plots 40, 44 and 45) formed part of Block 2, where the team had rented in land for one season to conduct experiments. The holder of Plot 40 rented out four (25%) of the 16 strips on his plot, the holder of Plot 44 rented out five (20%) of the 25 strips on his plot and the holder of Plot 45 rented out six (33%) of the 18 strips on his plot. The arrangement that applied at Plot 45 was apparently long-term and complex. However for Plot 40 and 44 the arrangement was for the winter only and quite simple in content. In both cases, for each strip the farmer renting in land was allowed to use during the winter, he had to fully prepare one strip for use by the farmer renting out land for use during that same season. In 2006, the full cost of preparing a strip at Dzindi (ploughing, disking and ridging) was R60 when using the collectively owned tractor and R75 when using a private service supplier. Using the average price (R67.50 to prepare a strip) the value of the rent paid by the farmer who rented land at Plot 40 was R1125 ha^{-1} per season and at Plot 44 the value was R1758 ha^{-1} per season. The difference in the value between the two results from the difference in the number of strips per plot and the fact that the price of preparing a strip at Dzindi is fixed, irrespective of the number of strips a plot has. It needs pointing out that all three plot holders were renting out land to the same farmer who has a tractor. During the 2007 winter this same land exchange arrangement was entered into by two additional plot holders. This course of events illustrates three important issues. Firstly, attitudes of plot holders on smallholder irrigation schemes towards exchange of land can change without modifying the tenure system. Secondly, the cost of land preparation is a factor that motivates plot holders to enter into land exchanges with others. Thirdly, on smallholder irrigation schemes there are farmers who seek to expand their operation by renting in land, even when the rental values are high. In the case of Dzindi the farmer who is expanding his operation in this way is a market-oriented farmer with a profit-maker farming style. This finding supports the notion that profit makers consider the small size of their plots as one of the farming constraints, as indicated in section 4.6.2 of this report.

6.5.2 Water at Dzindi

The majority (85%) of plot holders at Dzindi identified water flowing in the canal and stored in the lay dam of Block 1 to be the property of Dzindi and that the surrounds should pay for water extracted from these sources. They indicated that these sources of water were only enough for irrigating the plots. However, all respondents indicated that river water belonged to the public and could be freely accessed by anyone. When asked whether they were satisfied with the availability of water for irrigation at the scheme, the majority (87%) of the 48 plot holders that were interviewed responded positively. This response contradicted the results in Table 4.10, which identified the lack of water as a key concern among all farmers. The respondents who were not satisfied with the availability of water for irrigation blamed it on three main factors, namely leaking canals (both primary and secondary), the location of their plots (tail enders) and the extractions of canal water by people from the surrounds. Considering the small amounts of water being extracted by people from the surrounds (see section 6.3.2) respondents assigned unduly importance to this factor. Only two respondents indicated that they did not receive enough irrigation water because some farmers did not adhere to the rules governing access to water at the scheme (see section 5.1).

6.6 Social relationships between Dzindi and its surrounds

The information that was collected in this study indicated that the community of plot holders at Dzindi maintained an ‘us versus them’ attitude towards the settlements that surround them, even though as residents they formed part of these settlements. This became clear from their attitude towards ideas about sharing resources with outsiders.

Along the main canal selected households from Itsani were growing crops on vacant land, using water from the canal to irrigate the crops. Almost all plot holders (94%)

that were interviewed were of the opinion that land alongside the canal belonged to Dzindi and outsiders should not be allowed to use that land. They claimed that outsiders were causing problems to the scheme by breaking the canals to steal irrigation water, which reduced the amount of water reaching the plots at Dzindi. Plot holders at Block 1 were very concerned about the threat of land invasion by people seeking residential plots. It needs stating that in 1998 the Municipality took away land that belonged to the scheme for use as residential land (see section 2.1.2) but this land was commonage, not scheduled irrigation land. Plot holders were adamant that farmers who wanted to rent out part of their plots should only do so with fellow farmers and not outsiders. Plot holders did acknowledge that being surrounded by densely populated settlements had advantages (Table 6.10).

TABLE 6.10: Benefits plot holders at Dzindi derived from the surrounding settlements (2006)

Benefits	Block 1 (n=15) (%)	Block 2 & 3 (n=18) (%)	Block 4 (n=15) (%)	All (n=48) (%)
Access to customers	93	94	100	96
Access to labour	33	78	40	52

People residing in the settlements surrounding Dzindi generally accepted that the Dzindi plot holders were the rightful owners of canal water and the irrigated land at the scheme. No evidence of contestation was identified. Many respondents acknowledged that they derived benefits from the presence of Dzindi as is shown in Table 6.11. In order of importance, these benefits were access to cheap and fresh vegetables; free produce from plots (vegetables and crops) and employment on the plots. Only households from Itsani and Manamani indicated employment as a benefit. Few respondents saw an opportunity for improved benefits but some would like to be given a chance to farm at Dzindi.

TABLE 6.11: Distribution of the different types of benefits residents of settlements surrounding Dzindi received from the scheme (2005-06)

Type of benefit	**Proportion of households obtaining benefits (%)**					
	Urban		**Peri-urban**		**Rural**	**All (n=175)**
	Shayandima (n=35)	**Muledane (n=35)**	**Itsani (n=35)**	**Tshisahulu (n=35)**	**Manamani (n=35)**	
Cheap and fresh vegetables	34	17	37	1	9	20
Free vegetables	6	0	3	-	3	2
Employment	0	0	17	-	3	4

6.7 Discussion and conclusions

Dzindi Irrigation Scheme is located in a zone of rapid urbanization. As a result, in the settlements surrounding the Scheme access to land for farming was extremely limited. Functionally, the livelihood of households residing in these settlements is urban, but the rural heritage of people still has a strong influence on their live styles and outlooks. This was evident from the high participation rates in the production of vegetables, crops and fruit in home gardens and from the widespread interest in obtaining access to arable land.

Access to arable land was extremely limited in the study area. The few households in the surrounds of Dzindi with access to arable land held this land elsewhere. Dzindi Irrigation Scheme is essentially the only potential source of arable land in the area. Residents of settlements surrounding Dzindi identified purchase or renting of unused land as suitable options to obtain access to land for crop production at Dzindi but were not interested in share cropping. No evidence was found that people in the settlements surrounding Dzindi entertained the idea of challenging ownership of land at Dzindi. Instead a general acceptance that plot holders were the legitimate owners of their plots appeared to prevail among those that participated in the study even though the demand for land, especially arable land, in the surrounds was high. This was evident from the use of residential sites for agricultural purposes and the cultivation of roadsides and land alongside the irrigation canal.

Access to rangeland was available in the study area. There was consensus that this land belonged to the community and was accessible by all its members, but utilization of this land was limited. The principal use of this land was for the collection of wood, to make fire or for building purposes. The total absence of livestock production on the rangeland among the 140 respondents was surprising, considering the amount of land that was available. The prevalence of livestock diseases is a possible explanation for the apparent absence of this activity in the study area. This is supported by the failure of the dairy project started by farmers at Dzindi as a result of the death of all the dairy cows.

Access to water in the settlements surrounding Dzindi was generally adequate. Households obtained water from different sources for various uses, including domestic and agricultural. Extraction of water from the canal by residents in these settlements was limited and probably did not materially affect water availability at the Scheme. A degree of tension between plot holders and members of surrounding communities who planted crops along the canal and used water from the canal to irrigate these crops was identified, even though on the whole the amounts of water extracted for this purpose were negligible. Probably it was the visibility of this use that irritated plot holders, especially during periods of water shortage. Above the weir that supplies Dzindi, extraction of water from the River occurred at several sites, by means of pumps and river diversions. These extractions undoubtedly had a reducing effect on the amount of water reaching the weir during periods of base flow but the overall impact was limited.

About one in every four households residing in the settlements surrounding Dzindi declared that they benefited from the presence of Dzindi Irrigation

Scheme. The main benefit was in the form of access to cheap, free and/or fresh food. One of the opportunities to distribute more widely the benefits arising from the availability of resources associated with Dzindi Irrigation Scheme and other similar projects is to broaden access to irrigation land. The land use surveys that were conducted at Dzindi (Table 3.1) show that land is available at the scheme, particularly during winter, suggesting room for others to join production. However, at this stage plot holders at Dzindi were reluctant to enter the land exchange market particularly when it concerns outsiders. Extracting water from the canal, particularly during the night and storing this water in tanks is another way in which more people could benefit from the presence of an irrigation scheme. This opportunity would benefit people living within close vicinity of the canal by enabling them to access irrigation water for home gardening purposes. However, existing extraction by outsiders, which mostly involved small quantities of water, already stirred up emotions among plot holders at Dzindi, suggesting that considerable negotiations would be needed before plot holders would allow for this to happen.

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7 INTEGRATING CROP AND ANIMAL PRODUCTION SYSTEMS ON SMALLHOLDER IRRIGATION SCHEMES

7.1 Introduction

When the framework for participatory co-operation between the different stakeholders in this project was negotiated the establishment of a poultry enterprise at Dzindi was one of the three goals that were prioritised (see section 1.5.2.2 and Table 1.2). Following a feasibility study of different types of poultry production, the idea of the research team was to introduce broiler production as part of an integrated farming system which was thought to hold particular advantages for small-scale farm enterprises. These included the creation of a local market for surplus grain and the generation of poultry litter for use as a fertiliser in crop production, as is shown in Figure 7.1.

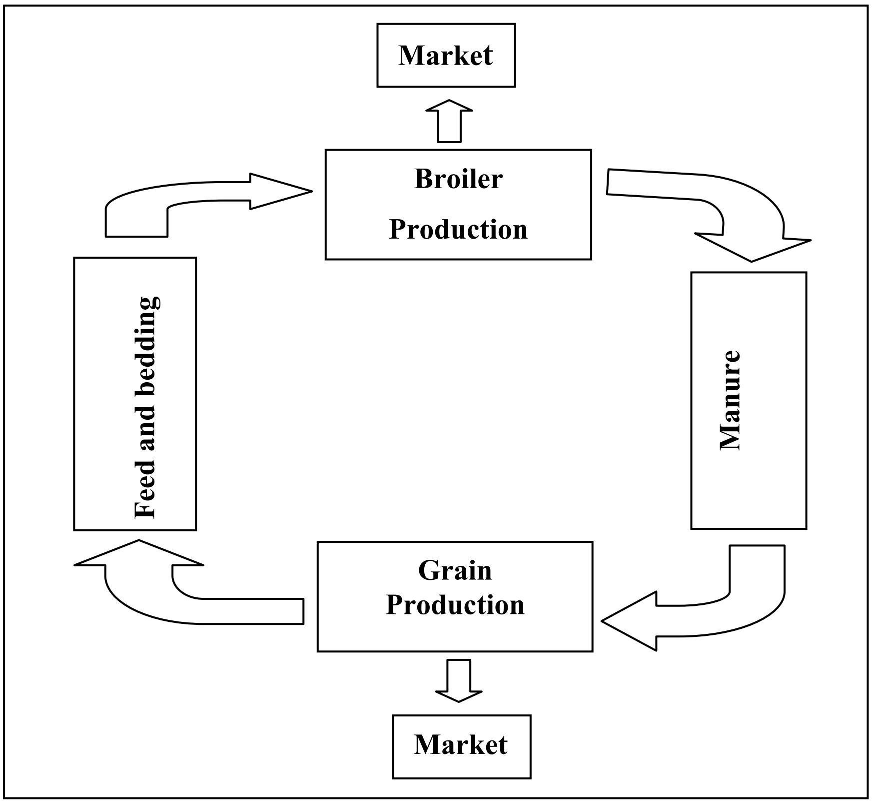


FIGURE 7.1: Integration of broiler and grain production systems

Broilers or fryers are chickens that have been specifically bred to grow very rapidly. They are kept to produce meat, not eggs (Wethli, 1999). Modern commercial broilers can grow from a 1-day-old chick with a weight of 45 g to a market-ready bird with live-weight of about 2 kg at about six weeks of age (Appleby *et al*., 1992; Welthli, 1999). Broiler chickens can be slaughtered between the ages of 6 to 13 weeks and gender of the birds does not play a role (Moreng and Avens, 1985). Being young immature birds at the time of slaughter, the meat of broilers is characteristically tender and their skin is soft, smooth and pliable.

Commercial broiler feeds used in South Africa primarily contain maize and another constituent rich in protein. Maize contributes approximately 65% of the metabolizable energy and 20% of the protein to the diets of intensively reared broilers (Summers, 2001; Cowieson, 2005). However, the protein in maize contains a balance of amino acids that is nutritionally poor (Smith, 1990; Peter *et al.,* 2000; Leeson and Summers, 2001; Cowieson, 2005). Farmers who grow maize for livestock feeding are encouraged to grow a maize cultivar that is high in lysine to add value in the feeds (Smith, 1990). The average composition of maize grain used in poultry feeds is presented in Table 7.1 and the amino acid, mineral and vitamin contents of selected cereals used in poultry feeds are presented in Table 7.2.

TABLE 7.1: Average composition of maize grain used in poultry feeds (after Summers, 2001)

Component	Units	Content
Metabolizable energy	kcal kg^{-1}	3198
Crude protein	(%)	8.1
Crude fat	(%)	2.8
Soluble fibre	(%)	1.0
Insoluble fat	(%)	9.1

TABLE 7.2: Average nutrient content amino acid, mineral and vitamin on cereal grain used in poultry feed on an air-dry basis (after Smith, 1990)

	Units	White maize	Yellow Maize	Sorghum	Wheat bran
Amino acids					
Lysine	%	0.24	0.27	0.22	0.75
Methionine	%	0.14	0.16	0.18	0.20
Minerals					
Calcium (Ca)	%			0.05	0.10
Total phosphorus (P)	%	0.40	0.40	0.30	1.10
Sodium chloride	%	0.08	0.08	0.13	0.05
Manganese (Mn)	mg 100 g^{-1}	5.00	5.00	13.00	110.00
Zinc (Zn)	mg 100 g^{-1}	23.00	23.00	15.00	130.00
Vitamin					
Choline	mg 100 g^{-1}	440.00	440	700.00	10000.00
Niacin	mg 100 g^{-1}	16.00	16.00	32.00	90.00
Pantothenic acid	mg 100 g^{-1}	3.30	3.30	9.00	16.00
Riboflavin	mg 100 g^{-1}	0.66	0.66	1.00	1.60
Vitamin A	IU*/kg		4 4000.00		1000.00
Vitamin D_3	IU*/kg				

* International unit

Soya beans are an excellent source of protein and energy for broilers. Full fat soya beans contain about 37% protein and up to 20% fat but they only contain about 5% fibre (Monari and Wiseman, 1996; Venter, 1999; Leeson and Summers, 2001). Whole soya beans are also a good source of calcium, iron, zinc, phosphorus, magnesium thiamin, riboflavin, niacin and folacin (Monari and Wiseman, 1996; Venter, 1999). The average nutritional composition of full fat soya beans is presented in Table 7.3, the average digestible amino acid content in Table 7.4, the average mineral content in Table 7.5 and the average vitamin content in Table 7.6.

TABLE 7.3: Average nutritional composition of air-dry full fat soya beans (after Monari and Wiseman, 1996)

Component	Units	Content
Moisture	(%)	10.5
Crude protein	(%)	37.1
Ash	(%)	4.5
Crude fibre	(%)	5.5
Crude fat	(%)	18.5

TABLE 7.4: Average digestible amino acid content of air-dry full fat soya beans (after Monari and Wiseman, 1996)

Components	Units	Contents (% air dry basis)
Lysine	%	1.93
Methionine	%	0.45
Cystine	%	0.43
Tryptophan	%	0.62
Isoleucine	%	1.72
Leucine	%	2.25
Phenylalanine	%	1.78
Tyrosine	%	1.26
Threonine	%	1.23
Valine	%	1.52
Agrinine	%	2.22
Histidine	%	0.82
Alanine	%	1.31
Asbartic acid	%	3.76
Glutamic acid	%	6.08
Glycine	%	1.24
Proline	%	1.70
Serine	%	1.68

TABLE 7.5: Average mineral content of air-dry full fat soya beans (after Monari and Wiseman, 1996)

Mineral	Units	Content
Calcium	(%)	0.25
Phosphorus	(%)	0.59
Sodium	(%)	0.03
Potassium	(%)	1.60
Chlorine	(%)	0.02
Magnesium	(%)	0.25
Sulphur	(ppm)	2850
Iron	(ppm)	80
Copper	(ppm)	13.25
Zinc	(ppm)	43.5
Manganese	(ppm)	23.75
Selenium	(ppm)	0.30
Iodine	(ppm)	0.05
Molybdenum	(ppm)	2.5
Nickel	(ppm)	6.0

TABLE 7.6: Average vitamin content of air-dry full fat soya beans (after Monari and Wiseman, 1996)

Vitamin	Units	Contents
Vitamin E	mg 100 g^{-1} grain	42
Vitamin B1	mg 100 g^{-1} grain	9
Vitamin B2	mg 100 g^{-1} grain	2.6
Vitamin B6	mg 100 g^{-1} grain	10
Pantothenic acid	mg 100 g^{-1} grain	14
Niacin	mg 100 g^{-1} grain	22
Choline	mg 100 g^{-1} grain	2427
Folic acid	mg 100 g^{-1} grain	3.74
Biotin	mg 100 g^{-1} grain	1.14

To be suitable for use as broiler feed, raw grains first need to be transformed. Transforming raw grains into animal feed is a value-adding process. When the processing of grain is done on-farm, the rewards of this value-adding process are injected into the local economy.

When maize is fed as part of a mash diet to broilers it is advantageous to grind the grain to a uniform a particle size of about 0.7 to 0.9 mm, which is referred to as medium ground. Birds fed on fine or coarse-ground maize exhibit lower digestibility values (Leeson and Summers, 2001). It follows that the transformation of maize grain for use in broiler feed involves a grinding process.

Soya beans contain a number of natural toxins or anti-nutritional factors (ANF's), which help to protect the beans against damage by insects (Smith, 1990; Monari and Wiseman, 1996; Leeson and Summers, 2001; Mateos *et al*., 2002; Coetzee, 2003). The most problematic ANF is trypsin inhibitor, which disrupts protein digestion. Heat treatment is necessary to denature trypsin inhibitor and other less important toxins, such as hemaglutinins (lectins) and to improve amino acid availability (Leeson and Summers, 2001). Roasting, extrusion, expansion, wave emission and treatment with heated gasses are methods that are used for the processing of soya beans by commercial enterprises (Monari and Wiseman, 1996; Mateos et al., 2002; Coetzee, 2003). These methods are expensive and often complicated and not well suited for application in small-scale farming.

Cooking can also be used to denature ANF's (Mateos *et al*., 2002). This technique involves the soaking of the beans for a period of 24 hrs followed by cooking, rinsing, drying and milling. This method is fairly simple and it can be easily applied in small-scale farming enterprises. Cooking soya beans greatly increases the availability and the value of protein for poultry and destroys the trypsin inhibitor contained within the seed. Adequately cooked soya beans provide a protein content that is nearly equal in value to the protein of meat or fishmeal (Smith, 1990). The duration of the cooking is critical, because it affects the solubility of the proteins. High solubility values of 85% or more indicate under-cooking and low values of 70% or less indicate over-cooking. Over-cooking soya beans also destroys lysine and other heat-sensitive amino acids (Leeson and Summers, 2001).

Compared to many other animal manures, poultry manure is tends to be richer in nitrogen and other minerals, especially P, K and Ca (Moreng and Avens, 1985; North, and Bell, 1991). When applied to the soil as a fertiliser it adds both nutrients and organic matter to the soil, improving both the chemical and physical soil fertility. Poultry manure contains trace elements of which small quantities are essential for crop growth (North and Bell, 1991). Differences in the composition of poultry manure occur due to difference in: temperature, housing system, manure storage, nutrition of the birds, dry matter content of the manure and the presence or absence of litter and its composition (North and Bell, 1991; Leeson and Summers, 1997). The average fertiliser value of selected poultry manures is shown in Table 7.7 and the average mineral content in Table 7.8.

TABLE 7.7: Fertiliser value of poultry manure (after Leeson and Summers, 1997)

	Fresh				Dry		
	DM	N	P	K	N	P	K
		------------------------ (%)-------------------------					
Cage layer manure	70	4.0	1.5	1.7	5.0	1.9	2.2
Cage layer manure	30	1.5	0.6	0.4	5.0	1.8	1.4
Deep-litter layer manure (one year old)	72	2.1	1.7	0.9	2.9	1.5	1.2

TABLE 7.8: Average mineral composition of dry poultry manure (after Leeson and Summers, 1997)

Mineral	Broiler	Cage layer
	(kg per ton^{-1} dry manure)	(kg per ton^{-1} dry manure)
Calcium	19.7	34.1
Magnesium	3.7	5.2
Manganese	0.28	0.33
Iron	1.3	0.03
Boron	0.04	0.03
Copper	0.03	0.12
Zinc	0.13	0.12
Molybdenum	0.02	0.02

As was explained earlier, the interest of plot holders at Dzindi was to establish a poultry enterprise. The research team explained its integrated farming systems idea to farmers and they supported its logic. To address both the wishes of plot holders and the research team, the decision was made to erect a poultry production unit at Dzindi and to initially use this facility for research and training, where after it would be handed over to plot holders. The first important question that needed to be answered through research was whether small-scale, on-farm processing of grains could provide an effective and efficient broiler diet. It is this question that was answered by the research activities conducted under the auspices of the project, which compared the performance of a single phase on-farm processed broiler diet with that of a three-phase commercial diet.

At present the production of maize is well established at Dzindi (see chapter 2) and the use poultry manure as a fertiliser on cropped land is also fairly common practice. However, plot holders are not familiar with the production of soya beans and subsequent research is necessary to introduce this crop at the scheme and to develop a system that suits local circumstances.

7.2 Methods

7.2.1 Processing of full fat soya beans (FSSB)

The optimum cooking time to denature the ANF's in FFSB was determined experimentally. The experiment consisted of six treatments, which represented different cooking times. The shortest cooking time was 10 minutes and subsequent treatments were obtained by increasing the cooking time with increments of 10 minutes. The resulting treatments were cooking times of 10 minutes, 20 minutes, 30 minutes, 40 minutes, 50 minutes and 60 minutes. Samples of the cooked soya beans were sent to ARC-Irene for analysis of urease activity, dry matter content, protein content, fat content, (ether extraction) and Ca and P content.

On-farm processing of full-fat soya beans consisted of soaking the beans for 24 hrs in water, decanting this water, transferring the soya beans to 200 litre steel drums containing fresh water and bringing the water in the drums to the boil. As soon as the water was boiling the gas burners were turned off and the water containing the beans was left to cool off. Thereafter the cooking water was drained from the drum. This was done using the tap that was installed near the bottom of the drum. To prevent the beans from pouring with the cooking water out of the drum a 2 mm wire mesh had been installed inside the drum at the height of 10 cm above the bottom of the drum. Once the cooking water had leaked from the beans, the beans were removed from the drum to be dried. Initially this was done on a black plastic sheet, but later on a sun-drier was constructed. This sun-drier consisted of corrugated iron sheets fitted to a metal frame. The frame had an angle of 10% to allow water to drain from the beans during the early stages of the drying process. Once the soya beans were air-dry, their size was reduced using a hammer mill, before they were mixed with the other constituents that made up the single-phase broiler diet. The on-farm processing of the soya beans is illustrated in Figure 7.2

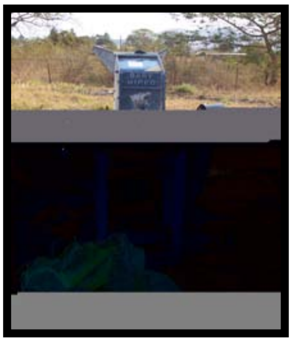
FIGURE 7.2: On-farm processing of full-fat soya beans at Dzindi

1. Raw full-fat soya beans

2. Soaking soya beans for 24 hours

3. Boiling soya beans on gas burner

4. Drying cooked soya beans on black plastic sheets



5. Processing soya beans with hammer mill

6. Mixing processed soya beans with other ingredients to produce poultry feed

7.2.2 Nutritive composition of the different broiler diets

The calculated nutritive composition of yellow maize and full-fat soya beans for use in the on-farm single-phase mixed diets is presented in Table 7.9, the composition of the on-farm single-phase broiler diet is presented in Table 7.10, the composition of the vitamin and mineral additives used in the on-farm single-phase broiler diet is presented in Table 7.11 and the calculated nutritive value of the three-phase commercial diet that consisted of starter, grower and finisher feeds is given in Table 7.12.

TABLE 7.9: Average composition of yellow maize and full fat soya beans (air-dry basis)

Analysis	Unit	Yellow maize	Full fat soya bean
Dry matter	%	89.57	92.35
Moisture	%	10.43	7.65
Ash	%	1.43	4.24
Protein	%	7.75	40.40
Fat (ether extraction)	%	3.70	19.96

TABLE 7.10: Composition of the on-farm single-phase broiler diet

Ingredients	kg per 100 kg feed
Yellow maize grain	64.25
Soya beans	30.00
Mono Ca P	1.75
Limestone	2.26
Lysine	0.68
Methionine	0.33
Salt	0.48
Vitamin and mineral additive	0.25
Total	100.00
Calculated analysis	
Dry matter	88.60
Moisture	11.40
Ash	5.83
Protein	17.45
Fat (ether extraction)	7.76
Crude fibre	3.27

Table 7.11: Composition of the vitamin and mineral additives used in the on-farm single-phase mixed broiler diet (Standard broiler starter + Cox + Nat Fe 1058) per unit of 2.5 kg feed

Vitamin and mineral	**Per unit of 2.5 kg**
Vitamin A (iu/ie)	12000000
Vitamin D3 (iu/ie)	3000000
Vitamin E (iu/ie)	40000
Vitamin K3 (g)	2.5
Vitamin B1(g)	4.0
Vitamin B2 (g)	6.5
Niacin (g)	42.0
Calcium Pantothenat (g)	13.0
Vitamin B12 (mg)	30.0
Vitamin B6 (g)	5.0
Chloline (g)	303.3
Folic Acid (g)	1.2
Biotin (mg)	120.0
Coxistac grandulated (g)	500.0
Zinc bacitracin (active) (g)	22.5
Vitamin (g)	60.0
Manganese (g)	75.0
Zinc (g)	70.0
Copper (g)	40.0
Iodine (g)	6.0
Cobalt (g)	1.0
Ferrous (g)	0.5
Selenium (g)	2.5

TABLE 7.12: Calculated nutritive value of the commercially multiphase broiler diet used (classic starter, grower and finisher feed)

Nutrients	**Classic broiler starter diet**	**Classic broiler grower diet**	**Classic broiler finisher diet**
		---------------(%)-------------	
Dry matter	89.22	89.05	91.28
Moisture	10.78	10.95	8.72
Ash	6.73	5.17	4.85
Protein	20.38	18.27	18.22
Fat (either extraction)	3.96	3.53	5.55
Crude fibre	4.07	5.18	4.03

7.2.3 Poultry housing

The two boiler growth experiments were conducted in prefabricated open-sided poultry house supplied by Spartan Equipment in Johannesburg, which the team had erected at Dzindi and which is shown in Figure 7.3. At the time of writing this report, the final experiment was being conducted in a broiler house with temperature control at Irene. The reason for conducting the final experiment at Irene was that the broiler facility at Dzindi had been transferred to plot holders at the end of the second experiment.

FIGURE 7.3: The open sided poultry house that was erected at Dzindi

7.2.4 Experimental design

The two experiments that were conducted at Dzindi involved two dietary treatments. These were the on-farm diet treatment (OF) and the commercial diet treatment (C). The OF treatment was a simple single-phase diet that was mixed on-farm with full fats soya bean and yellow maize as the main feed ingredients. The on-farm diet was presented in a mash form (from day one until an average body weight of 2300 g was attained) and served as the experimental diet. The C treatment was a commercial multiphase feed that consisted of starter, which was presented in a crumble form (1-21 days), grower in the form of pellets (22-35 days) and finisher in the form pellets (36- until an average body weight of 2300g was attained.

7.2.5 Allocation procedures

A total of 192 day-old chicks were procured from Alfa Kuikenplaas, inoculated according to the standard procedures, randomly allocated to the two treatments and kept under the gas brooder for the first three week (starter phase). Upon the arrival at the experimental site, the chicks were examined and obviously sick or dehydrated birds were culled. Standard management practices as prescribed by the supplier of the day old chicks were applied. The same care and management were provided to both treatments. During the first 21 days the birds allocated to each treatment were kept in separate pens to conserve heat. Each pen had a surface area of 3.12 m^2 and was covered with 7.5 kg of wood shavings. The pens were equipped with drinking founts and day old feed trays. The positioning of feeders and founts were the same in each pen and remained unchanged during the 21-day period. The layer of wood shavings was turned over weekly but was not replaced during this period.

After 21 days of brooding, the broiler house was partitioned into 16 compartments (pens), and 16 of these (eight replicates per treatment), were used for the experiment. A total of 192 birds were divided into 16 groups of 12 birds (Table 7.13) each and randomly assigned to the 16 pens (Figure 7.4). Each pen provided a floor area of 1 m^2 which was covered with 3 kg of fresh wood shavings. Each pen had one tube feeder and one day-old water fount. The position of feeders and drinkers were the same in each pen and were adapted regularly as the birds grew up. Maximum and minimum temperature values were recorded in degrees Celsius on a daily basis to one decimal point using a minimum-maximum thermometer that was suspended in the middle of the broiler house at the height of 30 cm above the floor. These temperatures were record ed every day at 8:00 am.

Pens were checked twice daily for mortality. All chicks that had died were weighed and submitted for post mortem by a veterinarian. Mortality was recorded daily, and dead birds and feed were weighed on the same day to correct feed intake data for mortality in both treatment. Mortality (%) were determined for each diet treatment and the differences between the OF and C treatment group were tested statistically. The stocking density was calculated as a floor space provided per bird or as number of the birds per m^2 floor spacing. In the broiler industry, the type of building and the final live weight are used to determine the optimal stocking density. Many stocking densities are employed around the world, ranging from 15 birds per m^2 for open-side type houses to 22 birds per m^2 for well designed, mechanically ventilated houses equipped with cooling systems. The most commonly used stocking density used aims at keeping the live broiler weight per m^2 floor space between 30 kg and 42 kg. In warm climates the stocking density of 30 kg m^{-2} is probably closer to ideal. In this experiment the stocking density was calculated according to the standard for open sided type housing, i.e. 12 birds per m^2 (28 kg live weight m^{-2}).

TABLE 7.13: Design of the poultry diet experiment applied from the ages of 22 to 49 days old

Replicates	**Number of birds in each treatment group**		**Total number of birdsS**
	OF*	**C****	
1	12	12	24
2	12	12	24
3	12	12	24
4	12	12	24
5	12	12	24
6	12	12	24
7	12	12	24
8	12	12	24
TOTAL	**96**	**96**	**192**

OF* = On-farm single-phase diet C** = Commercial three-phase diet

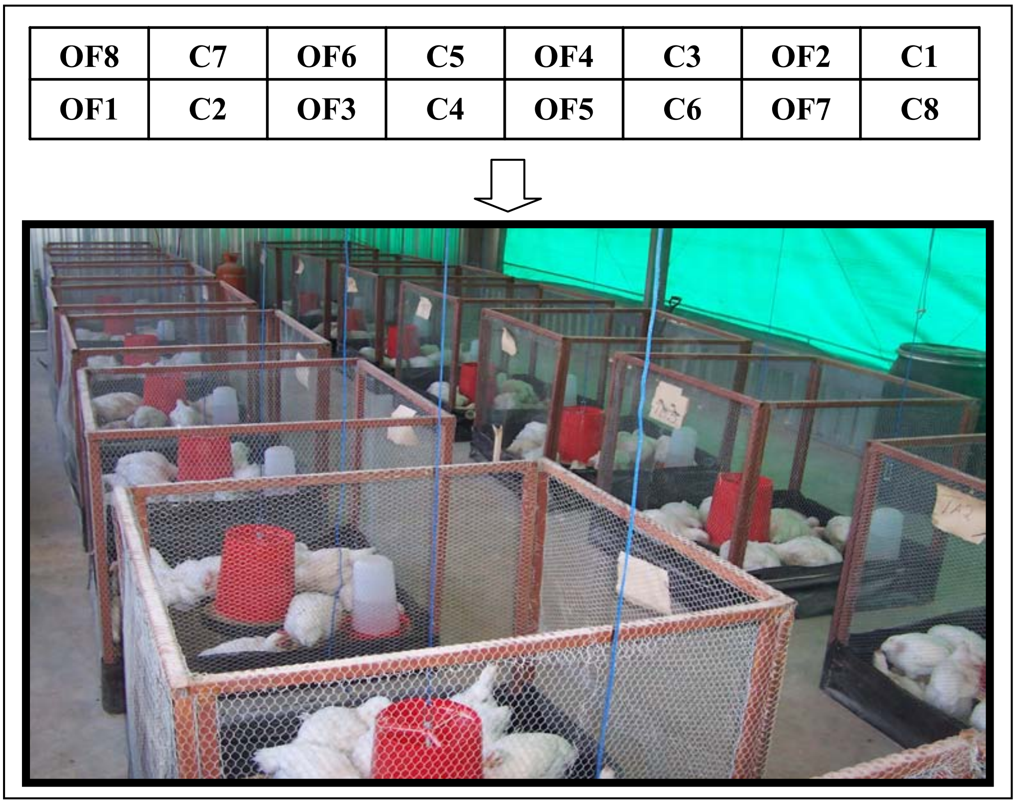


FIGURE 7.4: Allocation of the two diet treatments (OF and C) to different pens when the broilers were aged 22-49 days old

7.2.6 Measurements

Observation of clinical signs and behaviour, mortality and minimum and maximum temperature were recorded on a daily basis. Body weight (g), weight gain (g) feed consumption (g) and cumulative feed consumption (g) were determined on a weekly basis. A calibrated electronic scale with an accuracy of 1 g was used to weigh the birds, the feed and the manure. The price of production inputs for the different treatment diets was recorded when the production inputs were purchased. The results of all these analyses were recorded according to the treatment. Records were placed in the permanent file and entered in the computer on a weekly basis.

7.2.7 Data analysis

To assess the biological efficiency of the two diet treatments an analysis was done of the feed intake, the body weight and the broiler yield. The weekly and cumulative feed intake was calculated in g. The feed was weighed every week at 8:00 in the morning. The weekly feed intake was the amount of feed eaten per treatment group over a seven-day period, less residual (left-over feed). The following calculations were made:

- Feed intake per replicate, which was the amount of feed consumed per group of 12 birds over a seven-day period less the residual.
- Actual average feed intake per bird per replicate, which was calculated using the data on feed intake per replicate taking into account mortality.
- Feed intake per treatment per week, which was the total amount of feed consumed by all eight replicates of a particular treatment over a period of seven days.
- Average feed intake per bird per treatment per week, which was the feed intake per treatment per week divided by the number of the birds per treatment.

These data were used to:

- Determine the average amount of feed consumed at the end of each feeding phase (7, 14, 21, 28, 35, 42, and 49 days) per treatment by 100 birds.
- Determine the cost of the feed consumed per treatment (OF) and (C) by 100 birds at the end of each feeding phase.

To monitor body weight all the birds were individually weighed on day 7, 14, 21, 28, 35, 42, and 49. Five birds were sampled per pen, i.e. a total of 40 birds per treatment since there were eight replicates. These birds were marked with plastic cable tags. Each cable tag had a code that identified the specific bird. The data of the sample birds were used to determine:

- The average body weight per replicate per week (g).
- The average body weight per treatment per week (g).
- The average body weight per bird/treatment at 49 days (g).
- The variation in growth rate within pens or treatment (only on sampled birds).
- The average body weight gain per pen and per treatment per week (only on sampled birds).

Broiler yield testing was done to determine whether there were any differences in the meat yield and meat distribution between birds in the two treatments (OF and C) Ten healthy birds representative for each treatment were selected randomly for analysis at Irene (ARC). At the facility in Irene, each bird was weighed and cut up into drumsticks, thighs, wings, backs, necks and feet. Each of these parts was weighed and the measurements were recorded. The broiler yields in each treatment were then compared statistically.

To assess the economic efficiency of the two treatments, a basic economic analysis was done. This involved a feed cost analysis of the two-treatment groups and a gross margin analysis.

At the end of the experimental period the poultry litter produced in each treatment was weighed, dried and analysed for nutrient content (N, P and K). Representative samples of the litter and a composite sample of wood shaving were taken from each treatment and dried for 48 hour in a forced-draught electric oven at a temperature of 60°C to determine the moisture content. Moist, composite samples of the litter produced in the two treatments were sent for analysis to the Irene Institute of the ARC to determine their nutrient content.

All data was captured on a MS Excel spreadsheet and analysed statistically using ANOVA by means of SAS (SAS Institute Inc, 2000). The t-test procedure was used to compare treatment means.

7.3 Results

7.3.1 Feed intake

Feed intake was used as a measure of broiler growth efficiency. Figure 7.5 shows the average feed intake (kg) per day (per bird) and per treatment during the first 21 days of growth (brooding period). During the first 7 days of growth, the average feed intake (g) per bird in the two treatments was similar, but from day 8 until the end of the brooding period the birds in the C treatment (commercial diet) consumed more feed than the birds in the OF treatment (On-farm diet). The mean feed intake (g), standard error and significance level of treatment effects of feed intake from 28 to 49 days are presented in Table 7.14. The data in Table 7.14 show that during the period of growth that lasted from 28 days of age to 42 days of age, the birds in the C treatment consumed more feed than the birds in the OF treatment. During the period of growth that lasted from 42 days of age to 49 days of age, feed intake of the birds in the two treatments was no longer different.

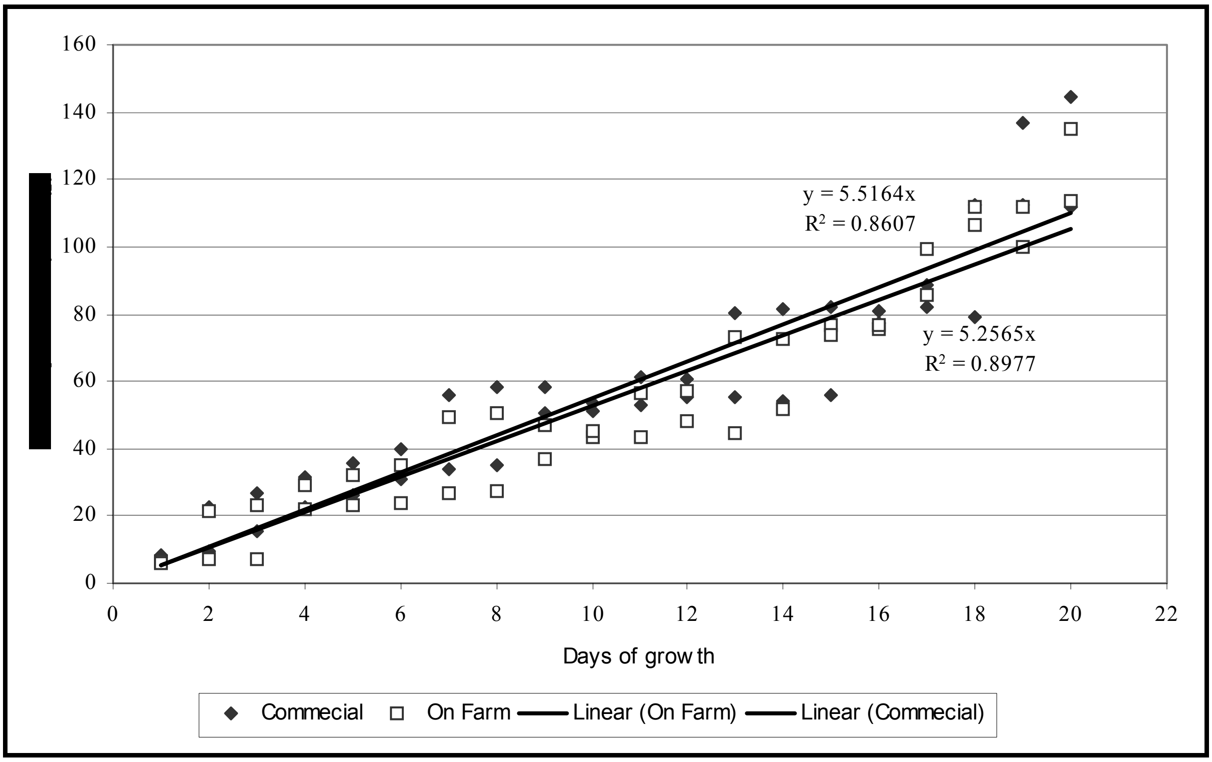


FIGURE 7.5: Average, daily feed intake (g per bird^{-1}) in the on-farm diet and commercial diet treatments during the first 21 days of growth (brooding period)

TABLE 7.14: Mean feed intake (g bird^{-1}), ± standard error and significance level of treatment effect on feed intake at different ages

Time (days)	On-farm single-phase diet (OF)	Commercial 3-phase diet	Significance level of treatment effect
	Average feed intake (g) per bird per treatment		
28	830.7 ± 14.1	1052.5± 13.6	$p < 0.0001$
35	1027.2 ± 16.1	1224.5± 15.6	$p < 0.0001$
42	1267.4 ± 25.6	1378.8 ± 24.8	$p = 0.0040$
49	1491.1 ± 19.2	1490.1 ± 18.6	$p = 0.9712$

7.3.2 Growth performance

The mean body weight per bird attained by the birds in the two diet treatments is presented in Table 7.15. The results show that birds in the C treatment were persistently heavier than birds in the OF treatment.

TABLE 7.15: Effect of diet treatment on mean body weight of broilers at different ages

Time (days)	On-farm single-phase diet	Commercial 3-phase diet	Significance level of treatment effect
	Average body weight per bird (g) per treatment		
1	41.0 ± 0.5	41.2 ± 0.5	p = 0.66
7	100.7 ± 1.9	132.9 ± 1.8	p < 0.0001
14	243. 9 ± 6.3	355.4 ± 6.1	p < 0.0001
21	463.5 ± 10.3	687.6 ± 9.9	p < 0.0001
28	793.2 ± 19.6	1162.1 ± 19.0	p < 0.0001
35	1212.2 ± 28.0	1810.6 ± 27.0	p < 0.0001
42	1707.1 ± 35.0	2403.9 ± 33.9	p < 0.0001
49	2400.7 ± 83.6	2667.2 ± 80.9	p = 0.002

7.3.3 Yield testing

The results of yield testing of the broilers fed with the OF and C diets are presented in Table 7.16. Statistically, birds in the C treatment had heavier breast and wings ($p \leq 0.05$). None of the differences in the yield of other body parts of the birds between diet treatments were statistically significant ($p \leq 0.05$).

TABLE 7.16: Mean broiler yield (g bird^{-1}), ± standard deviation and significance level of treatment effect on yield of broilers fed with the OF and the C diets

Variable	On-farm single-phase diet (OF)	Commercial three-phase diet (C)	p>t
Carcass weight	1706.4±384.39	2198.9±342.96	p = 0.065
Drum	243.14±64.53	297.92±46.31	p = 0.162
Thigh	255.48±56.51	325.5±50.375	p = 0.072
Wings	180.72±37.74	233.26±30.31	p = 0.041
Breast	463.38±95.72	679.66±108.12	p = 0.010
Back	372.74±107.2	461.86±80.97	p = 0.176
Feet	79.8±22.83	103.3±30.41	p = 0.204
Neck	105.96±10.37	111.9±18.0	p = 0.541

7.3.4 Poultry manure

The moisture content of the wood shavings used as bedding in the broiler experiments was 1.8%. The average production of manure by birds in the OF treatment over a period of 49 days was 2.90 kg per bird with an average moisture content of 31.7%. Over the same period birds in the commercial treatment group produced on average 3.00 kg manure per bird with an average moisture content of 49.6%. The nutrient contents of poultry manure produced by birds in the C and OF treatment groups are presented in Table 7.17. The poultry litter of birds fed on the OF diet was richer in nitrogen than that of birds fed on the C diet, which had a higher K content. The P content of both litters was similar.

TABLE 7.17: The nutrient content of poultry litter produced by birds in the C and OF treatment groups (dry mass basis)

Analysis	On-farm diet (OF)	Commercial diet (C)
Nitrogen (N) (%)	4.71	3.97
Phosphorus (P) (%)	1.45	1.46
Potassium (K) (%)	1.39	1.79

7.3.5 Economic evaluation

Table 7.18 shows the cost of feed consumed by broilers in the OF and C treatments for the different periods in the growth of the birds.

TABLE 7.18: Quantity of feed (kg) consumed by 100 broilers in the two diet treatments until the age when they had reached the target body weight of 2.3 kg and associated costs (R)

Age of the broilers	**On-farm diet treatment (OF)**[1]	**Commercial three-phase diet treatment (C)**[2]		
	Quantity of feed (kg) consumed by 100 broilers			
	Single-phase diet Mixed on-farm (kg)	Starter feed (kg)	Grower feed (kg)	Finisher feed (kg)
0-21 days	108.78	116.91	-	-
22-28 days	83.28	-	105.25	-
29-35 days	102.72	-	122.45	-
36-42 days	126.74	-	-	137.88
43-49 days	149.11	-	-	-
Sub-total	**570.63**	**116.91**	**227.70**	**137.88**
Grand total			482.49	
	Cost of feed (kg) consumed by 100 broilers			
	Single-phase diet Mixed on-farm (R)	Starter feed (R)	Grower feed (R)	Finisher feed (R)
0-21 days	287.18	350.72	-	-
22-28 days	219.86	-	294.70	-
29-35 days	271.18	-	342.85	-
36-42 days	334.59	-	-	366.75
43-49 days	393.66	-	-	-
Total	**1506.63**	**350.72**	**637.55**	**366.75**
Grand total	**1506.63**		**1355.02**	

[1] The cost of feed was based on the producer price of maize grain at Dzindi, which was R2 per kg in 2006; the price of R2 per kg for soya beans (nationally the producer price at the time was R1.80 per kg) and the actual cost of the vitamin and mineral additives.
[2] The cost of the starter-, grower- and finisher feeds were based on the prices that were paid in 2006 when purchasing these feeds from the Magnifisan Community Shop in Muledane and delivering them to Dzindi.

Statistically ($p \leq 0.05$) treatment had no effect on total cost of feed consumed per bird and per kg live weight, even though birds in the OF treatment only attained the targeted body weight of 2300 g at 49 days of age, whereas birds in the C treatment reached this target weight at 42 days of age.

The gross margin analysis for the on-farm (OF) and the commercial (C) diet treatments is presented in Table 7.19.

TABLE 7.19: Gross margin analysis of the experimental enterprise that used the single phase on-farm mixed diet (OF) and the experimental enterprise that used the commercial three-phase diet (C)

Variable cost	On-farm diet treatment (OF)	Commercial three-phase diet treatment (C)
	(R per 100 birds)	(R per 100 birds)
Chicks	365.76	365.76
Feed[1]	1506.63	1355.02
Heating (gas)	192.00	192.00
Light (electric)	34.29	40.00
Vaccines and medicines	70.00	70.00
Water and disinfectant	15.00	15.00
Wood shavings	17.50	17.50
Total variable costs	**2206.89**	**2049.57**
Gross income		
Sale of broilers[2]	2600.00	2600.00
Sale of broiler litter	145.00	128.50
Total gross income	**2745.00**	**2728.50**
Gross margin above Variable costs	**538.11**	**678.93**

[1] Cost of feed until broilers reached the target live weight of 2300 g, which took 42 days in the C treatment and 49 days in the OF treatment.
[2] Broilers were sold at farm gate at R26 per bird, which was the going price of live birds sold directly to consumers at that time.

The results presented in Table 7.19 show that both experimental enterprises provided positive gross margins above total variable costs. The experimental enterprise that used the three-phase commercial diet (C) provided a higher gross margin (R6.79 $bird^{-1}$) than the enterprise that used the on-farm single-phase diet (OF) (R5.38 $bird^{-1}$), a difference of R1.32 $bird^{-1}$. The cost of feed contributed 68% to the total variable costs of the OF experimental enterprise and 66% to that of the C experimental enterprise. This means that application of the OF approach to the broiler enterprise is expected to inject about two-thirds of the value of the total variable costs back into the local agrarian economy, whereas in the case of the C approach all inputs are purchased outside this economy.

7.4 Conclusions

In this study the performance of a single-phase broiler diet obtained by on-farm processing of yellow maize grain and soya beans was assessed using a commercially available three-phase diet as the benchmark for comparison. Overall, birds fed of the commercial diet (C) grew faster and were ready for marketing one week earlier than birds fed on the on-farm diet (OF). From an economic perspective, the performance of the enterprises based on the use of the two diets was not very different. The experimental enterprise that used the three-phase commercial diet (C) provided a higher gross margin (R6.79 $bird^{-1}$) than the enterprise that used the on-farm single-phase diet (OF) (R5.38 $bird^{-1}$), a difference of R1.32 $bird^{-1}$. The main advantage of using the on-farm diet was that it provided the opportunity to integrate crop and animal production locating a large part of the value chain within the local agrarian economy.

In September 2006, the management of the poultry enterprise at Dzindi was transferred to plot holders. Before the transfer occurred plot holders had decided that production of poultry should be done by two unemployed members of the community. These two members were identified by the plot holders and they were trained by the research team during the conduct of the second experiment. The plot holders offered the two employees a payment of R1000 each for every batch of broilers sold. Plot holders and the employees were also taught how the on-farm diet was prepared, including the processing of maize grain and soya beans. They followed the progress of the two experimental groups of broilers during the two experiments that were conducted at Dzindi and they were impressed with the performance of the broilers that were fed on the single phase on-farm diet. This resulted in a request to the team for advice of soya bean production at the scheme.

In the light of the positive results obtained in this study and the response by plot holders, the next step in the development of an integrated farming system at Dzindi needs to focus on the introduction of soya beans in the cropping system of plot holders at Dzindi. Additional research could also include an investigation into alternative sources of plant protein, particularly cowpeas, and the introduction of additional poultry enterprises, particularly egg production.

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8 IMPROVING PRODUCTION OF CHINESE CABBAGE AND NIGHTSHADE AT DZINDI

8.1 Introduction

The analysis of the commodity systems at Dzindi presented in chapter 3 identified the important role of Chinese cabbage and nightshade in the production of vegetables during winter at Dzindi. The analysis also showed that the gross margin of these two enterprises were poor. When the goals of the project were prioritised (Table 1.2) improving the production of indigenous crops was identified as level three priority. All of these reasons contributed to the decision to conduct research on ways in which the production of Chinese cabbage and nightshade could be improved. The research activities involved a study of the nutrient response of these two crops, which was done by means of pot experiments in the green house of the Tshwane University of Technology in Pretoria and the response of Chinese cabbage to soil water availability and planting date, which was done by means of field experiments at Dzindi.

Nightshade (*Solanum retroflexum* Dun.) is indigenous to South Africa (Grabandt, 1985; Schippers, 2002). It forms part of the *S. nigrum* complex, which contains a range of leafy vegetable species that are harvested from the wild or cultivated by rural people in Africa (Edmonds and Chweya, 1997). In South Africa, cultivation of *S. retroflexum* is a recent development and at this stage limited to the Vhembe District of the Limpopo Province (Van Averbeke and Juma, 2006). *Brassica rapa* L. subsp. *chinensis* (non-heading Chinese cabbage) is an indigenized vegetable in the northern parts of South Africa. In the Vhembe District, several landraces of *B. rapa* subsp. *chinensis* are being cultivated, but the land race called *dabadaba* in Tshivenda is one of the two most commonly grown (Tshikalange and Van Averbeke, 2006).

8.2 Yield response of Chinese cabbage and nightshade to nitrogen, phosphorus and potassium

8.2.1 Problem identification and study objectives

The analysis of the irrigated smallholder production systems of Chinese cabbage and nightshade in Vhembe identified a great deal of variability in the rates at which nitrogen (N), phosphorus (P) and potassium (K) were applied by producers (Van Averbeke and Juma, 2006; Tshikalange and Van Averbeke, 2006). Optimum crop growth and yield depend on adequate availability of the different plant nutrients, but the application of fertilisers also contributes significantly to the variable costs of production. As is shown in chapter 3, on average the application of fertilisers accounted for about 40% of the total variable costs smallholders at Dzindi incurred when producing *S. retroflexum* and *B. rapa* subsp. *chinensis*.

Only a limited number of plant nutrient response studies involving species of the *S. nigrum* complex have been conducted (Table 8.1), but none of these involved *S. retroflexum*. Generally, these studies demonstrated positive effects of fertiliser application on the growth and yield of these crops and provided an indication of optimum application rates for nitrogen (N), phosphorus (P) and potassium (K) for species in this complex.

TABLE 8.1: Optimum application rates of nitrogen, phosphorus and potassium for selected species of the *Solanum nigrum* complex (after Merinyo (1996); Shang'a (1996); Chweya (1997); AVRDC (2004))

Species	Spacing	**N**	**P**	**K**
	(m^2 plant^{-1})	----------(kg ha^{-1})----------		
S. villosum	0.08	149	40	40
S. americanum	0.24	149	40	40
S. pseudonigrum	0.09	200	-	-
S. nigrum	-	150	-	-
S. nigrum	0.25	200	-	-

Research results documenting the response of *B. rapa* subsp. *chinensis* to N, P and K-availability are also limited, at least in the English language. Yoshizawa *et al*., (1981) determined the effect of nitrogen application rate on the yield of the Chinese cabbage cultivars AVRDC 58 and Yuon-Pao 2, but no research results documenting the response of *B. rapa* subsp. *chinensis* to P and K availability were retrieved. Application rates of N, P and K recommended for other *Brassica* species (Hartman *et al*., 1985; FSSA, 2003; Schippers, 2002) suggest that in the case of low fertility soils, application rates of 100 kg N ha^{-1} to 260 kg N ha^{-1}, 100 kg P ha^{-1} to 205 kg P ha^{-1} and 160 kg K ha^{-1} to 205 kg K ha^{-1} may be necessary to achieve optimum yield.

The high variability in the application rates of fertilisers used by smallholders in the production of *S. retroflexum* and *B. rapa* subsp. *chinensis* and the dearth of information on the way these two crops respond to the availability of these three important plant nutrients prompted the current investigation, which involved a series of pot experiments in the green house of TUT in which the response of the two crops to N, P and K availability was assessed (Figures 8.1 and 8.2). The objectives of the study were to determine the growth and yield response of the two crops to different levels of N, P and K availability in the soil, to determine the interaction effects of these three nutrients and to obtain preliminary information on the application rates of the three nutrients that are required for optimum growth and yield.

FIGURE 8.1: Greenhouse pot experiment with Chinese cabbage

FIGURE 8.2: Greenhouse pot experiment with nightshade

8.2.2 Materials and methods

The soil used in the pot experiments was supplied by JL Coetzer cc in Pretoria. It was excavated in Swartspruit west of Pretoria and consisted of the subsoil of a Hutton Hayfield type soil (Soil Classification Working Group, 1991). The soil was a yellowish red (5YR 4/5 when dry), low fertility, sandy clay loam with a pH in water of 5.9 and 4.9 when measured in KCl. The soil contained 2.5 mg NH_4^+-N and 8.8 mg NO_3^--N kg^{-1}, 2 mg P kg^{-1} (Bray 1) and 32 mg K kg^{-1} (1 M ammonium acetate extraction) in its natural state. The soil was screened through a 2 mm mesh sieve before being used in the pot studies. The gravimetric water content of the soil was 14.3% at field capacity, 5.2% at permanent wilting point when *S. retroflexum* was used as the test crop and 6.7% when *B. rapa* subsp. *chinensis* was used. The experiments were conducted in a greenhouse that had a wet-wall and two fans to control maximum temperature but no heating to control minimum temperature. The fans engaged thermostatically as soon as the temperature in the greenhouse reached 25°C. The experiments were conducted in plastic pots with a content of seven litres and five perforations at the bottom for drainage. The chemical fertilisers limestone ammonium nitrate (28% N), single super phosphate (10.5% P) and potassium chloride (50% K) which had been ground to pass through a 0.5 mm sieve were used to apply N, P and K to the soil in the pots. The *S. retroflexum* seed that was used in the experiments was obtained from Ms Ratshitanga, a small-scale vegetable seed producer in Ngulumbi, Vhembe District, Limpopo Province. The seed of the *dabadaba* landrace of *B. rapa* subsp. *chinensis* was obtained from a single plant grown at the Tshwane University of Technology in Pretoria. Biomass measurements were made using a portable electronic scale (Scout® Pro SPU123 manufactured by Ohaus) with a capacity of 120 g and an accuracy of 0.001 g.

Four pot experiments were conducted for each of the two crops. In the first three experiments the response of the crops to different rates of added N, P and K was separately evaluated. In the fourth experiment, the interaction effects among the three nutrients were determined. In all experiments the pots were filled with a homogenised mixture of 8000 g of soil (air-dry mass) and the relevant amounts of the chemical fertilisers. A filter paper was placed at the bottom of the pots to avoid soil losses through the drainage holes during filling. The amount of nutrients applied per pot were obtained by converting the application rate of elemental nutrient per ha to the amount per plant using the spacing of 0.177 m^2 $plant^{-1}$ (56 497 plants ha^{-1}) for *S. retroflexum* and the spacing of 0.195 m^2 $plant^{-1}$ (51 282 plants ha^{-1}) for *B. rapa* subsp. *chinensis*. For each of the two crops these were reportedly the average spacing used by smallholders at Dzindi Irrigation Scheme (Van Averbeke and Khosa, 2004). In all experiments the soil in the pots was brought to field capacity one week before planting to allow the fertilisers to react with the soil. The pots were then covered with cling wrap to prevent water from evaporating. *S. retroflexum* was planted at a density of 10 seeds per pot using an off-centre planting pattern, where after the pots were again covered with cling wrap until the seedlings emerged. Thinning was undertaken at the third leaf stage and only a single healthy seedling was retained in each pot. The planting and thinning procedure used in the *B. rapa* subsp. *chinensis* experiments was the same as for *S. retroflexum*, but only five seeds were planted per pot and thinning occurred at the sixth leaf stage. The available water content in the pots was kept in excess of 50% of total throughout the duration of the experiments. Drainage water that had collected in the drainage trays was returned to the corresponding pot before each watering, but this rarely happened. The economic yield was used as the indicator of plant response for each crop. This involved the measurement of fresh above-ground biomass for *S. retroflexum* and the fresh mass of marketable leaves for *B. rapa* subsp. *chinensis*. Oven-dry mass measurements were also made by drying the fresh biomass in a forced-draught oven at 70^{o}C until constant mass. In the experiments involving *S. retroflexum*, the crop was harvested three times. The first harvest commenced about eight weeks after seedling emergence and subsequent harvests followed at intervals of approximately three weeks. At harvest the entire shoot was removed by cutting the plant stem 5 cm above the soil surface as recommended by Edmonds and Chweya (1997). In the experiments with *B. rapa* subsp. *chinensis* the marketable leaves were harvested in stages in accordance with farmer practice (Tshikalange and Van Averbeke, 2006). The fifth true leaf, considered by farmers as the first marketable leaf, was harvested when the plants had reached the eight leaf stage. One week later the sixth leaf was harvested, and the remaining marketable leaves were harvested when the peduncle had commenced elongation in 50% of the plants.

In the single nutrient experiments with *S. retroflexum*, the first experiment involved seven application rates of N covering a range of 0 to 300 kg N ha^{-1}, whilst applying P and K at the rates of 50 kg P ha^{-1} and 150 kg K ha^{-1}. The second involved seven application rates of P covering a range of 0 to 200 kg P ha^{-1} whilst ensuring optimum availability of N as determined in the first experiment and supplying K as in the first experiment. The third experiment had eight application rates of K covering a range of 0 to 200 K kg ha^{-1}, whilst ensuring optimum availability of N and P as identified in the first and second experiment. Planting dates, number of replications and the temperature range experienced over the duration of these three experiments are shown in Table 8.2.

TABLE 8.2: Planting date, number of replications and temperature range for the different pot experiments with *Solanum retroflexum* Dun. *and Brassica rapa* L. subsp. *chinensis*

Experiment	Planting date	Number of replications	Absolute minimum temperature (^{o}C)	Absolute maximum temperature (^{o}C)
		Solanum retroflexum		
N single nutrient	23/09/2004	10	19	29
P single nutrient	22/01/2005	10	18	28
K single nutrient	19/04/2005	10	9	26
NPK factorial	19/01/2006	5	22	27
		Brassica rapa* subsp. *chinensis		
N single nutrient	23/09/2004	10	19	29
P single nutrient	26/03/2005	7	16	28
K single nutrient	02/06/2005	10	9	26
NPK factorial	14/08/2005	5	14	28

In the single nutrient experiments with *B. rapa* subsp. *chinensis*, the first experiment involved additions of nitrogen at rates ranging between 0 and 300 kg N ha^{-1}, whilst applying both P and K at 300 kg ha^{-1} each. These high rates of P and K application were opted for because of the very low P and K content of the soil and the high P and K requirements of other *Brassica* species. The second experiment determined the response of the crop to the availability of P and involved additions of P at rates ranging between 0 and 400 kg P ha^{-1} whilst ensuring optimum availability of N as determined in the first experiment and supplying K as in the first experiment. The third experiment determined the response of the crop to the availability of K and involved additions of K at rates ranging between 0 and 400 kg K ha^{-1}. Planting dates, number of replications and the temperature range experienced over the duration of these three experiments are shown in Table 8.2.

In the NPK factorial experiments with each of the crops the three nutrients were applied at four rates, which included a control (application withheld), the optimum rate determined in the single nutrient experiments, half the optimum rate, and a rate in excess of the optimum. Planting dates, number of replications and the temperature range experienced over the duration of the two experiments are shown in Table 8.2.

Analysis of variance using the SAS statistical package was performed to test for treatment effects (SAS Institute, 2000). Following the recommendation of Dr B Eisenberg, the consulting biometrician at TUT at the time of the study, the Duncan's Multiple Range Test ($p \leq 0.05$) was used to separate treatment means obtained in the single nutrient experiments and the Fisher's LSD test ($p \leq 0.05$) to separate the treatment means obtained in the factorial experiments.

8.2.3 Response of *Solanum retroflexum* to N, P and K availability

The results obtained in the three single nutrient experiments with *S. retroflexum* are presented in Table 8.3. Application of N increased total fresh and oven-dry above-ground biomass of *S. retroflexum* until the rate of 150 kg N ha^{-1}. Increasing the application rate to 200 kg N ha^{-1} did not affect total above-ground biomass, but when the application rate was increased to 250 kg N ha^{-1} or higher, there was a decline. Application of P increased total fresh and oven-dry above-ground biomass of *S. retroflexum* until the rate of 100 kg P ha^{-1}. Relative to this optimum application rate total above-ground biomass declined when the application rate of P was raised further. Application of K increased total fresh and oven-dry above-ground biomass of *S. retroflexum* until the rate of 100 kg K ha^{-1} and a reduction in total above-ground biomass was observed when the rate of K application was raised to 200 kg K ha^{-1}. Using quadratic regression curves fitted to the fresh above-ground biomass data obtained in the three single nutrient experiments the application rates of 196 kg N ha^{-1}, 122 kg P ha^{-1} and 125 kg K ha^{-1} were identified as optimal.

TABLE 8.3: Effects of application rate of nitrogen, phosphorus and potassium on total fresh and oven-dry above-ground biomass of *Solanum retroflexum* Dun. obtained from three harvests

N experiment			P experiment			K experiment		
Application rate of N	Total fresh above-ground biomass	Total oven-dry above-ground biomass	Application rate of P	Total fresh above-ground biomass	Total oven-dry above-ground biomass	Application rate of K	Total fresh above-ground biomass	Total oven-dry above-ground biomass
(kg N ha^{-1})	--- (g pot^{-1}) ---		(kg P ha^{-1})	--- (g pot^{-1}) ---		(kg K ha^{-1})	--- (g pot^{-1}) ---	
0	16.7_{e}	2.5_{d}	0	15.6_{e}	1.7_{e}	0	43.8_{e}	5.2_{d}
50	164.3_{d}	16.5_{c}	17	69.1_{d}	6.5_{d}	15	141.3_{d}	16.8_{c}
100	271.2_{ab}	25.5_{b}	34	136.5_{c}	11.8_{c}	30	182.9_{c}	20.9_{b}
150	306.3_{a}	32.2_{a}	50	175.9_{b}	14.6_{b}	45	194.1_{bc}	21.4_{b}
200	305.9_{a}	32.5_{a}	100	209.3_{a}	17.2_{a}	60	237.4_{ab}	25.6_{a}
250	246.6_{bc}	26.6_{b}	150	188.9_{ab}	13.7_{bc}	100	255.4_{a}	27.0_{a}
300	209.7_{c}	23.1_{b}	200	156.4_{bc}	13.6_{bc}	150	256.5_{a}	25.9_{a}
						200	214.3_{b}	21.9_{b}
Mean	217.2	22.7		135.6	11.3		190.7	20.6
CV %	13.0	15.0		19.0	19.4		18.8	18.9

For each of the three nutrients, treatment means followed by different letters differed significantly ($p \leq 0.05$).

Table 8.4 shows the treatment means obtained in the NPK factorial experiment using total fresh above-ground biomass as the biomass response indicator.

TABLE 8.4: Interaction effects of nitrogen, phosphorus and potassium application rates on the total fresh above-ground biomass of *Solanum retroflexum* Dun. obtained from three harvests

K	P	Nutrient application rates N: N0	N1	N2	N3
		Total fresh above-ground biomass (g pot^{-1})			
K0	P0	4.66_{f}	9.83_{f}	5.33_{f}	3.47_{f}
	P1	37.20_{f}	132.10_{ed}	113.04_{ed}	87.98_{e}
	P2	30.24_{f}	148.57_{d}	87.58_{ef}	72.82_{ef}
	P3	45.48_{ef}	148.19_{ed}	79.31_{ef}	77.81_{ef}
K1	P0	11.37_{f}	16.77_{f}	3.44_{f}	2.39_{f}
	P1	27.75_{f}	313.89_{ab}	282.03_{b}	244.80_{bc}
	P2	29.89_{f}	307.08_{ab}	138.54_{ed}	167.59_{cd}
	P3	47.84_{ef}	266.36_{bc}	137.87_{ed}	176.42_{cd}
K2	P0	6.06_{f}	15.75_{f}	0.59_{f}	2.92_{f}
	P1	36.10_{f}	339.83_{ab}	320.08_{ab}	233.77_{bc}
	P2	34.54_{f}	283.24_{b}	197.97_{cd}	206.02_{c}
	P3	33.19_{f}	343.62_{a}	241.34_{bc}	58.78_{ef}
K3	P0	10.88_{f}	14.90_{f}	3.77_{f}	2.12_{f}
	P1	26.23_{f}	310.94_{ab}	267.82_{bc}	213.40_{bc}
	P2	29.70_{f}	310.40_{ab}	233.04_{bc}	221.67_{bc}
	P3	34.61_{f}	285.65_{ab}	310.95_{ab}	109.37_{ed}

N0=0 kg N ha^{-1}; N1=98 kg N ha^{-1}; N2=196 kg N ha^{-1}; N3=260.68 kg N ha^{-1};
P0=0 kg P ha^{-1}; P1=61 kg P ha^{-1}; P2=122 kg P ha^{-1}; P3=203.74 kg P ha^{-1};
K0=0 kg K ha^{-1}; K1=62.5 kg K ha^{-1}; K2=125 kg K ha^{-1}; K3=166.25 kg K ha^{-1}.
Treatment means followed by different letters differed significantly ($p \leq 0.05$).

Statistically, the main effects, the three first order interactions and the second order interactions were all highly significant ($p < 0.0001$). As was observed in the single nutrient experiments, exclusion of any of the three nutrients had a strong negative effect of fresh above-ground biomass production. In the case of N, the optimum level tended to be lower (N1 = 98 kg N ha^{-1}) than that identified in the N experiment (N2 = 196 kg N ha^{-1}). As was the case in the N experiment adding N in excess of the optimum (N1) had a negative effect on biomass production. Indications were that applying P at a rate of 61 kg P ha^{-1} was optimal (P1), which was also less than the optimum identified in the P experiment (P2 = 122 kg P ha^{-1}). Evidence of a decline in biomass production due to excess P was inconclusive. The results largely confirmed the optimum rate of application of K (K2 = 125 kg K ha^{-1}) identified in the K experiment, but the effects on fresh above-ground biomass production of reducing this rate to 62.5 kg K ha^{-1} (K1) or increasing it to 166 kg K ha^{-1} (K3) were limited. Similar results were obtained when using oven-dry above-ground biomass as the indicator of plant response (not shown).

8.2.4 Response of *Brassica rapa* subsp. *chinensis* to N, P and K availability

The results obtained in the three single nutrient experiments with *Brassica rapa* subsp. *chinensis* are presented in Table 8.5. Fresh and oven-dry mass of marketable leaves increased with application rate of N and tended to peak when nitrogen was applied at the rate of 200 kg N ha^{-1}. There was a tendency for fresh and oven-dry mass of marketable leaves to decline when the application rate exceeded 250 kg N ha^{-1}, suggesting a fairly narrow optimum N availability range. For the prevailing conditions this range was achieved when N was applied at rates that ranged between 100 and 250 kg N ha^{-1}. The trend of the response of *B. rapa* subsp. *chinensis* to the availability of P in the soil differed from that to N availability. In the case of P, total fresh and oven-dry mass of marketable leaves increased as P was added to the soil until the rate of about 37.5 kg P ha^{-1} at which it levelled off. This suggests that P availability only affected the mass of leaves below some critical level, which in this experiment was reached when P was applied at the rate of 37.5 kg P ha^{-1}. Once this critical level of P availability in the soil had been attained, adding more P no longer had an effect. The response of the crop to K was similar to that observed for N. Total mass of fresh and oven-dry marketable leaves increased significantly ($p \leq 0.05$) as the rate of application of K was raised up to the rate of 80 kg K ha^{-1} and tended to decline when this optimum rate was exceeded.

TABLE 8.5: Effects of application rate of nitrogen, phosphorus and potassium on the fresh and oven-dry mass of marketable leaves of *dabadaba* (*Brassica rapa* L. subsp. *chinensis*) in pots

N experiment			P experiment			K experiment		
Application rate of N	Fresh mass of marketable leaves	Oven-dry mass of marketable leaves	Application rate of P	Fresh mass of marketable leaves	Oven-dry mass of marketable leaves	Application rate of K	Fresh mass of marketable leaves	Oven-dry mass of marketable leaves
(kg N ha^{-1})	--- (g pot^{-1}) ---		(kg P ha^{-1})	--- (g pot^{-1}) ---		(kg K ha^{-1})	--- (g pot^{-1}) ---	
0	0.00_{c}	0.00_{c}	0.0	0.00_{e}	0.00_{e}	0	0.00_{f}	0.00_{f}
50	113.00_{b}	11.50_{b}	12.5	95.86_{d}	4.57_{d}	10	127.10_{e}	10.00_{e}
100	139.80_{ab}	12.91_{b}	25.0	230.86_{c}	10.99_{bc}	20	190.50_{d}	16.27_{d}
150	140.90_{ab}	12.92_{b}	37.5	306.14_{a}	13.42_{ab}	40	241.10_{bc}	20.60_{c}
200	162.10_{a}	16.02_{a}	50.0	291.71_{ab}	12.32_{bc}	60	254.70_{b}	23.33_{b}
250	153.20_{a}	14.74_{ab}	75.0	285.14_{ab}	13.04_{bc}	80	278.80_{a}	25.46_{a}
300	128.00_{b}	12.59_{b}	100.0	313.57_{a}	13.03_{bc}	100	256.50_{b}	22.42_{bc}
			200.0	267.14_{b}	11.25_{c}	200	241.90_{bc}	20.01_{c}
			300.0	285.14_{ab}	12.95_{bc}	400	231.60_{c}	18.05_{cd}
			400.0	308.42_{a}	15.26_{a}			
Mean	119.59	11.52		238.40	10.68		202.47	17.35
CV %	22.39	24.37		14.81	18.14		12.29	13.70

For each of the three nutrients, treatment means followed by different letters differed significantly ($p \leq 0.05$).

Table 8.6 shows the treatment means obtained in the NxPxK factorial experiment using total fresh mass of marketable leaves as the biomass response indicator.

TABLE 8.6: Interaction effects of nitrogen, phosphorus and potassium application rates on the total fresh mass of marketable leaves of *dabadaba* (*Brassica rapa* L. subsp. *chinensis*)

K	P	Nutrient application rates N			
		N0	N1	N2	N3
		Total mass of fresh marketable leaves --------------------(g pot^{-1})--------------------			
K0	P0	0	0	0	0
	P1	0	0	0	0
	P2	0	0	0	0
	P3	0	0	0	0
K1	P0	0	0	0	0
	P1	0	186.4$_{bc}$	183.4$_{bc}$	142.6$_{c}$
	P2	0	185.6$_{bc}$	168.0$_{c}$	171.0$_{bc}$
	P3	0	192.0$_{ab}$	198.0$_{ab}$	168.0$_{c}$
K2	P0	0	0	0	0
	P1	0	186.8$_{bc}$	215.2$_{ab}$	172.8$_{bc}$
	P2	0	196.4$_{ab}$	222.8$_{a}$	200.4$_{ab}$
	P3	0	197.0$_{ab}$	207.2$_{ab}$	200.8$_{ab}$
K3	P0	0	0	0	0
	P1	0	177.0$_{bc}$	208.4$_{ab}$	177.2$_{bc}$
	P2	0	184.2$_{bc}$	205.8$_{ab}$	182.0$_{bc}$
	P3	0	172.8$_{bc}$	203.4$_{ab}$	203.2$_{ab}$

N0 = 0 kg N ha^{-1}; N1 = 94 kg N ha^{-1}; N2 = 188 kg N ha^{-1}; N3 = 376 kg N ha^{-1};
P0 = 0 kg N ha^{-1}; P1 = 50 kg P ha^{-1}; P2 = 100 kg P ha^{-1}; P3 = 200 kg P ha^{-1};
K0 = 0 kg K ha^{-1}; K1 = 50 kg K ha^{-1}; K2 = 100 kg K ha^{-1}; K3 = 200 kg K ha^{-1}.
Treatment means followed by different letters differed significantly ($p \leq 0.05$).

Statistically, the main effects, the three first order interaction effects and the second order interaction effects were all highly significant ($p < 0.0001$). Treatments in which one or more of the three nutrients were not applied failed to produce marketable leaves. The highest mean mass of marketable leaves was obtained when N was applied at the rate of 188 kg N ha^{-1} and P and K each at the rate of 100 kg ha^{-1}. This particular treatment (N2P2K2) more or less represented the combination of the three optimum application rates identified in the previous single-nutrient experiments except for P. In the P experiment the identified optimum application rate (37.5 kg P ha^{-1}) was lower than in the factorial experiment (100 kg P ha^{-1}).

Statistically and relative to the N2P2K2 treatment, there was no significant reduction ($p \leq 0.05$) in the fresh mass of marketable leaves when the application rate of P was increased to 200 kg P ha^{-1} (P3) or reduced to 50 kg P ha^{-1} (P1), as long as N was applied at the rate of 188 kg ha^{-1} (N2). There was also no significant reduction ($p \leq 0.05$) in the fresh mass of marketable leaves when the application rate of K was raised from 100 kg K ha^{-1} (K2) to 200 kg K ha^{-1} (K3) as long as P was applied at the rate of 50 kg P ha^{-1} (P1) or higher and N at the rate of 188 kg ha^{-1} (N2). Reducing the rate of K application from 100 kg K ha^{-1} (K2) to 50 kg K ha^{-1} (K1) brought about a reduction in the fresh mass of marketable leaves except when P was applied at the highest rate (P3). Increasing the rate of N to 376 kg N ha^{-1} (N3) reduced ($p \leq 0.05$) mean mass of marketable leaves relative to the N2P2K2 treatment only when the application rates of P and K were less than 100 kg ha^{-1} (P2 and K2), but when the application rate of K was raised to 200 kg ha^{-1} (K3), the application rate of P had to be increased to 200 kg P ha^{-1} (P3) also to avoid a reduction ($p \leq 0.05$) in the fresh mass of marketable leaves. Applying N at the rate of 94 kg N ha^{-1} (N1) reduced ($p \leq 0.05$) the fresh mass of marketable leaves except when K was applied at the rate of 100 kg K ha^{-1} (K2) and P at the rate of 100 kg P ha^{-1} or higher (P2 and P3). Similar results were obtained when using total oven-dry mass of marketable leaves as the indicator of plant response (not shown).

8.2.5 Discussion

The results of this study indicate that both crops were most sensitive to the availability of nitrogen in the soil. To optimise their economic yield sufficient nitrogen had to be applied to the soil but adding too much had a distinctly negative effect on biomass production. Production of the two crops was also dependent on the adequate availability of phosphorus and potassium, but the adverse effects caused by applying these two nutrients in excess of the rate at which biomass production reached an optimum were less distinct than for nitrogen. The results of the two factorial experiments showed that the decline in biomass production caused by adding N in excess of the optimum was to an extent counteracted by applying both P and K at rates that were in excess of their respective optima, particularly in the case of *B. rapa* subsp. *chinensis*. This indicates that balance in the availability of the three nutrients is also important.

The negative effect of excessive application of N on biomass production has been documented for several crops (Robert *et al*., 1989), including *S. nigrum* (Merinyo, 1996; Chweya, 1997). Nkoa *et al*. (2000) suggest that biomass reductions caused by excessive N applications may be the result of osmotic imbalances due to N accumulation in plant tissues. Biomass reductions associated with excessive application of K, which in this study were most evident in the case of *B. rapa* subsp. *chinensis*, have been associated with imbalances in the K:Mg and K:Ca ratios (Jones, 2003) and with excessively high salt concentrations in the soil solution (Pasternak, 1987). Biomass reductions associated with excessive application of P, which in this study were most evident in the case of *S. retroflexum*, have been linked to reduced availability of micronutrients (Hopkins and Elsworth, 2003).

The results of the factorial experiment with *S. retroflexum* suggest that optimum biomass production was achieved when N was applied at the rate of about 100 kg N ha^{-1}, P at the rate of about 60 kg P ha^{-1} and K at the rate of about 125 kg K ha^{-1}. The optimum application rate of N identified in this study was lower than the optimum rate reported for *S. nigrum* by Merinyo (1996) (150 kg N ha^{-1} in combination with the application of farm yard manure at the rate of 10 t ha^{-1}) and Chewya (1997) (200 kg N ha^{-1}). No research findings documenting the response of *S. nigrum* to P and K availability were retrieved. The results of the factorial experiment with *B. rapa* subsp.

chinensis suggest that optimum production of marketable leaves was achieved when N was applied at the rate of about 190 kg N ha^{-1}, P at the rate of about 100 kg P ha^{-1} and K at the rate of about 100 kg K ha^{-1}. The identified optimum rates of application of the three nutrients fall within the optimum range identified for other *Brassica* species grown in low fertility soils (Hartman *et al*., 1985; FSSA, 2003; Schippers, 2002). For *B. rapa* subsp. *chinensis* specifically Yoshizawa *et al*. (1981) reported the application rate of 120 kg N ha^{-1} as optimal, but their field experiment was conducted in soil that was fertile. In this study the results were obtained in pot experiments using a low fertility soil. It needs pointing out that pot experiments provide only an initial indication of the nutrient requirements of a crop (Tening *et al*., 1995; Cox *et al*., 1999). They have the advantage over field experiments in that they enable the elimination of a great deal of environmental variability (Rowell, 1994) but their disadvantage is that they employ small quantities of soil, resulting in the containment and concentration of plant roots, creating conditions that are different from those found in the field. Although fairly large quantities of soil were used in this study, the volume of soil available to the plants was only about 10% of that expected to be available to plants growing in the field. To develop fertiliser recommendations for use by farmers, field experiments that take the nutrient status of the soil into account need to be conducted.

8.2.6 Conclusions

The results of this study suggest that optimising soil nitrogen availability is the most critical nutrient management concern in the production of *S. retroflexum* and *B. rapa* subsp. *chinensis*. Sufficient nitrogen needs to be available in the soil to achieve optimum growth, but adding too much nitrogen adversely affects biomass production. Considering that smallholders in Vhembe produce *S. retroflexum* and *B. rapa* subsp. *chinensis* under irrigation, which increases the likelihood of nitrogen losses due to leaching, maintaining optimum availability of N in field soils throughout the growing season is expected to be difficult to achieve. The use of split application of N, which is common practice among smallholders at present (Juma, 2006; Tshikalange, 2006), is likely to be the appropriate strategy to achieve this objective but this needs to be investigated. Production of the two crops was also shown to be dependent on the adequate availability of phosphorus and potassium, but the adverse effects caused by applying these two nutrients in excess of the rate at which biomass production reached an optimum were less distinct than for nitrogen. The findings of this study suggest that growers stand to benefit financially from optimizing fertiliser application rates in the production of *S. retroflexum* and *B. rapa* subsp. *chinensis*, but field experiments are needed to identify these rates.

8.3 Effect of planting date on the yield of Chinese cabbage

8.3.1 Problem identification and study objectives

Planting date affects crop productivity because several environmental factors that influence crop growth and development vary with planting date. These factors include temperature, day length (photoperiod), and light intensity. The activity of enzymes that catalyse photosynthetic reactions is highly dependent on temperature (Campbell and Norman, 1989). Vegetables grow and develop most rapidly at an optimum temperature, which is crop specific (Decoteau, 2000). At low temperatures growth is retarded (Rubatzky and Yamaguchi, 1997). The temperature at which growth comes to a halt is called the base temperature, which is about 10°C for many crops. At temperatures higher than the base temperature, the rate of plant growth increases as temperature is raised until an optimum temperature is reached at which growth rate peaks (Rubatzky and Yamaguchi, 1997). When the temperature is raised in excess of the optimum there is no effect on growth initially, but when increased further there is a negative effect on growth, resulting in a linear decline in growth rate until a temperature is reached where growth stops completely. This temperature is called the maximum or ceiling temperature of a crop (Squire, 1990). According to Hopkins (1995), the ceiling temperature for most plants is about 45°C. Figure 8.3 portrays the typical response of plant growth to temperature.

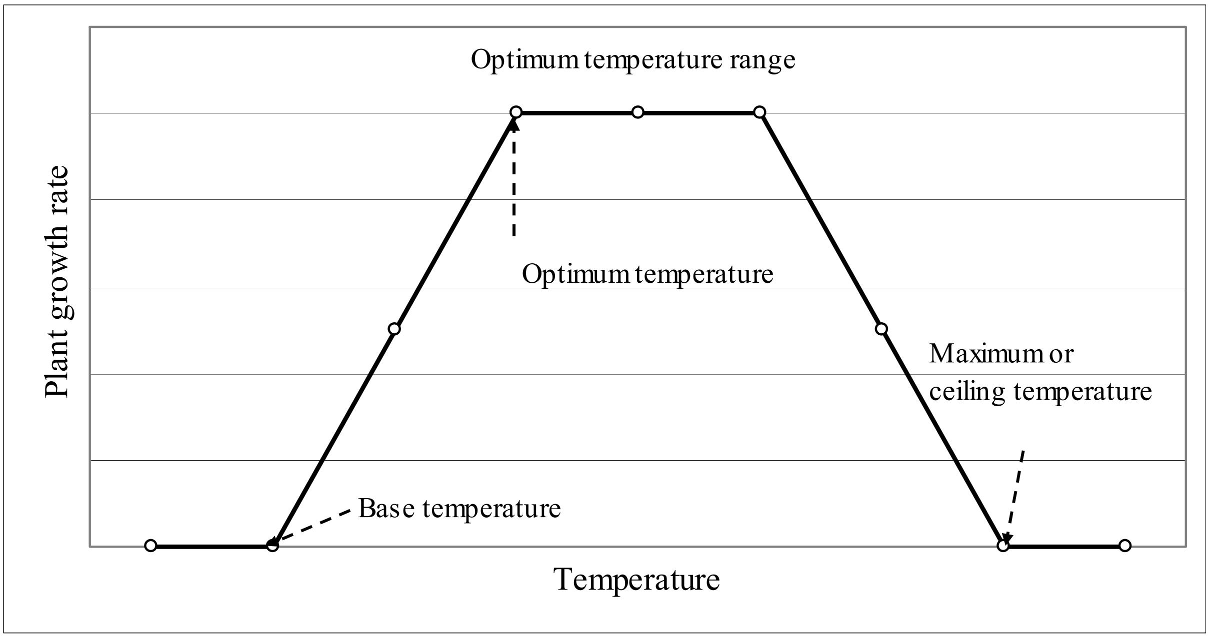

FIGURE 8.3: Generalized effect of temperature on plant growth

Brassica vegetable species originated in areas with temperate climates (Decoteau, 2000; Rubatzky and Yamaguchi, 1997). They show preference for growing temperatures that range between 10°C and 18°C (Rubatzky and Yamaguchi, 1997). For this reason, most of the Brassicas are classified as cool-season crops (Decoteau, 2000). Chinese cabbage is no exception (Matsumura, 1981; Guttormsen and Moe, 1985). The optimal growing temperature for Chinese cabbage is between 16°C and 21°C (Matsumura, 1981; Pierce, 1987; Rubatzky and Yamaguchi, 1997). According to Pierce (1987), flowering in both non-heading and heading varieties of Chinese cabbage is accelerated when the plants are exposed to temperatures of 10°C or less and is inhibited when the plants are exposed to temperatures exceeding 26°C, but at these high temperatures there is also a decline in shoot dry matter production (Kuo and Tsay, 1981). Table 8.7 summarises the effect of temperature on the growth of a selection of *Brassica* vegetable species.

TABLE 8.7: Effect of temperature on a selection of *Brassica* vegetable species (adapted from Rubatzky and Yamaguchi, 1997; Decoteau; 2000; Peirce, 1987)

Common English name	**Scientific name**	**Optimal temperature range (ºC)**	**Effect of sub-optimal temperature**	**Effect of supra-optimal temperature**
White cabbage	*Brassica oleraceae* var. *capitata*	15 to 20	Suppresses growth, leading to small heads.	Head density is reduced and shape is affected.
Cauliflower	*Brassica oleraceae* var. *botrytis*	17 to 20	Promotes early curd initiation.	Compactness of curds is reduced.
Brussels sprouts	*Brassica oleraceae* var. *gemmifera*	17 to 21	Initiates bolting.	Stem elongation is suppressed and bud compactness is reduced.
Broccoli	*Brassica oleraceae* var. *italica*	15.5-20	Initiates flowering, rendering the plant unmarketable.	Heads become loose and puffy.

Planting date also affects the light regime in terms of day light duration and light intensity. Light intensity governs the rate of photosynthesis in plants (Decoteau, 2000). Light intensity changes with elevation, latitude, altitude and time of year. The intensity of incident light and the length of the day affect the quantity of light received by plants in a particular locality. According to Decoteau (2000), vegetables vary in terms of their optimum light intensity requirements. The optimum light intensity of a plant is referred to as the light saturation point. Increases in light intensity in excess of the saturation point no longer increase the rate of photosynthesis. Photosynthesis can still occur at very low intensities but becomes negligible at intensities of 5 lux or less (Rubatzky and Yamaguchi, 1997). The light compensation point for many plants, which is the light intensity at which the rate of photosynthesis equals the rate of respiration, is about 1000 lux. According to Rubatzky and Yamaguchi (1997), an individual leaf may be saturated at an intensity of 30 000 lux but the entire plant may not be saturated at even higher intensities because the lower leaves may not experience the light saturation point. In general, 10 000 lux is regarded as low light intensity and 50 000 lux or more as high intensity. Generally, *brassica* crops grow satisfactorily at low levels of light intensity (Decoteau, 2000). In Chinese cabbage, high levels of light intensity induce broadening of leaves, whereas shading causes sagging of the lower leaves (Waters *et al*., 1992).

The length of the light period, also called photoperiod, varies according to time of year and latitude. Some plants change their growth and development in response to day length and exhibit photoperiodism (Decoteau, 2000; Peirce, 1987). Plants respond differently to photoperiod. Short-day plants flower rapidly when light period (day length) is less than a specific threshold. Long-day plants flower more rapidly when the light period exceeds a particular threshold. Plants that are not affected by day length are called day-neutral plants (Decoteau, 2000; Peirce, 1987). Chinese cabbage and other *Brassica* vegetable species are classified as long-day plants. As the days get longer, the plants flower more quickly (Decoteau, 2000; Peirce, 1987). Temperature and day length interact to induce flowering in Chinese cabbage. Long days and cold temperature enhance flowering, whilst short days counteract the flower enhancing effect of cold temperatures (Matsui *et al*., 1981)
.

In the area around Thohoyandou, marketing of Chinese cabbage is problematic during June and July because during that time many producers supply the market. The glut of Chinese cabbage occurs because the majority of farmers plant the crop during April and May (Tshikalange, 2006). Farmers indicated that planting earlier or later than April or May increased the incidence of damage by pests but they did not raise any other negative effects associated with variability in planting date suggesting that with appropriate pest control management a wider range of planting dates could be exploited. This, in turn, could alleviate the marketing problem. For this reason the effect of planting date on the growth and yield of Chinese cabbage at Dzindi was investigated by means of field experiments. The study is at a stage where the data have been collected but the analysis of the data is still outstanding. As a result, the information that is provided in this report is limited in extent and preliminary in nature.

8.3.2 Materials and methods

The effect of planting date on the growth and yield of Chinese cabbage was studied by means of a field experiment that was conducted three times, namely during 2003, 2004 and 2006. The experiment involved the measurement of growth and yield of Chinese cabbage that was planted on different dates, spread two to three weeks apart. Table 8.8 presents the planting dates that were used in the different years that the experiment was conducted. The experiment was conducted on the research plot (Plot 1) at Dzindi (see Figure 2.1). The soil on the plot is a deep, red, well-drained soil of the Hutton form (Soil Classification Working Group, 1991) with an effective rooting depth in excess of 1200 mm and a B-horizon with a clay content that ranges between 25 and 35 %.

TABLE 8.8: Planting dates of Chinese cabbage at Dzindi during the 2003, 2004 and 2006 experiments

2003	2004	2006
19-Mar	27-Apr	24-Mar
11-Apr	13-May	4-Apr
25-Apr	27-May	5-May
8-May	10-Jun	26-May
22-May	24-Jun	6-Jun
5-Jun	8-Jul	23-Jun
19-Jun	23-Jul	4-Jul
3-Jul	6-Aug	26-Jul
17-Jul	3-Sep	4-Aug
21-Aug		25-Aug
23-Sep		5-Sep
23-Oct		22-Sep
21-Nov		
19-Dec		

The experiment employed a complete randomized block design with four replications. The individual plots were 5.1 m long and 4.5 m wide. The planting rows were spaced 0.75 m apart and the spacing between plants in the row was 0.3 m. Plants in the two outer rows and the first and the last plant in the four inner rows were considered as guard plants and were excluded when conducting measurements. The resulting net plot was 4.5 m x 3 m in size and contained 60 plants. Soil preparation consisted of ploughing, disking and ridging as practised by all farmers at the scheme. Nutrient supply was based on farmer practices (Van Averbeke, Tshikalange and Juma, 2007) and on the results obtained in pot experiments presented in section 8.2. Cattle and chicken manure were both applied at the rate of 3000 kg ha^{-1} (air-dry), after the soil was ploughed and these manures were incorporated in the soil by disking. At planting the fertiliser mixture 2:3:2 (22) was applied in the planting furrow at the rate of 624 kg ha^{-1}. After the first harvest, LAN (28 % N) was band placed at the rate of 150 kg ha^{-1} and after the second harvest LAN was again band placed at the rate of 100 kg ha^{-1}. Table 8.9 summarizes the supply of nutrients to the crop over the full growing season.

TABLE 8.9: Summary of the supply of nutrients to Chinese cabbage in the planting date experiments at Dzindi

Fertiliser	Application rate (kg ha^{-1})	Nitrogen applied (kg N ha^{-1})	Phosphorus applied (kg P ha^{-1})	Potassium applied (kg K ha^{-1})
Cattle manure	3000	42	10	23
Poultry manure	3000	62	31	13
2:3:2 (22)	624	39	58	39
LAN (28)	250	70	0	0
Total	**-**	**213**	**99**	**75**

The crop was propagated directly from seed. At planting, furrows were opened using a hand hoe and the required amount of 2:3:2 (22) was applied in the furrows and mixed with the soil using a stick. About 10 litres of water was poured in the furrows and then Lamdex, containing *lambda cyhalothrin* was applied using a knapsack sprayer to protect the seed and the germinating plants against pests. A marked planting chain was used to space the planting stations in the rows. Seed of *dabadaba*, a land race of non-heading Chinese cabbage commonly planted in the area (Van Averbeke, Tshikalange and Juma, 2007), was used in all the experiments. At each planting station, five seeds were pressed into the wet soil in the planting furrow and there after the seeds were covered with about 10 mm of dry soil. At the fourth leaf stage, the plants were thinned out to one plant per hill in order to establish the desired plant population. In order to eliminate soil water availability as a limiting factor, the soil was recharged to field capacity every second day. Soil water was monitored to a depth of 1500 mm using a neutron hydro probe (Waterman, model FY500, Geotech, Pretoria). For that purpose, two access tubes were inserted close to the middle of each plot. One access tube was positioned in the planting row (aligned with the plants) and the other in the furrow. The neutron hydro probe had been calibrated specifically for the soil at the experimental site (Adriaens, 2005). Appropriate pest control measures were applied to avoid insect damage to the crop.

Data collected in this study included daily weather data, fresh mass of marketable leaves and total oven-dry above-ground biomass of the crop. In the 2003 and 2004 experiments the crop was harvested when 50 % of the crops in the net plots had commenced flowering. At harvest, the marketable leaves were removed from the plants and weighed separately from the rest of the biomass. The findings of the survey by Tshikalange (2006) showed that farmers start harvesting the fifth leaf when the plants have reached the eight leaf stage, followed by the harvest of the sixth leaf about one week later and the rest of the marketable leaves at or just before the start of peduncle elongation. This procedure was standardised for use in the pot experiments (see section 8.2) and was also adopted for use in the 2006 planting date experiment. When removal of marketable leaves is delayed until the start of peduncle elongation the fifth and sometimes the sixth leaf have already started to show signs of senescence (yellowing) and are no longer marketable. The change in harvesting procedure may explain why peak yields of marketable leaves obtained in the 2006 experiment were higher than those in the other two experiments.

8.3.3 Preliminary results

Figure 8.4 shows the effect of planting date on the fresh mass of marketable leaves of Chinese cabbage obtained in 2003, 2004 and 2006.

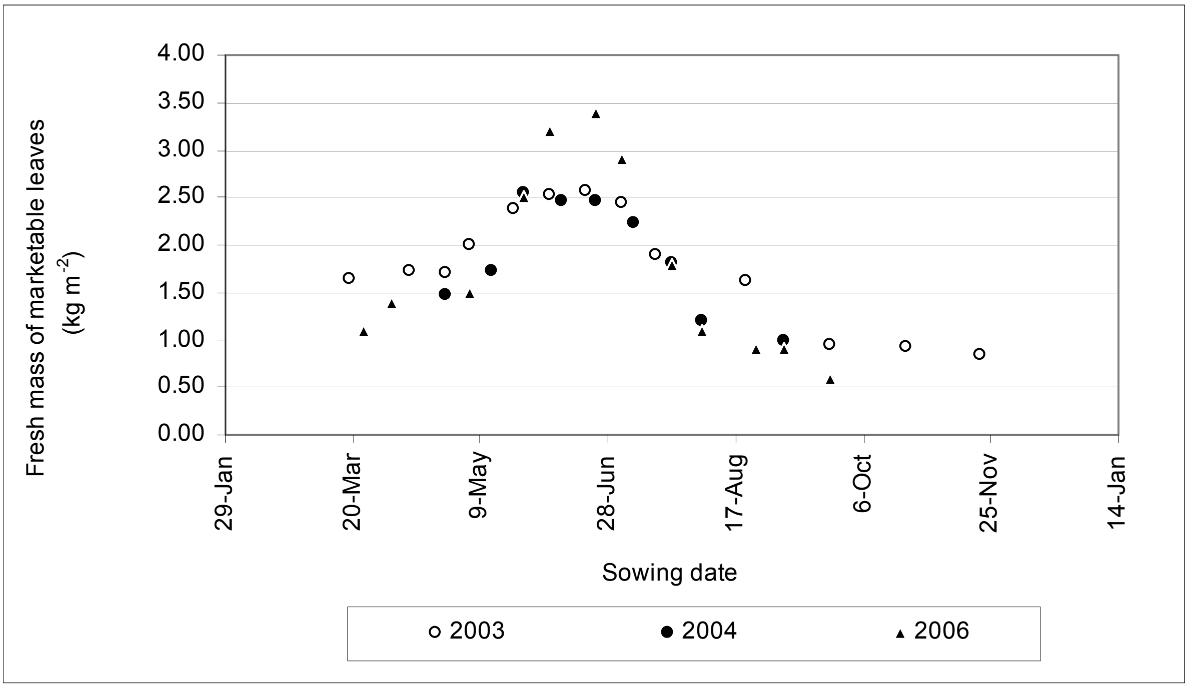

FIGURE 8.4: Effect of planting date on the yield of fresh marketable leaves (kg m^{-2}) of Chinese cabbage at Dzindi

Peak yields of fresh marketable leaves ranging between 2.5 to 3 kg m^{-2} were obtained when the crop was planted during the period 25 May until 2 July.

When the crop was planted at the beginning of May, the yield of fresh marketable leaves was reduced to between 1.5 and 2 kg m^{-2}. When the crop was planted during April, the yield of fresh marketable leaves ranged between 1.5 kg m^{-2} and 1.7 kg m^{-2}

When planting was delayed beyond the 2nd of July, the yield of fresh marketable leaves declined substantially. When the crop was planted at the beginning of August the yield of fresh marketable leaves was about 1.5 kg m^{-2}. When planting date was delayed further the yield rapidly dropped to 1 kg m^{-2} or less.

When the yield trend shown in Figure 8.4 is compared with the monthly mean daily temperature data shown in Figure 8.5, it appeared that temperature during the early stages of growth was the critical environmental factor that affected the yield of fresh marketable leaves of this crop. The highest yields were obtained when the crop was planted during the months with the lowest mean daily temperature. These results are not surprising because Chinese cabbage is known to be a cool-season vegetable (Matsumura, 1981; Guttormsen and Moe, 1985).

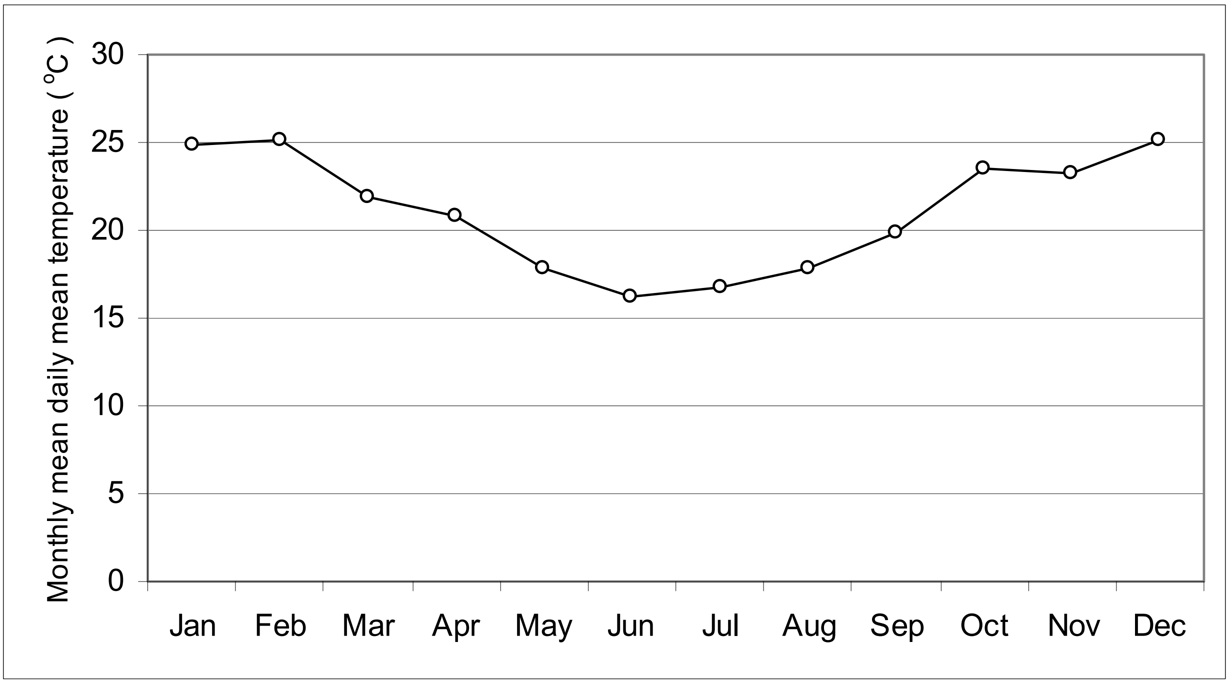

FIGURE 8.5: Monthly mean daily temperatures recorded at Dzindi during 2006

One of the main reasons for the differences in the yield of fresh marketable leaves of Chinese cabbage among the different planting dates was the difference in the number of marketable leaves (Table 8.10). When planted during relatively hot months, the crop produced fewer marketable leaves before the commencement of peduncle elongation than when the crop was planted during relatively cool months. Another reason was that leaves of the crop were smaller in size when planted during hot months than when planted during cold months.

TABLE 8.10: Effect of planting date on the mean number of marketable leaves of Chinese cabbage (2006 experiment)

Planting date	Number of leaves per plant
06 June	8
23 June	9
04 July	9
26 July	6
04 August	5
25 August	5
05 September	5
22 September	4

Observations during the conduct of the planting date experiments indicated that when the soil temperature became too hot, germination and emergence of the seed of Chinese cabbage (*dabadaba* land race) were affected negatively. In 2003, germination and emergence failed completely when the crop was planted in December and in

2004, when the weather was particularly hot, germination and emergence failed from October onwards.

8.3.4 Preliminary conclusions

The results obtained in this study demonstrated the important effect of planting date on the yield of Chinese cabbage. The study showed that the yield of fresh marketable leaves produced by the crop peaked when the crop was planted during the period 25 May until 2 July. Postponement of the planting date beyond the 2nd of July resulted in a rapid decline in yield. Bringing planting forward to dates earlier than 25 May also reduced the yield, but in a less extreme way than when the crop was planted later than the optimum planting window. Temperature was identified as the critical factor that affected variance in yield associated with planting date.

Tshikalange (2006), who documented farmer practices at several smallholder irrigation schemes in the Venda region, but not at Dzindi, reported that the majority of Chinese cabbage producers planted the crop during April and May. Although climatic conditions at the different schemes visited by Tshikalange (2006) may differ from those at Dzindi, the results obtained in this experiment suggest that purely from a yield perspective, farmers in the region may not be planting Chinese cabbage at the optimum time. What has become clear from this study is that the option of spreading the planting date of the crop more widely, to avoid the period of excess supply on the local market, is seriously compromised by the effect of planting date on the yield of the crop.

8.4 Effect of soil water availability on the yield of Chinese cabbage

8.4.1 Problem identification and study objectives

When plants experience water stress, nutrient uptake slows down and cells plasmolyze and lose turgor. This in turn affects gas exchange and photosynthesis (Peirce, 1987; Decoteau, 2000). Water deficit also has an impact on cell division, reducing leaf growth (Kuo and Tsay, 1981). In the case of Chinese cabbage, which is a leafy vegetable, leaf yield is expected to be reduced by water stress. In the study of plant water relations, the plant availability of soil water is of critical importance. (Decoteau, 2000). The amount of plant available water in soils is affected by the type and depth of soil, the rooting depth of the crop and the atmospheric demand.

Brassica vegetable species, including Chinese cabbage, contain up to 95 % of water (Decoteau, 2000) and are sensitive to water stress. For the production of high quality plants the maintenance of high levels of plant available water in the soil is essential, especially during leaf development and enlargement (Rubatzky and Yamaguchi, 1997). In general, *Brassica* vegetables require frequent irrigation (Sanders, 1993), because plant available water in the soil needs to be maintained above 60% of the total for optimum growth (Decoteau, 2000).

The available evidence suggests that Chinese cabbage is also sensitive to water stress. Opeña *et al*. (1988) categorise the crop as a shallow rooted vegetable. More than 90 % of the root system of mature vegetative Chinese cabbage plants is found in the zone of soil that extends 35 cm deep and 20 cm wide around the stem (Opeña *et al.*, 1988). As a result, Chinese cabbage requires frequent irrigation for optimum growth (Fritz and Homma, 1987; Sanders, 1993). Water stress stunts growth, enhances flower flowering and causes leaves to become tough and leathery, reducing the quality of the produce (Sanders, 1993). Sanders (1993) reported that for optimum yield and quality in Chinese cabbage production, the soil water content must be maintained above 70% of the total plant available water content at all times. He observed reductions in yield when soil water potential was allowed to drop below –250kPa. Chinese cabbage is also sensitive to excessive soil water availability, a condition which increases the likelihood of soft rot disease (Fritz and Homma, 1987).

The general objective of this study was to investigate the effect of soil water availability on the growth and yield of Chinese cabbage with specific reference to the circumstances at Dzindi. For this reason the existing irrigation practices of the local farmers were taken into account when the different water treatments were defined.

8.4.2 Materials and methods

In this experiment, Chinese cabbage was subjected to five different levels of soil water availability, namely (i) full irrigation; (ii) minimal irrigation; (iii) farmer treatment; (iv) double farmer treatment; and (v) pre-charged farmer treatment.

The highest level of soil water availability, designated full irrigation (FI), consisted of charging the upper 800 mm of the soil profile to field capacity before planting, followed by recharging this zone to field capacity every second day.

The lowest level of water, designated minimal irrigation (MI), consisted of charging the upper 800 mm of the soil profile to field capacity before planting, followed by the application of 20% of the amount of water applied to the FI treatment on a weekly basis.

The third water level, designated farmer treatment (FT) mimicked the irrigation practices of farmers at Dzindi involved in the production of Chinese cabbage. The FT treatment consisted of applying 20 mm of water before planting followed by weekly applications of 20 mm each. The amount of 20 mm was the average amount of water that entered when using short furrow irrigation on the red soils at Dzindi (Van der Stoep and Nthai, 2005). The weekly irrigation interval corresponded with the water sharing arrangements at Dzindi which provide individual plot holders with access to water during daylight hours once a week (see section 5.1.2).

The fourth level of water, designated double frequency farmer treatment (DFFT), consisted of applying 20 mm of water before planting followed by two applications of 20 mm each per week. This treatment represented a potential improvement on the existing farmer irrigation practice by doubling the irrigation frequency. The DFFT treatment can be implemented by farmers at Dzindi, either by irrigating the crop once per week during the night, or by negotiating additional access to water with other plot holders using the same supply furrow. At present, both of these ways of accessing additional water are being used by farmers at Dzindi (see section 5.1.2).

The results presented in Table 8.11 show that full irrigation (FI) was necessary to achieve optimum yield of fresh marketable leaves of Chinese cabbage. Relative to the farmer treatment (FT), practising full irrigation increased the yield of fresh marketable leaves from 0.829 kg m^{-2} to 1.371 kg m^{-2}, which represented an improvement of 65 %. However, from a farmers' perspective full irrigation at Dzindi is probably only possible when night irrigation is practised. The other two irrigation treatments that produced yields in excess of the overall mean were the double frequency farmer treatment (DFFT) and the charged farmer treatment (CFT). Relative to the farmer treatment the double frequency farmer treatment increased the yield of fresh marketable leaves from 0.829 kg m^{-2} to 1.113 kg m^{-2}, which represented an improvement of 34 %, and the charged farmer treatment increased the yield of fresh marketable leaves to 0.994 kg m^{-2}, which represented an improvement of 20 %. As indicated, implementing these two treatments is practically possible at Dzindi, particularly the charged farmer treatment, which does not require farmers to irrigate at night or negotiate access to additional water.

Total consumptive water use was highest in the double frequency farmer treatment (DFFT) and lowest in the minimal irrigation (MI) treatment. Consumptive water use in both the farmer treatment (FT) and the charged farmer treatment (CFT) was less than the overall mean. The full irrigation (FT) treatment and the charged farmer treatment (CFT) were the most efficient in terms of water use.

The effects of irrigation strategy on the yield of fresh marketable leaves, total consumptive water use and water use efficiency (in terms of the yield of fresh marketable leaves) obtained in the 2006 experiment are presented in Table 8.12.

TABLE 8.12: Effect of irrigation strategy on the yield of fresh marketable leaves of Chinese cabbage (Dzindi, 2006)

Water treatment[1]	Yield of fresh marketable leaves (kg m^{-2})	Total consumptive water use (mm)	Water use efficiency In terms of fresh marketable leaves (g mm^{-1} m^{-2})
FI	3.983	279	14.6
MI	2.166	124	19.9
FT	2.644	171	14.8
DFFT	3.815	239	16.2
CFT	3.156	174	18.6
Mean	**3.153**	**197**	**16.8**
LSD ($p \leq 0.05$)	0.404	61	NSD

FI = full irrigation; MI = minimal irrigation; FT = farmer treatment; DFFT = double frequency farmer treatment; CFT = charged farmer treatment; NSD = no significant differences among means

The results obtained in the 2006 experiment confirmed that full irrigation (FI) was necessary to achieve optimum yield of fresh marketable leaves of Chinese cabbage. Relative to the farmer treatment (FT), practising full irrigation increased the yield of fresh marketable leaves from 2.644 kg m^{-2} to 3.983 kg m^{-2}, an improvement of 51 %.

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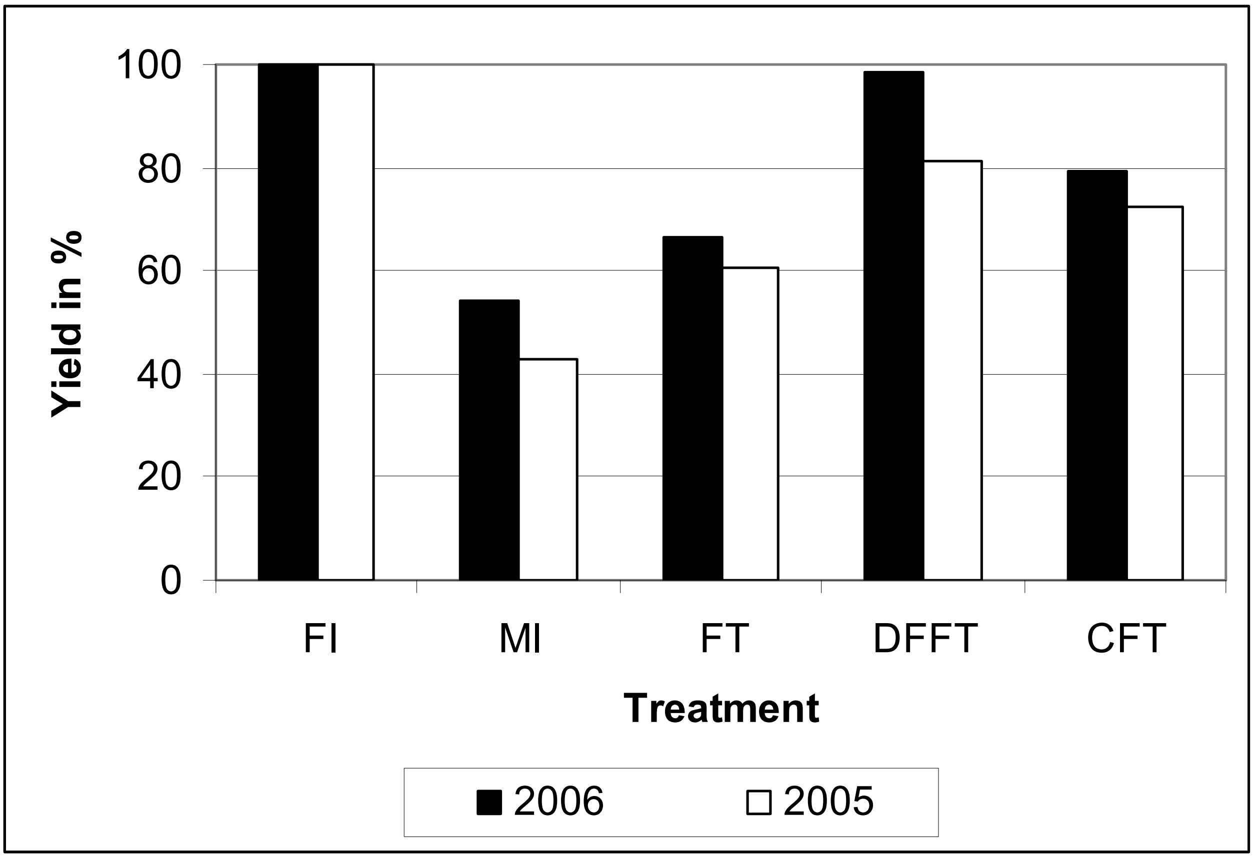
As in the 2005 experiment the double frequency farmer treatment (DFFT) and the charged farmer treatment (CFT) resulted in yields that exceeded the overall mean. Relative to the farmer treatment the double frequency farmer treatment increased the yield of fresh marketable leaves from 2.644 kg m^{-2} to 3.815 kg m^{-2}, an improvement of 44 %, and the charged farmer treatment increased the yield of fresh marketable leaves to 3.156 kg m^{-2}, which represented an improvement of 19 %.

Total consumptive water use was highest in the full irrigation (FI) treatment (279 mm), which also produced the highest yield and lowest in the minimal irrigation treatment (MI) treatment (124 mm), which produced the lowest yield. Consumptive water use in the farmer treatment (FT) was 171 mm. Consumptive water use in the double frequency farmer treatment (DFFT) (239 mm) was higher than in the farmer treatment but tended to be lower than in the full irrigation treatment. Consumptive water use in the charged farmer treatment (CFT) (174 mm) was lower than in the full irrigation treatment but tended to be higher than in the farmer treatment.

When the availability of irrigation water is limited, as is common at Dzindi, the efficiency with which the crop uses water to produce economic yield (fresh marketable leaves) is of great importance. Although differences among the treatment means were not statistically significant, the results in Table 8.11 do illustrate certain trends. The highest water use efficiency was achieved in the minimal irrigation (MI) treatment, which produced 19.9 g of fresh marketable leaves mm^{-1} m^{-2}. However, considering that this treatment also produced very low yields its implementation by farmers is not recommended. The water use efficiency of the farmer treatment was relatively low (14.8 g of fresh marketable leaves mm^{-1} m^{-2}), and was very similar to the water use efficiency achieved in the full irrigation treatment (14.6 g of fresh marketable leaves mm^{-1} m^{-2}). The water use efficiency achieved in the charged farmer treatment was 18.6 g of fresh marketable leaves mm^{-1} m^{-2} and that in the double frequency farmer treatment 16.2 g of fresh marketable leaves mm^{-1} m^{-2}. Relative to the farmer treatment these two treatments, which can be implemented by farmers at Dzindi, appeared more efficient in water use.

In Figure 8.6 the effect of irrigation strategy on the economic yield performance (fresh mass of marketable leaves) is summarised for the two experiments. Since the absolute values of the yields obtained in the two experiments were substantially different due to the planting date, the yields of the different treatments were expressed as a proportion of the yield obtained in the full irrigation (FI) treatment in each case.

Figure 8.6 shows that in spite of the difference in planting date used in the two experiments, resulting in large differences in the yield of the crop, the effect of irrigation strategy on yield was similar in both cases. The results confirm the superior yield performance of the double frequency farmer treatments and to a lesser extent the charged farmer treatment when compared with the farmer treatment.



FI = full irrigation; MI = minimal irrigation; FT = farmer treatment; DFFT = double frequency farmer treatment; and CFT = charged farmer treatment

FIGURE 8.6: Effect of irrigation strategy on the relative yield performance of Chinese cabbage at Dzindi over two growing seasons

8.4.4 Preliminary conclusions

In this study four different irrigation strategies were compared with the existing irrigation practices of farmers at Dzindi in terms of yield, consumptive water use and water use efficiency. The full irrigation strategy produced the highest yield but at Dzindi farmers can only implement this strategy when they irrigate the crop twice a week at night in addition to the weekly day-light irrigation.

Two of the four alternatives to the farmer irrigation strategy that were tested in this study, namely the double frequency farmer treatment and the charged farmer treatments showed considerable promise for implementation by farmers at Dzindi, because they resulted in substantial increases in yield, whilst still being relatively easy to implement in the context of the water sharing arrangements that prevail at the scheme.

Relative to the farmer treatment, the double frequency farmer treatment, which consisted of applying 20 mm of water before planting followed by two applications of 20 mm each per week, increased economic yield by 30 to 40 % and also improved water use efficiency. Implementation of this strategy would require farmers to either irrigate the crop once per week during the night in addition to the weekly day-light irrigation, or negotiate additional access to water with other plot holders using the same supply furrow.

The charged farmer treatment, which consisted of charging the upper 800 mm of the soil profile to field capacity before planting, followed by the application of 20 mm irrigation water per week, increased economic yield by about 20 % relative to the farmer treatment but had two important advantages. Firstly this treatment is entirely congruent with the prevailing water sharing arrangements at Dzindi and does not require farmers to irrigate at night or negotiate access to additional water and secondly, it uses water very efficiently.

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9 IMPROVING GREEN MAIZE PRODUCTION AT DZINDI

9.1 Introduction

In the Thohoyandou area, green maize is one of the commodities that have the potential to increase income amongst local smallholder. However, for green maize to be marketable, it has to meet particular selection criteria, with ear length being most vital. A study was initiated to improve green maize production at Dzindi Irrigation Scheme.

Agronomic research on maize has largely been focused on maximising grain production. Grain yield per unit area is maximised when competition for resources reach the level at which plant barrenness is about to occur. At this level of competition maize produces relatively small cobs (Van Averbeke and Marais, 1994). Maximising the number of marketable green maize cobs per unit area is expected to be achieved at lower levels of intra-specific competition than in the case of grain production, because the market for green maize favours cobs that are long and large. Agronomic research aimed specifically at optimising green maize production is lacking. The proposed research project addresses this gap.

For any particular maize cultivar, cob size and the degree of ear filling depends on kernel set, which is dependent on the rate of dry matter production per plant (Edmeades and Daynard, 1979, Tollenaar, Dweyer and Stewart, 1992; Otegui *et al*., 1995). The rate of dry matter production of maize depends on environmental factors, including solar radiation, temperature, carbon dioxide concentration in the air and the availability of water and nutrients in the soil (Stoskopf, 1981). When other factors are not limiting, the assimilation rate per plant depends on the photo-synthetically active radiation (PAR), the temperature and the extent to which neighbouring plants compete with each other for light. Apart from a plant's morphological characteristics, the intercepted photo-synthetically active radiation per plant (IPARP) depends on the level competition among plants brought about by plant spacing and size variability among plants in a stand.

Several studies have shown that kernel number per ear (KNE) declines with increasing planting density due to a decline in IPARP because low IPARP causes spikelet and kernel abortion (Van Averbeke and Marais, 1994; Otegui and Bonhomme, 1998; Westgate *et al*., 1996; Andrade, Otegui and Vega, 2000).

Andrade, Otegui and Vega (2000) and Kiniry, Xie and Gerik (2001) developed models to simulate the relationship between IPARP, kernel set and KNE. According to Andrade, Uhart and Frugone (1993), Otegui and Bonhomme (1998) and Andrade, Otegui and Vega (2000), the critical period for kernel set in maize is about 30 days around silking, 15 days before and 15 days after. Sub-optimal assimilate supply during this period causes a reduction in KNE by disturbing fertilization and later by causing kernel abortion (Cirilo and Andrade, 1994b; Otegui and Bonhomme, 1998; Andrade; Otegui and Vega, 2000).

Planting date affects PAR and temperature, with late planting causing a decline in KNE due to reduced PAR and reduced temperature during the critical period of kernel set (Cirilo and Andrade, 1994a and 1994b; Otegui and Melón, 1997). Low radiation and temperature after silking reduce dry matter production, resulting in kernel abortion (Cirilo and Andrade (1994b).

Modern maize hybrids have been developed with a view of maximising grain yield under specific growing conditions. According to Aldrich *et al*. (1975), small-eared hybrids better tolerate suboptimal environmental conditions than large-eared cultivars. Breeding for ear prolificacy, which refers to the ability of maize to produce multiple cobs under favourable conditions, has been another way in which the tolerance of maize to environmental variability has been improved (Aldrich *et al*., 1975; Varga *et al*., 2004). However, when producing maize for harvest as green cobs, production of small ears and ear prolificacy are undesirable cultivar traits. As indicated earlier, the market for green maize does not favour small ears and ear prolificacy is disadvantageous because the number of kernels on the primary ear of prolific hybrids tends to be lower than that on the single ear of non-prolific hybrids (Varga *et al*., 2004). Cultivar selection is, therefore, an important factor in green maize production.

In conclusion, models have been developed to predict KNE for particular planting date-cultivar-locality-plant spacing combinations. For a specific cultivar, cob size or cob length is expected to be closely related to KNE. If this is indeed the case, it would be possible to model cob size or cob length. Knowledge of the minimum cob size or length required by the green maize market would then enable the prediction of the optimum planting density at which the number of marketable green maize cobs per unit area is expected to reach a maximum for specific planting date-cultivar-locality combinations. The model that enables prediction of optimum planting density would be a valuable decision support tool for green maize producers.

The study initiated at Dzindi sought to answer three questions, namely

(i) Which maize cultivars are suitable for green maize production, with specific reference to cob length?

(ii) What are the effects of plant spacing and planting date on IPARP, the relationship between IPARP and kernel set and the relationship between kernel number and cob length for selected single-eared maize cultivars?

(iii) To what extent can this information be used to simulate cob length in function of the cultivar planting date and plant spacing used?

Scientifically, the study was aimed at testing the application of existing knowledge in a domain where this knowledge has not been applied before. From a practical perspective the purpose of the study was to optimise production of green maize producers at Dzindi by developing a decision support tool. The hypotheses to be tested in this study were:

(i) In maize, cob length and KNE are closely related variables;

(ii) Cob length, KNE and the relationship between these two variables are attributes that are cultivar specific;

(iii) Planting date and planting density in maize interact to affect IPARP, KNE and cob length.

This project is being conducted by Mr TB Khosa for the purpose of obtaining the D Tech (Agric.) degree.

9.2 Methods

The study employed field plot experimentation to test the different hypotheses that were formulated. All field plot experiments were conducted at Dzindi Irrigation Scheme in the Vhembe District of Limpopo Province, on a deep, well drained, loamy Hutton type soil. Two different experiments were conducted, namely the planting date x planting density experiment and the cultivar experiment.

The planting date x planting density experiment was aimed at determining the interaction effects of planting date and planting density on IPARP, the relationship between IPARP and kernel set and the relationship between kernel number and cob length for a selection of single-eared maize cultivars. The results from this experiment will be used to test all three hypotheses. The experiment was planned to be planted in September, December, March and June to investigate planting date effects. It used a split plot design with four replications involving four planting densities (main plots), i.e. 13 000 (PD 1), 26 000 (PD 2), 52 000 (PD 3) and 80 000 (PD 4) plants ha-1, and two cultivars (splits), i.e. SC 701 and PAN 93. These cultivars were selected because they are amongst the most promising large- and single-eared, commercially available cultivars that are recommended specifically for green maize production (Barrow, 2005: personal communication). In the experiment, water and nutrient availability were kept at optimum levels to prevent these factors from limiting plant growth. For the same reasons the plots were kept free of weeds and a programme to prevent damage by diseases and pests was implemented.

The cultivar x planting density experiment also used a split plot design and involved two planting densities (main plots) and four cultivars including PAN 93, ETZ 200, SC 701 and SNK 2147 (splits). The cultivar SNK 2147 was included because that was the cultivar used by green maize producers at Dzindi at the start of the project. The cultivars PAN 93 and ETZ 200 were selected because they performed exceptionally well in an earlier cultivar trial that was conducted as part of this study. The cultivar SC 701 was selected because it is known to produce large cobs. The two planting densities (20 000 and 60 000 plants ha^{-1}) were selected to represent conditions of minimal competition resulting in maximum KNE, and high competition resulting in reduced KNE. The experiment was planted on the 29^{th} of August 2006. All the agronomic practices were identical to those applied in the planting date x planting density experiment.

Data collected in the plant spacing x planting date experiment included global solar radiation, photo-synthetically active radiation above and below the canopy, IPARP, minimum and maximum temperature, leaf area, cob length and number of kernels per ear (KNE). In each plot, 10 plants were randomly selected for the determination of leaf area using the method described by Van Averbeke (1991). When the maize plants reached the hard dough stage, 20 ears from each plot were harvested. The length of the ears was measured and the kernels on the ears were counted. Interception of PAR by the canopy was measured using a ceptometer (Model LP-80, Decagon devices, USA). In each plot one measurement above and five below the canopy in different positions within the stands were made once per week between 11h00 and 14h00 on clear days (Gallo and Daughtry, cited by Madonni and Otegui, 1996). Daily fraction interception between observation dates were estimated by linear interpolation between midday values and applied to corresponding daily values of PAR to estimate IPAR during the period of kernel set (30 days around silking). Global radiation recorded using an automated weather station erected about 500 m from the experimental plot was converted into PAR using the conversion factor of 0.45 determined by Monteith as cited by Madonni and Otegui (1996). IPAR per plant (IPARP) was estimated by dividing IPAR by the number of plants per unit area of measurement.

Data collected from the cultivar experiment included the number of marketable cobs per plot, the incidence of diseases, freshness of the ears two days after harvest, number of rows per ear, number of kernels per row and ear diameter. Ten plants per plot were randomly selected for these observations. Additional data sets that were collected in this experiment include date of silking (50% of sampled plants), incidence of diseases including Maize Streak Virus and stem rot, ear height, kernel shrink at soft dough stage, ear hang, husk cover. The incidence of diseases and the other attributes were evaluated qualitatively using a numerical scale of 1 to 9 as recommended by Barrow (2006).

Associations between IPARP, KNE and cob length were investigated using regression analysis. Data from the cultivar experiments will be analysed using analysis of variance.

9.3 Results and discussion

9.3.1 Planting date x planting density x cultivar experiment

This report documents the progress that had been made with this study at the time the project officially came to an end on the 31st of March 2007. As indicated the intention is to plant the critical planting date x planting density x cultivar experiment in four different months of the year, namely September, December, March and June. The first run of the experiment was planted in September 2005. The September planting was repeated during 2006 because of two reasons. First, SNK 2147 was replaced by SC 701 following its poor performance in a farmer cultivar trial. The replacement cultivar, SC 701, was identified after the 2005 experiment had been planted. This cultivar is the most widely used for commercial green maize production (Mcunu, 2006). For that reason its inclusion in the study from 2006 onwards was meaningful considering that the findings of the study are intended to be applicable in various parts of the country. The second reason for repeating the September planting was that there were weaknesses in the methods used during the 2005 experiment, calling for methodological refinements. In this chapter only the results obtained in September 2006 experiment are presented. Since the project then the December 2006, March 2007 and June 2007 have been planted but the results of these were not yet available for inclusion in this report.

Table 9.1 presents daily mean air temperature and incident solar irradiance for the entire season and for the critical period for maize kernel set (30 days around silking).

TABLE 9.1: Selected climatic data describing conditions at Dzindi during the period September to December 2006 and during the critical period of kernel set

Climatic variable	Season	30 days around silking
Mean daily minimum temperature (^oC)	18.05	18.45
Mean daily maximum temperature (^oC)	34.55	32.31
Mean daily mean temperature (^oC)	26.30	25.38
Mean daily solar radiation (MJ $m^{-2}day^{-1}$)	18.00	15.78
Mean daily PAR (MJ $m^{-2}day^{-1}$)	8.10	7.10

Figure 9.1 shows the average proportion of PAR that was intercepted by the four planting densities x two cultivars during the 30-day period around silking.

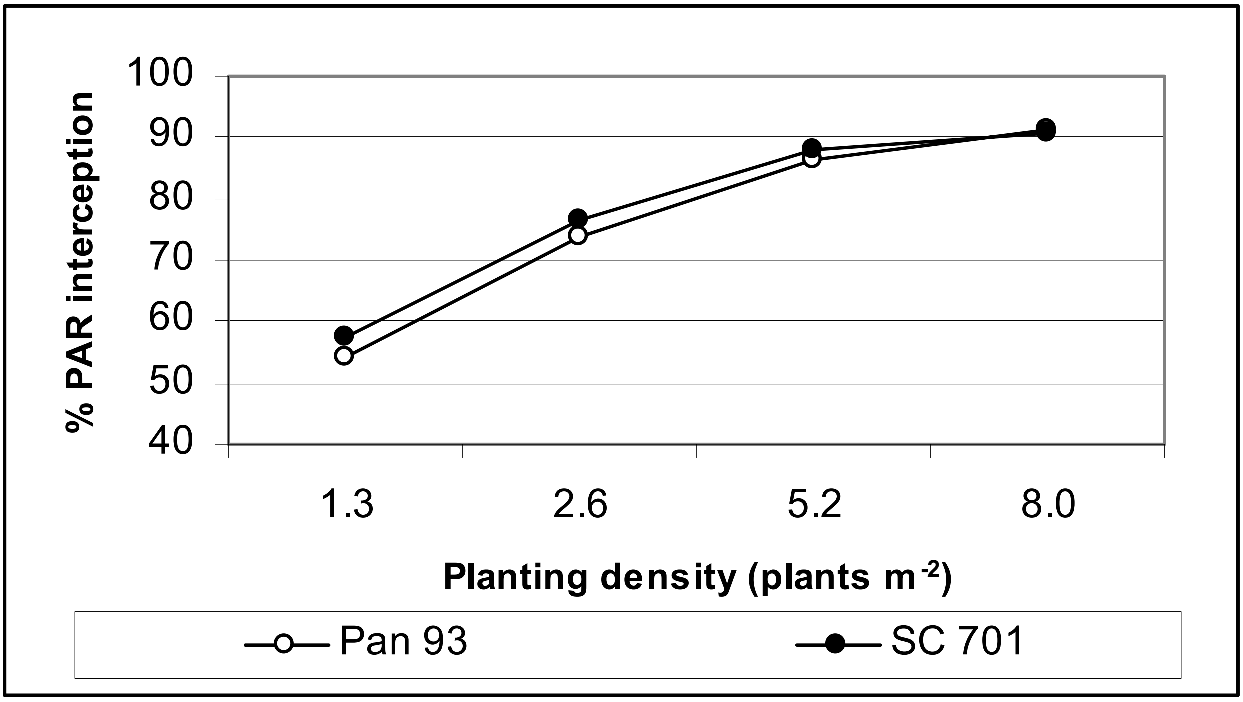

FIGURE 9.1: Mean proportion of photo-synthetically active radiation intercepted by maize at silking in the different treatments of a planting density x cultivar experiment at Dzindi

The proportion of PAR that was intercepted by each of the treatments was calculated using equation 1 proposed by Cirilo and Andrade (1994).

IPAR (%) = as $(1-I_t / I_o) \times 100\%$ ***equation 1***

With IPAR % = proportion of incident PAR intercepted by the canopy
I_t = incident PAR below the canopy
I_o = incident PAR above the canopy

Generally, at silking SC 701 intercepted slightly more PAR than PAN 93 (Figure 9.1). Interception of PAR increased with increasing planting densities from as low 55% and 58% in the lowest planting density (1.3 plants m^{-2}) to about 92% in the highest planting density of 8 plants m^{-2}.

Table 9.2 presents the amounts of PAR intercepted in the four planting density treatments at silking.

TABLE 9.2: Effect of planting density and cultivar on mean intercepted photosynthetically active radiation per plant (IPARP) during the 30 day period around silking in the experiment with maize planted in September 2006 at Dzindi

Density (plants m^{-2})	Total IPAR (±30days around silking) (MJ m^{-2})	Daily average IPAR (MJ m^{-2})	Daily average IPARP (MJ $plant^{-1}$)
		PAN 93	
1.3	111.85	3.73	2.28
2.6	157.52	5.25	2.02
5.2	181.30	6.04	1.16
8.0	190.05	6.33	0.79
		SC 701	
1.3	121.94	4.06	3.13
2.6	164.64	5.49	2.11
5.2	189.09	6.30	1.21
8.0	191.71	6.39	0.80

The interception of PAR per unit area increased with increasing planting density in both cultivars (Table 9.2) but IPARP declined as planting density was increased. The two cultivars differed notably in terms of PAR interception. SC 701 intercepted more PAR than PAN 93.

Table 9.3 presents summary statistics of ear length, number of kernels per row and per cob recorded in the different treatments. Ear length was measured during the hard dough stage, which is the stage at which maize is harvested for green cobs in the study area.

TABLE 9.3: Mean cob length, kernels per row and kernels per ear obtained from the two cultivars

Planting Density (plants m^{-2})	PAN 93			SC 701		
	Cob length (cm)	No. of kernels row^{-1}	No. of kernels cob^{-1}	Cob length (cm)	No. of kernels row^{-1}	No. of kernels cob^{-1}
1.3	32.40	48	595	35.86	52	666
2.6	32.34	47	590	34.52	49	643
5.2	28.11	43	513	28.00	39	489
8.0	22.89	34	399	22.21	31	378

Table 9.3 shows that mean ear length, kernel number per row and per ear declined with increasing planting density for both cultivars. The decline in these three variables resulted from an increase in intra-specific competition. The rate of decline was considerable when planting density was raised from 2.6 plants m^{-2} to 5.2 plants m^{-2}. The observed decline in ear length brought about by an increase in crowding is explained by the reduction in IPARP associated with an increase in mutual shading of the maize plants (see Table 9.2). The considerable decline in the three variables observed when planting density was increased from 2.6 plants m^{-2} to 5.2 plants m^{-2} coincided with a reduction of the IPARP to below 2.02 MJ $plant^{-1}$ day^{-1} for PAN 93 and below 2.11 MJ $plant^{-1}$ day^{-1} for SC 701 (Table 9.2). In the experiments of Kiniry, Xie and Gerik (2001) and Andrade, Otegui, Vega (2000), in which IPARP varied between 0.3 and 3.5 MJ day^{-1}, an IPARP of about 1.8 MJ day^{-1} was required for maize plants to produce maximum kernel number. In their experiments the very low IPARP values were obtained by using shade nets. Table 9.3 also shows that cob length, kernel number per row and kernel number per ear obtained at the planting densities of 1.3 and 2.6 plants m^{-2} were higher for SC 701 than for PAN 93. When planting density was increased to 5.2 and 8.0 plants m^{-2} the opposite trend was observed. These results indicate that SC 701 is more sensitive than PAN 93 to low levels of PAR brought about by planting densely.

Hawkers play an important role in sales of green maize in the study area. They select cobs suitable for sales to consumers, with cob size being the key criterion used for selection. Considering their importance, five hawkers working in the study area were asked to select cobs they considered suitable for marketing. The hawkers categorised the green maize cobs in three distinctive grades, namely easy to sell (grade 1), difficult to sell (grade 2), and not suitable for sale (grade 3). Each of the five hawkers harvested 10cobs they considered representative of the three categories or grades. After harvesting, they removed the husk in preparation for boiling in the same manner they handled cobs for the market. They broke the stem of the cob in a way that a few nodes (one to three) were left and during this process the husks attached to the part of the stem that was broken off were removed. Part of the stem of the cob was left deliberately to make the cobs appear to be long. Figure 9.2 shows a cob ready for boiling, with the unwanted parts removed.

FIGURE 9.2: A green maize cob ready for boiling

The cobs that were categorised in the different grades were then measured using a tape measure. A summary of the results is presented in Table 9.4.

TABLE 9.4: Length of cobs in the three grades of cobs identified by green maize hawkers at Dzindi

Statistic	**Grade 1**	**Grade 2**	**Grade 3**
Description	Easy to sell	Difficult to sell	Not suitable
Producer price	R1.20	R1.00	-
Mean cob length (cm)	34	29	25
Median (cm)	35	29	25
Range (cm)	29-41	21-35	18-34
95.0% confidence interval (cm)	33-36	29-30	23-26

On average, first grade cobs were 34 cm long and fetched a producer price of R1.20 each. Second grade cobs in were on average 29 cm long and were bought from farmers for R1.00 each. Third grade cobs were 25 cm long on average and hawkers explained that such cobs could not be sold as green maize in Thohoyandou, because customers wanted long cobs. One of the reasons for customer resistance against short cobs is the practice of hawkers to fix the price of boiled cobs. In other words on the market in Thohoyandou a boiled cob of maize costs the same, irrespective of who one buys from. As a result, consumers buy from the hawkers who offer the longest cobs. To apply the findings of the grading of cobs by hawkers to the results of the experiment, cob length intervals were constructed as shown in Table 9.5.

TABLE 9.5: Cob length intervals used to grade cobs produced in the critical planting date x planting density x cultivar experiment planted in September 2006 at Dzindi

Grade of maize cobs	**Length of maize cobs** (cm)	**Producer price**
1	>31	R1.20
2	27 to 30	R1.00
3	<26	-

Table 9.6 shows the analysis of the length of the cobs produced in the experimental plots of the September 2006 planting date x planting density x cultivar experiment. The results are presented using 1000 m^2 as unit area, because this is more or less representative of the size of an irrigation strip at Dzindi.

TABLE 9.6: Effect of planting density and cultivar on the grade of cobs produced in an experiment with maize planted in September at Dzindi

Cob length (cm)	Number of cobs produced per 1000 m^2 in the different grades							
	1.3 plants m^{-2}		2.6 plants m^{-2}		5.2 plants m^{-2}		8 plants m^{-2}	
	PAN 93							
	% of total	No of cobs	% of total	No of cobs	% of total	No of cobs	% of total	No of cobs
Barren	0	0	0	0	5	650	13	1 000
< 31	3	35	3	65	20	3 640	70	5 600
27 – 30	19	243	20	520	46	520	10	800
>26	79	1 023	78	2 015	29	390	8	600
Total	**100**	**1 300**	**100**	**2 600**	**100**	**5 200**	**100**	**8 000**
	SC 701							
Barren	0	0	0	0	4	195	16	1 300
< 31	1	17	3	67	30	1 560	70	5 600
27 – 30	1	17	4	100	45	2 340	13	1 000
>26	97	1 267	94	2 433	21	1 105	1	100
Total	**100**	**1 300**	**100**	**2 600**	**100**	**5 200**	**100**	**8 000**

Table 9.6 shows that the proportion of green cobs rated as grade 1 declined as planting density was increased. The number of first grade cobs declined sharply when planting density was increased from 2.6 plants m^{-2} to 5.2 plants m^{-2}. SC 701 produced more first grade cobs than PAN 93 at planting densities of 1.3, 2.6 and 5.2 plants m^{-2}. PAN 93 produced more first grade cobs at the planting density of 8.0 plants m^{-2}, suggesting that PAN 93 tolerates intra-specific competition better than SC 701 as was also observed from the results presented in Table 9.2.

The number of first grade cobs per unit area, which is the important indicator for farmers, increased when planting density was increased from 1.3 plants m^{-2} to 2.6 plants m^{-2} and declined sharply when the planting density was raised to 5.2 plants m^{-2}, suggesting that the optimum planting density for the cultivars and planting date concerned was located between these two levels of competition. Table 9.6 also shows that when planting density was increased to 5.2 plants m^{-2} and higher, plant barrenness started to occur. This confirmed that increasing intra-specific competition for IPAR ultimately starts to affect kernel set.

The relationship between KNE and cob length was analyzed using linear regression for the two cultivars (Figures 9.3 and 9.4).

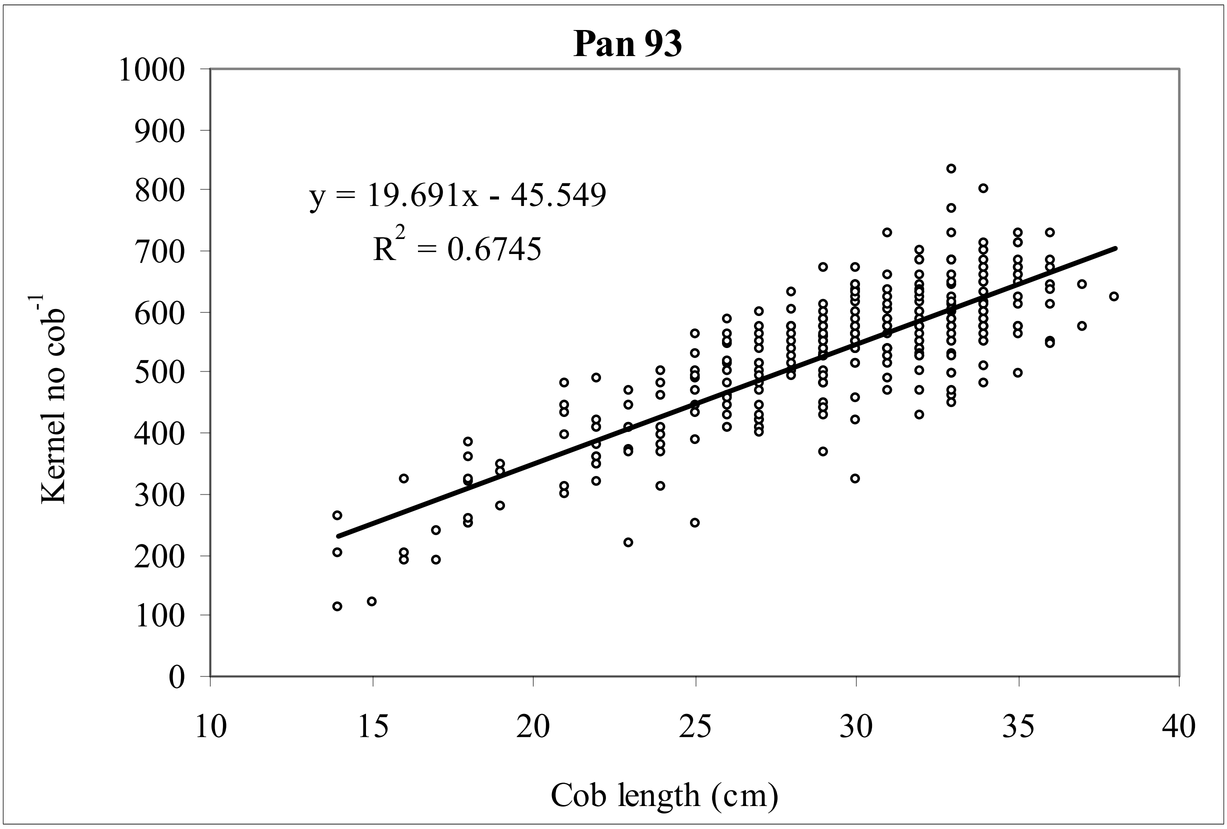

FIGURE 9.3: Relationship between KNE and cob length for the PAN 93 maize cultivar planted at Dzindi in September 2006

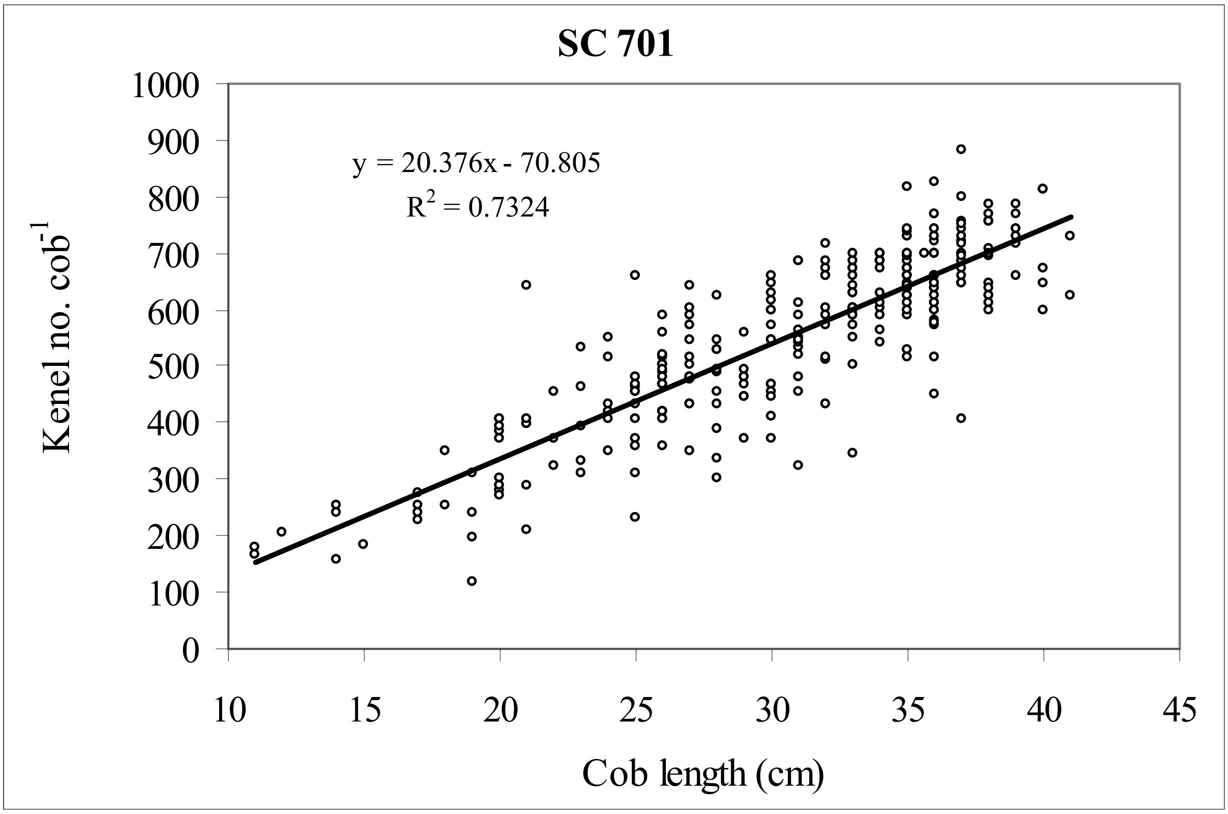

FIGURE 9.4: Relationship between KNE and cob length for the SC 701 maize cultivar planted at Dzindi in September 2006

The regression analyses presented in Figures 9.3 and 9.4 show that there was a linear relationship between cob length and KNE for the two cultivars that were tested. This relationship explained 67% of the variability of the two variables in the case of PAN 93 and 73% in the case of SC 701, indicating that KNE can be used to predict cob length, linking the current study to the existing theory that was reviewed in the introduction to this chapter.

Using the regression equations presented in Figures 9.3 and 9.4, the KNE of the minimum length of a first grade cob was determined. Two cob lengths were used, namely 31 cm and 34 cm. The cob length of 31 cm was 1 cm longer than the upper limit of the 95% interval of the lengths of second grade 2 cobs (Table 9.4). The cob length of 34 cm was the mean cob length of first grade cobs (Table 9.4). Using the cob length of 31 cm, the estimated KNE was 565 for PAN 93 and 561 for SC 701 and using the cob length of 34 cm the estimated KNE was 624 for PAN 93 and 622 for SC 701.

In Figures 9.5 and 9.6 a quadratic regression function was fitted to mean KNE and IPARP during the 30-day period around silking for the two maize cultivars that were employed.

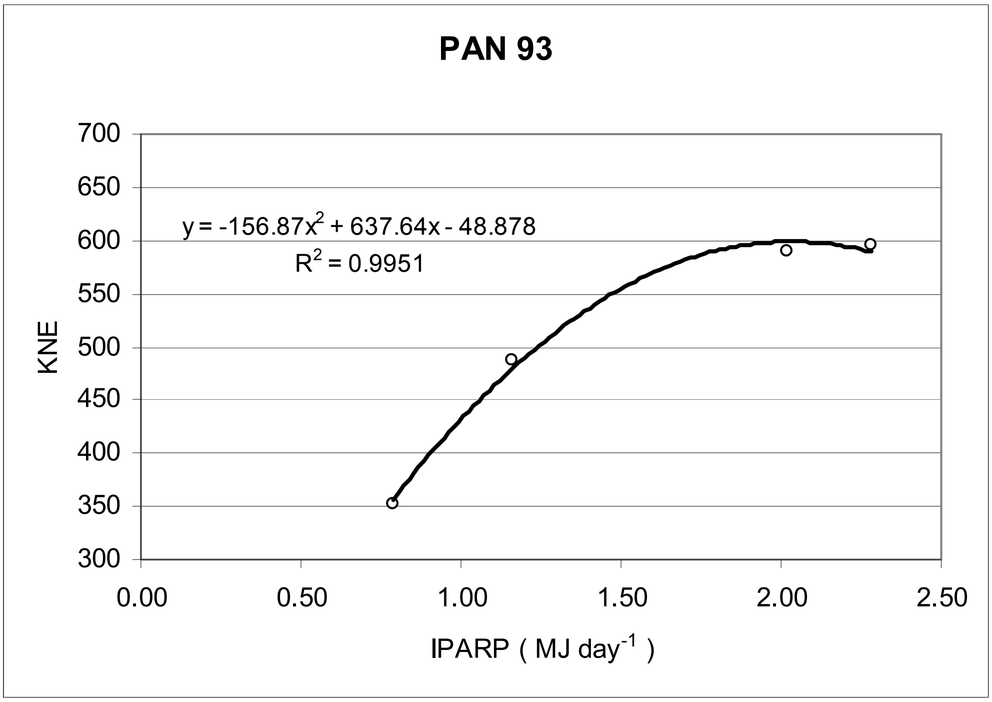

FIGURE 9.5: Relationship between mean IPARP during the 30-day period around silking and KNE for the PAN 93 maize cultivar planted at Dzindi in September 2006

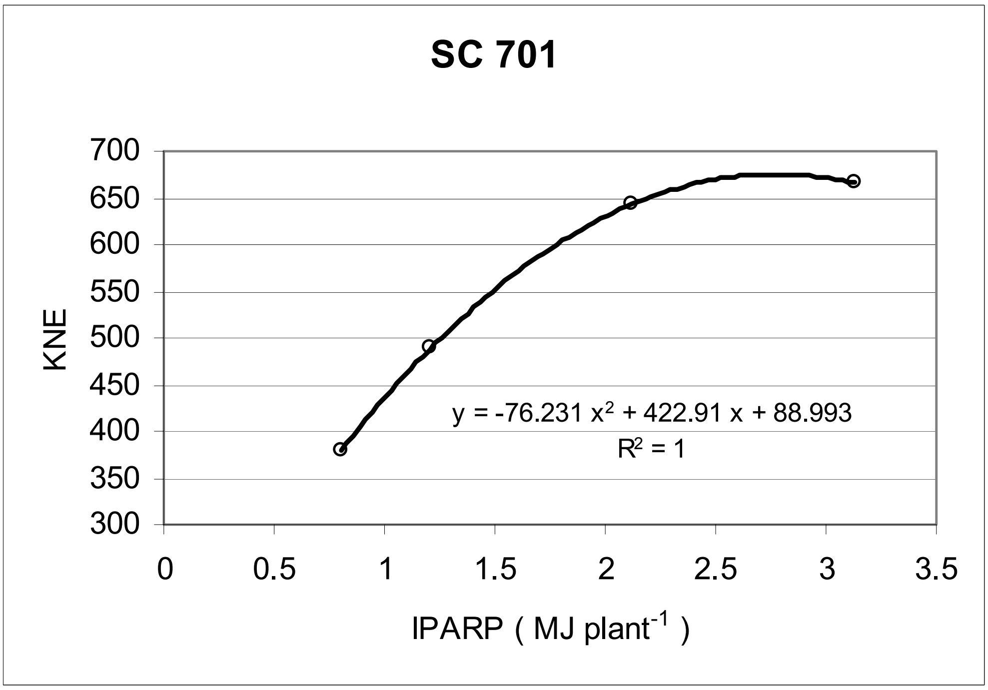

FIGURE 9.6: Relationship between mean IPARP during the 30-day period around silking and KNE for the SC 701 maize cultivar planted at Dzindi in September 2006

The regression analyses presented in Figures 9.5 and 9.6 indicated that the minimum IPARP required for the production of a cob with a length of 31 cm, which corresponded with the KNE of 565 for PAN 93 and 561 for SC 701, was 1.58 MJ plant^{-1} day^{-1} for PAN 93 and 1.55 MJ plant^{-1} day^{-1} for SC 701. In the case of SC 701 (Figure 9.6), the IPARP needed to be increased to 1.94 MJ plant^{-1} day^{-1} to produce cobs with an average length of 34 cm (KNE of 622). The regression equation presented in Figure 9.5 predicted that it was not possible to produce cobs with an average length of 34 cm (KNE of 624) when using the PAN 93 cultivar. The equation indicated that KNE of PAN 93 reached the maximum value of 599 at the IPARP of 2.05 MJ plant^{-1} day^{-1}, which was predicted to result in an average cob length of 32.7 cm, 0.3 cm less than the lower limit of the 95% interval of the lengths of first grade 2 cobs (Table 9.4)

In Figures 9.7 and 9.8 the relationship between planting density and IPARP was analysed using a logarithmic regression function.

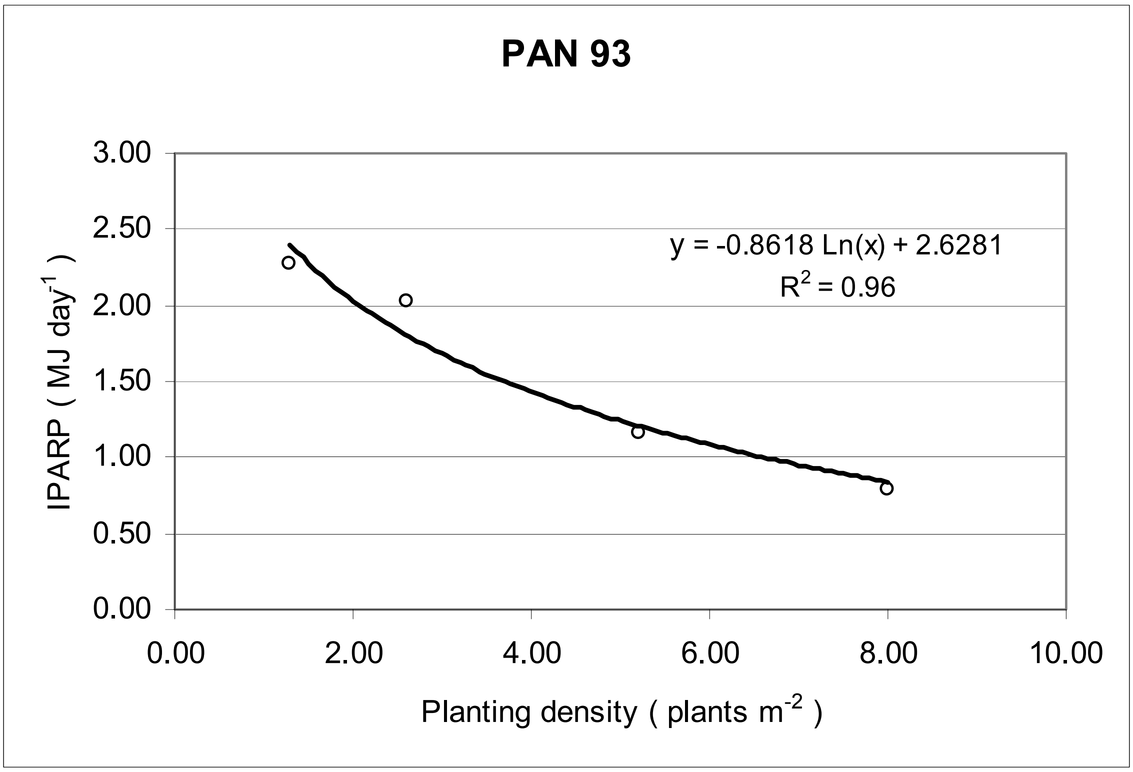

FIGURE 9.7: Relationship between planting density and IPARP during the 30-day period around silking for the PAN 93 maize cultivar planted at Dzindi in September 2006

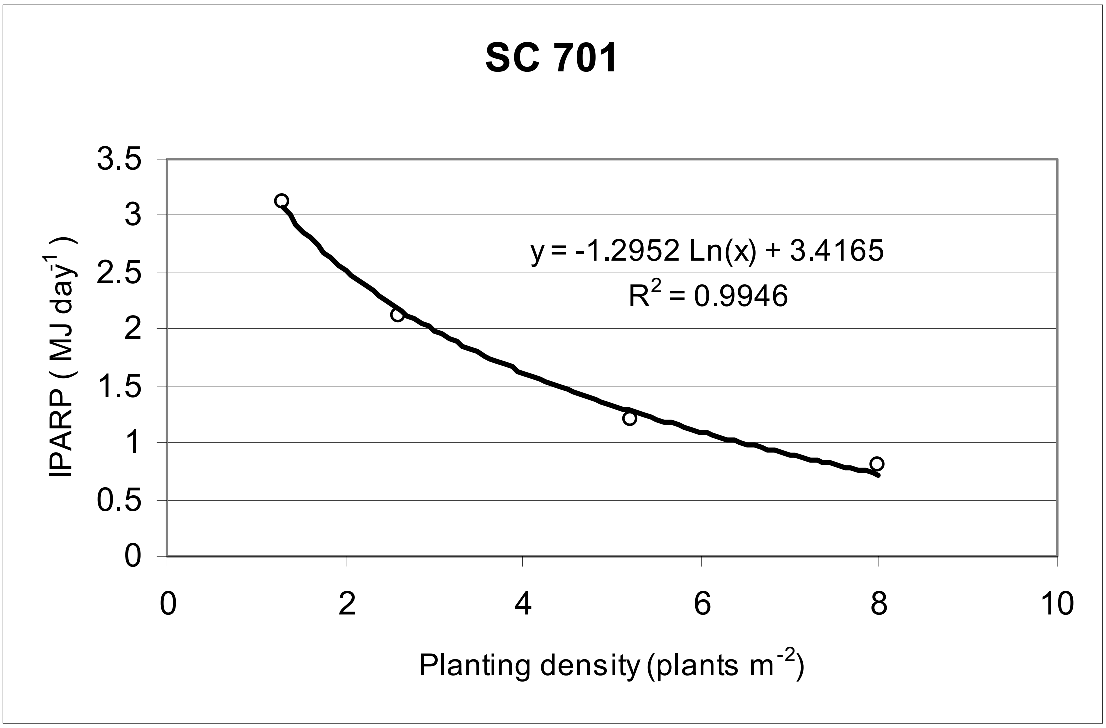

FIGURE 9.8: Relationship between planting density and IPARP during the 30-day period around silking for the SC 701 maize cultivar planted at Dzindi in September 2006

The regression equations presented in Figures 9.7 and 9.8 enabled the estimation of the planting density for green maize production at which specified average cob lengths would be obtained at the specific light regime that prevailed during the experiment. In the case of PAN 93 (Figure 9.7), the planting density that was predicted to produce the average cob length of 31 cm (KNE of 565 and IPARP of 1.58 MJ plant^{-1} day^{-1}) was 3.37 plants m^{-2}. To maximise average cob length of PAN 93 (KNE of 599 and IPARP of 2.05 MJ plant^{-1} day^{-1}), the planting density had to be reduced to 1.95 plants m^{-2} (Figure 9.7). In the case of SC 701 (Figure 9.8), the regression equation predicted that the crop needed to be planted at the planting density of 4.22 plants m^{-2} to produce cobs with an average length of 31 cm and at the planting density of 3.12 plants m^{-2} to produce cobs with an average length of 34 cm (KNE of 622 and IPARP of 1.94 MJ plant^{-1} day^{-1}).

In summary, the results of this experiment demonstrated close relationships between planting density, IPARP, KNE and cob length. These relationships enabled the prediction of the planting density that would produce cobs with a specified average length for the two maize cultivars that featured in the experiment.

For September plantings at Dzindi the optimum planting density for green maize production ranged between 1.95 plants m^{-2} and 3.37 plants m^{-2} in the case of PAN 93 and 3.12 and 4.22 plants m^{-2} in the case of SC 701, depending on the average length of the cobs that was specified. Considering that income from green maize production is largely the linear function of the number of cobs per unit area that meet particular length requirements, the results of this experiment emphasise the importance of cultivar selection. The results showed that in terms of producing cobs that met specific minimum length requirements, the cultivar SC 701 was superior to PAN 93, because SC 701 could be planted at considerably higher planting densities than PAN 93 to produce cobs with specified minimum lengths.

Depending on the minimum length requirement that was specified, the average IPARP during the 30-day period around silking ranged between 1.55 and 2.05 MJ plant^{-1} day^{-1}. Planting maize at Dzindi during September and October is expected to result in optimum light conditions during the 30-day period around silking. Bringing forward or delaying the planting date is expected to result in less light being available to the crop during this critical period. By planting this experiment in December, March and June the effects of planting date on IPARP, KNE and cob length will be determined.

In the planting date x planting density x cultivar experiment, practices were aimed at optimising water and nutrient availability to ensure that availability of light was the only factor limiting crop growth and yield. When nutrient and/or water availability are also limiting factors, as is probably the case in many of the Dzindi green maize enterprises, planting densities would have to be reduced further to ensure that cobs are produced that meet the minimum length requirements. More importantly for farmers would be the optimisation of production practices, but particularly in relation to water availability, the prevailing institutions make it difficult to achieve this goal.

9.3.2 Cultivar x planting density experiment

The effects of cultivar and planting density on mean cob length, kernel number row^{-1} and KNE of the four cultivars planted at Dzindi in August 2006 are shown in Table 9.7.

TABLE 9.7: Effect of cultivar and planting density on mean cob length, kernel number row^{-1} and KNE of the four cultivars planted at Dzindi in August 2006

Cultivar	**20000 plants m^{-2}**			**60000 plants m^{-2}**		
	Cob length (cm)	**Kernel no. row^{-1}**	**KNE**	**Cob length (cm)**	**Kernel no. row^{-1}**	**KNE**
PAN 93	31.76	45.10	545	26.33	37.99	452
ETZ 200	32.92	50.89	707	26.27	37.50	516
SC 701	33.34	50.81	700	25.89	36.15	475
SNK 2147	29.66	46.78	642	25.37	36.70	484

At the planting density of 20 000 plants ha^{-1} SC 701 produced the longest cobs (mean of 33 cm). ETZ 200 produced the second longest cob followed by PAN

93. At this planting density only the mean cob length of SNK 2147 was less than 31 cm, which is the minimum length for first grade cobs in the study area. (see Table 9.5). At the planting density of 20 000 plants ha^{-1} the ears of ETZ 200 had the highest number of kernels, followed by SC 701, SNK 2147 and PAN 93. When the planting density was increased from 20 000 to 60 000 plants ha^{-1}, there was a sharp decline in cob length and KNE. At this high planting density SC 701 produced shorter cobs than ETZ 200 and PAN 93 and also the lowest KNR. This confirms that SC 701 is sensitive to low levels of PAR caused by intra-specific competition.

Table 9.8 shows the categorisation of the maize cobs that were harvested using the grading system explained in Table 9.5.

TABLE 9.8: Effect of planting density and cultivar on the grade of cobs produced in an experiment with maize planted in September at Dzindi in August 2006

Grade	Cob length (cm)	Number of cobs produced per 1000 m^2 in the different grades			
		PAN 93	ETZ 200	SC 701	SNK 2147
		2 plants m^{-2}			
1	> 31	1 414	1 549	1 742	879
2	27 – 30	552	423	226	909
3	< 26	34	28	32	212
	Total	**2 000**	**2 000**	**2 000**	**2 000**
		6 plants m^{-2}			
1	> 31	553	649	405	179
2	27 – 30	2 684	2 189	2 351	1 522
3	< 26	2 763	3 162	3 243	4 299
	Total	**6 000**	**6 000**	**6 000**	**6 000**

Table 9.8 shows that SC 701 produced the highest number of first grade cobs per unit area (longer than 31 cm) at the low planting density, followed by ETZ 200, PAN 9 and SNK 2147. When planting density was increased to 6 plants m^{-2}, ETZ 200 produced the high number of first grade cobs per unit area, followed by PAN 93, SC 701 and SNK 2147. These results confirm that SC 701 is sensitive to low levels of PAR. Compared to the other three cultivars SNK 2147 performed poorly. The study group of green maize producers at Dzindi who participated in the assessment of the experiment came to the same conclusion and requested access to alternative cultivars.

Apart from cob length, other aspects that are important in green maize production and marketing were considered as recommended by Barrow (2006).

These include kernel shrink at green harvesting stage, ear hang, husk cover and ear circumference.

To assess kernel shrinkage after harvest, a random sample of 40 cobs of each cultivar (10 each from each of the four low density plots) was kept for two days in a room without removing the husks for two days the husks where after the husks were removed and the kernels were assessed for shrinkage using a scale from 1 to 9, depending on the state of shrinkage. Table 9.9 shows the results of this assessment.

TABLE 9.9: Effect of cultivar on kernel shrinkage in green maize cobs following their removal from the plants

Kernel Shrinkage	**PAN 93**		**ETZ 200**		**SC 701**		**SNK 2147**	
	Number	**(%)**	**Number**	**(%)**	**Number**	**(%)**	**Number**	**(%)**
None	0	0	11	28	23	58	0	0
Slight	5	13	19	48	13	33	1	3
Moderate	16	40	10	25	4	10	24	60
High	19	48	0	0	0	0	15	38
Total	40	100	40	100	40	100	40	100

The extent of kernel shrinkage amongst the four cultivars appeared to be related to the structure of the husk, which was cultivar specific. When the husk cover was assessed in a score of 1 (excellent) to 9 (very poor), SC 701 and ETZ 200 were rated 2 whilst the husks of PAN 93 and SNK 2147 were rated 6. In the field the cobs of PAN 93 and SNK 2147 showed a higher degree of bird damage to the tips. This is important because cobs with damaged tips are rejected by hawkers. The relatively high degree of resistance against kernel shrinkage following harvest observed in the cobs of SC 701 and ETZ 200 is important in green maize production because cobs of these cultivars remain ‘fresh’ for longer, allowing for transportation to areas that are far from the farms.

The effects of cultivar and planting density on the circumference of cobs obtained at a planting density of 2 plants m^{-2} is shown in Table 9.10.

TABLE 9.10: Effects of cultivar on cob circumference obtained at a planting density of 2 plants m^{-2} in an experiment with maize planted at Dzindi in August 2006

Statistic	PAN 93	ETZ 200	SC 701	SNK 2147
Mean (cm)	19.95	20.22	20.30	18.70
Median (cm)	20.00	20.00	20.00	18.50
Mode (cm)	20.00	20.00	21.00	18.00
Range (cm)	17.00-22.00	18.00-23.00	18.00-23.00	17.00-21.00

Table 9.10 shows that there was little difference in the circumference of the cobs harvested from PAN 93, ETZ 200 and SC 701. Cobs produced by SNK 2147 had the smallest circumference. The mean number of rows per cob is shown in Table 9.11.

TABLE 9.11: Effect of cultivar on the mean number of rows per ear of maize planted at Dzindi in August at a density of 2 plants m^{-2}

Cultivar	Mean number rows ear^{-1}
PAN 93	12
ETZ 200	14
SC 701	14
SNK 2147	14

Table 9.11 shows that ETZ 200, SC 701 and SNK 2147 had similar numbers of rows per cob, whilst PAN 93 had less. The ear height from the soil surface was measured using a tape measure. Ear height has been linked to the likelihood of diseases reaching the cob (Barrow, 2006). Cobs positioned close to the soil surface are more likely to be infected by diseases that those that located high on the stem.

Figure 9.9 shows that the ears of SC 701 were located the highest (mean of 150 cm above the soil surface) followed by the ears of PAN 93 and ETZ 200 (mean of 130 cm above the soil surface) and those of SNK 2147 were closest to the ground (mean of 110 cm above the soil surface).

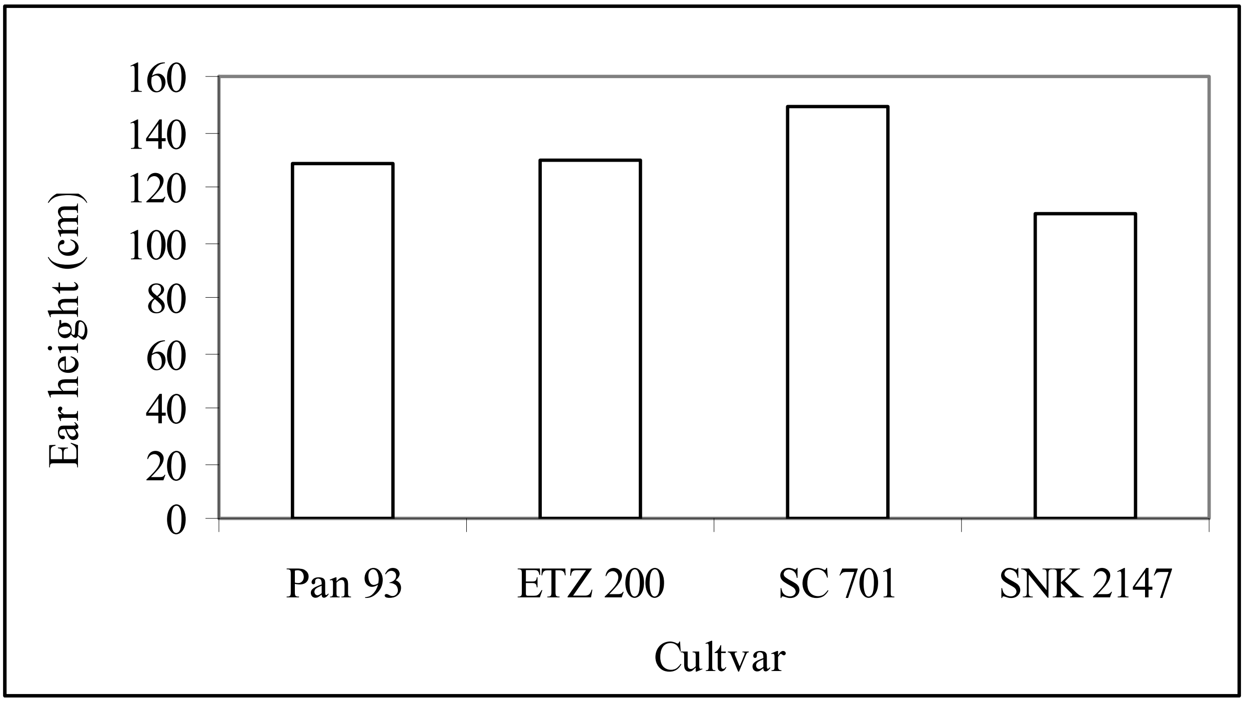

FIGURE 9.9: Effect of cultivar on ear height of maize planted at Dzindi in August at a density of 2 plants m^{-2}

Ear hang was assessed during the soft dough stage (Figure 9.10). Ear hang is also contributes to the incidence of cob diseases, particularly at maturity (Barrow, 2006). Figure 9.10 shows that the incidence of ear hang at the soft dough stage was relatively low. The proportion of ears that had dropped was highest in SNK 2147 and ETZ 200 and PAN 93 was had the lowest proportion of ears that had dropped.

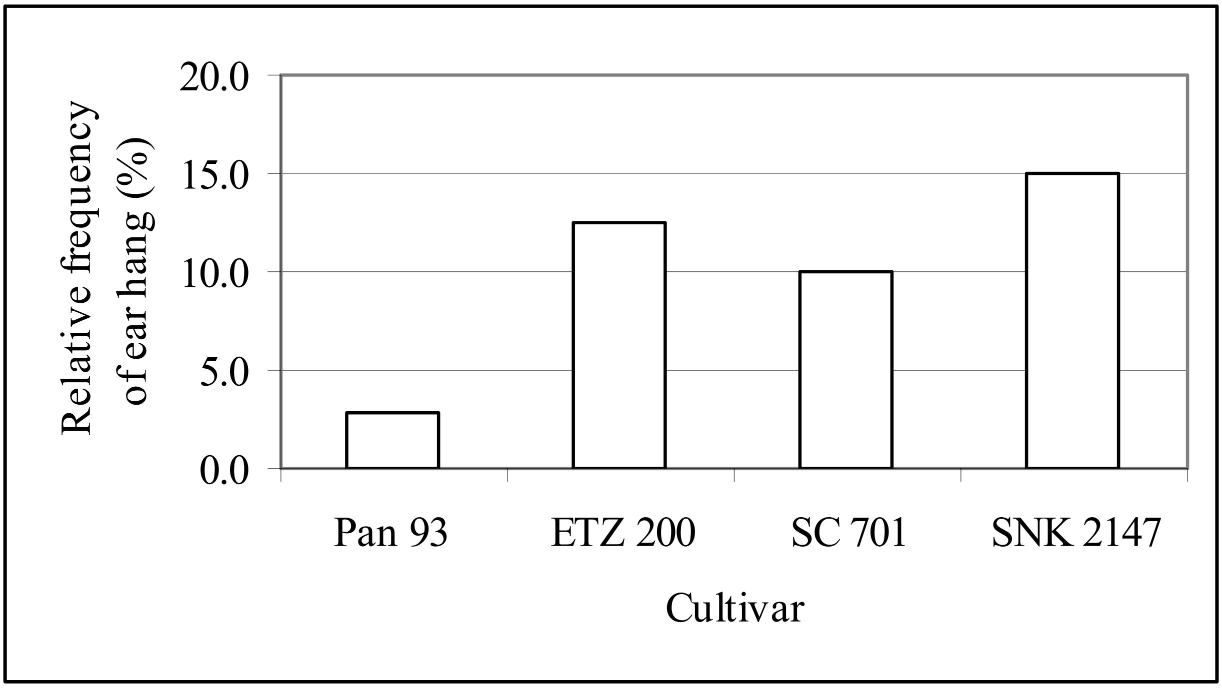

FIGURE 9.10: Effect of cultivar on ear hang of maize planted at Dzindi in August at a density of 2 plants m^{-2}

9.3.3 On-farm cultivar experiment

A second cultivar experiment was conducted in the plot of one of the members of the green maize production group. In this experiment five additional cultivars were included. The nine cultivars planted were PAN 93, SC 701, ETZ 200, SNK 2147, PAN 8m–95, ETC 791, ETD 646, ETD 634, and ETD 538. The aim of this experiment was to assess the performance of the different cultivars under local farmer management. The plot holder who was nominated by group members to conduct the experiment made all the agronomic decisions. Researchers only assisted during the planting of the experiment. Data that were collected by the researchers were limited to recording the agronomic practices used by the farmer and the counting of the number of marketable cobs in each plot. The emphasis was on the perceptions of the members of the group. The experiment used a complete randomized pattern with four replications. The planting density of 30 000 plants ha^{-1} was used throughout and the experiment was planted on the 23rd of August 2006. In preparation for planting, three tillage operations were carried out. The first consisted of working in the sod of the previous crop using a disk plough. That was followed by breaking up of the large clods and levelling the soil using a disc harrow. Finally, furrows were constructed using a ridger. The furrows were closed at intervals of 6 meters in line with the practice of short furrow irrigation (Van der Stoep and Thai, 2005). At each planting station two seeds were pressed into the wet soil. Wooden markers were used to ensure constant distance between plants in the row. The farmer thinned the plants to one per hill at when they had reached the sixth leaf stage. The experiment was irrigated only once per week in accordance with the irrigation timetable that governs water sharing at the scheme. Weeds were controlled three times during the growing season by hand hoeing. The first weeding occurred immediately after thinning, the second when the plants had reached knee height and the last just before tasselling. The farmer the fertiliser mixture 2:3:2 (22) at planting and urea when the plants had reached knee height. The fertilisers were band placed. Combined these applications resulted in the addition of nitrogen at the rate of 45 kg N ha^{-1}, phosphorus at the rate of 14 kg P ha^{-1} and potassium at the rate of 10 kg K ha^{-1}. All of these rates were very low. The farmer controlled pest by applying dipterex, which contains carbaryl as the active ingredient, at the sixth leaf stage and once more when the plants had reached knee height. When the plants had reached the stage where the cobs were ready to be harvested as green maize, the members of the green maize interest group were invited to come and assess the results (see Figure 9.11).

FIGURE 9.11: Farmers evaluating cultivars at the farmer managed cultivar trial that was planted in August 2006 at Dzindi

Eight of the twenty members attended the event. All were from Block 4 where the experiment was conducted. During the assessment, the researcher again explained the layout of the experiment and the farmer responsible for the experiment described the agronomic practices he had used in the production of the crop. After these presentations farmers were asked which aspects they considered important when producing green maize. They identified cob length and husk cover as the two critical aspects and these were subsequently assessed. During the assessment farmers moved around the experiment in the company of researchers. For each plot farmers were requested to rate the performance of the maize cultivar using a scale from one to four (1 = excellent, 2 = good, 3 =, poor 4 = and unacceptable. The results of this assessment are summarized in Table 9.12.

TABLE 9.12: Rating of maize cultivars by Dzindi farmers

Rating	Cultivars
Excellent	SC 701 and ETZ 200
Good	PAN 8m-95, ETD 538, ETD 646, ETD 634,
Poor	ETC 791
Unacceptable	SNK 2147 and PAN 93

Farmers at Dzindi were impressed with ETZ 200 and SC 701 because these cultivars produced the largest cobs. The cobs of PAN 8m-95, ETD 538, ETD 646, and ETD 634 were small compared to those of SC 701 and ETZ 200 but still of marketable size. ETC 791, SNK 2147 and PAN 93 received the lowest rankings. PAN 93 produced relatively long cobs but its problem was that the husks opened at the tip, leaving kernels exposed, which resulted in the kernels at the tip of the cobs being damaged by birds. SNK 2147 produced cobs which mostly did not meet the minimum length for marketing purposes and also had the problem of open husks. ETC 791 produced cobs that were too short.

Following the farmer assessment, the marketability of the cobs produced by the different cultivars was also assessed by local green maize hawkers. The hawkers were requested to harvest all the green maize they were interested in purchasing from each of the trial plots. For each plot the number of cobs that were harvested was counted (Table 9.13).

At the planting density that was employed (30 000 plants ha^{-1}), the proportion of the cobs that were considered marketable was well below the proportion observed in the researcher-managed experiment, probably because the practices that were applied by the farmer (irrigation scheduling and rate of nutrient supply) were not optimum. The results of the assessment by hawkers (Table 9.13) were somewhat different from those obtained in the assessment by farmers (Table 9.12). ETD 634 and ETD 646 had the highest proportion of cobs selected by hawkers, SC 701 only came third and ETZ 200 fourth. PAN 8m-95 had the third lowest proportion of cobs harvested whereas it was considered among the better cultivars by farmers. A large proportion of the cobs produced by SNK 2147 and PAN 93 were rejected because they were damaged by birds.

TABLE 9.13: Effect of cultivar on the mean proportion of cobs that were considered marketable by hawkers

Cultivar	Proportion of the total number of cobs that were considered marketable by hawkers (%)
ETD 634	48
ETD 646	41
SC 701	40
ETZ 200	38
ETC 791	38
ETD 538	24
PAN 8M-95	23
PAN 93	23
SNK 2147	10

9.4 Conclusions

The results of this study demonstrated that opportunities exist to improve green maize production in the study area. The relationship between planting density, IPARP, KNE and cob length was demonstrated enabling the prediction of cob length on the basis of IPARP. For September plantings at Dzindi the optimum planting density for green maize production was estimated to be 3.4 plants m^{-2} for the cultivar PAN 93 and 3.9 plants m^{-2} for SC 701. The two cultivar experiments identified cultivars, which when planted in August, performed much better than SNK 2147, the cultivar farmers had been using until then. ETZ 200 and SC 701 were identified as superior cultivars in terms of cob length and other important attributes.

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10 IMPACT OF THE PROJECT: PLOT HOLDER PERSPECTIVES

10.1 Introduction

In this chapter the results of a survey that was conducted to assess the impact of the project from the perspective of Dzindi plot holders are presented. The specific objectives of the survey were to determine (i) the extent of awareness of the existence of the project among plot holders; (ii) awareness of the objectives of the project among plot holders; (iii) the extent to which these objectives had been actively pursued by the project; (iv) the tangible and intangible benefits farmers had derived from participating in the project; and (v) what plot holders would like future participation between TUT researchers and Dzindi plot holders to focus on. As was explained in section 1.5, an independent consultant was contracted to analyse the perceptions and expectations of the different groups of stakeholders participating in the project. The view of the plot holders at Dzindi on what the goals of the project should be were summarized in Table 1.2 and are again shown in Table 10.1 including a brief justification for the choices plot holders made.

During the development of the action plan for the project, the priorities of the plot holders featured prominently but a balance had to be found between the interests of the plot holders, which were directly related to their livelihood and farming and the interest of the researchers, who primarily sought to contribute to knowledge and the building of research capacity among students attached to the project. As the project evolved, the interests of researchers came to dominate. As was explained in section 1.5.3, the shift in the balance of power of decision making and control over the project from plot holders to researchers was a consequence of the approach that was selected to conduct the different research activities. Instead of adopting an action research approach, which would have been congruent with the idea that this project needed to be participatory as indicated by the title and the terms of reference, a more traditional research approach was used.

The decision to use a traditional approach to research was mainly due to the lack of experience with action research of the project leader, particularly in terms of using this approach for post-graduate degree purposes. An important factor influencing this decision was that the WRC, NRF and TUT, which supported the project financially, expected returns in the form of graduating students, research reports and research outputs in the form of journal publications and book chapters. Still, throughout the conduct of the project the research team consciously reminded itself that research activities and outcomes were expected to address the needs of plot holders.

TABLE 10.1: Research and development priorities identified by plot holders at Dzindi (after Van Vlaenderen, 2003)

Priority	Issues	Justification
Highest	Improve the water conveyance system	Poor state of infrastructure reduces water availability in the scheme
	Establish a poultry project	Job opportunities for women
	Acquire a second collectively-owned tractor	Eliminate waiting periods and create reserve capacity for when tractor needs service or repairs
	Repair scheme fences	Prevent people and livestock from entering the scheme and damage crops
	Restart the dairy project	Income generation
	Obtain title deed	Increase tenure security
	Resurrect the co-operative	Convenient access to inputs at low prices
	Establishment of a nursery	Convenient access to planting material at favourable prices and job creation
	Improve marketing	Eliminate waste and increase income, particularly in vegetable production
	Obtain hybrid seed	Increase productivity of particularly maize and cabbages
	Improve knowledge on fertiliser use	Increase productivity and avoid waste
Lowest	Develop agronomic knowledge on indigenous crops	Improve the productivity of Chinese cabbage and nightshade
	Develop knowledge on soils	Improved soil management
	Establish a pig production project	Job opportunities for women

As a community of practice, academics at universities primarily seek to contribute to knowledge and the building of research capacity among students attached to the project. This is to be expected because these pursuits are the key performance areas of academics. The third key performance area of contemporary academics is community service, at least this is what is said at the policy level of modern universities in South Africa. However, community service in the context of universities remains poorly defined and in terms of generating subsidy from the Department of Education, it is not recognized.

The joint action plan for the project was endorsed by all participants on the 26th of March 2004. Table 10.2 shows the relationships between farmer priorities and the planned research projects.

TABLE 10.2: Relationship between the priorities identified by plot holders at Dzindi and the planned research and development activities

Farmer priorities	Related research projects
1. Improve the water conveyance system	Institutions and organisations
2. Establish a poultry project	Integrating poultry production in the farming system at Dzindi
3. Acquire a second collectively-owned tractor	Tractors and fences (only partially executed)
1. Repair scheme fences	Tractors and fences (only partially executed)
2. Restart the dairy project	Not pursued
1. Obtain title deed	Institutions and organisations
2. Resurrect the co-operative	Institutions and organisations
3. Establishment of a nursery	Not pursued
4. Improve marketing	Analysing the production, transformation, storage and transaction systems of the commodities produced at Dzindi
1. Obtain hybrid seed	Not pursued
2. Improve knowledge on fertilise	Agronomy of indigenous vegetables
1. Develop agronomic knowledge indigenous crops	Agronomy of indigenous vegetables
2. Develop knowledge on soils	Optimising the use of available water at Dzindi
3. Establish a pig production proj	Not pursued

From Table 10.2 it is clear that several of the farmer priorities did not receive attention.

To determine the perception of plot holders about the impact of the project a survey was conducted. Prior to the conduct of the survey, the project leader consulted with the Scheme Management Committee (SMC) on the 18th of July 2006. The concept of the impact assessment was introduced and the need for the assessment to be a truthful reflection of the perceptions of Dzindi plot holders about the project was explained to the SMC. The SMC supported the proposal and the concept of the impact assessment was then explained by the project leader to plot holders at a general meeting that same day. It was also explained that only a sample of plot holders would be interviewed during the survey. Plot holders unanimously agreed to participate in the survey.

10.2 Materials and methods

A structured interview schedule was developed in English and then translated into Tshivenda by two Venda-speaking M Tech students, Ms TE Tshikalange and Mr MM Netshitomboni. Using the list of 102 plot holders at Dzindi as the sampling frame, a probability sample of 50 plot holders (sampling fraction of 49%) was selected. Data were collected by means of face-to-face interviews. The survey was conducted during the third week of August 2006. The fieldwork was conducted by Ms TE Tshikalange. She was selected to be the enumerator because she was not known to the plot holders, although she had conducted research towards her M Tech degree under the auspices of the Project. It was postulated that using a person with whom farmers were not familiar to conduct the survey would reduce any inhibitions to communicate their true opinions.

At the start of each interview the enumerator encouraged plot holders to respond freely to the questions. It was explained that they would remain anonymous and that their responses would be kept confidential.

The data were captured on a spreadsheet using MS Office Excel and analysis of the data was limited to the calculation of frequencies for the different variables. No inferential statistical procedures were performed.

10.3 Results and discussion

All 50 plot holders who participated in the survey stated that they knew about the project. Their responses to the question what the objectives of this project were and to what extent these objectives had been actively pursued by the project are shown in Table 10.3. The ordering of the objectives of the project identified by farmers reflects declining response frequencies.

TABLE 10.3: Relative frequency of respondents identifying particular objectives of the Dzindi-TUT project and their opinion on whether the project had actively pursued the identified objectives

Project objective	**Identified** (%)	**Actively pursued** (%)
Establish a poultry project at Dzindi	88	88
Improve knowledge of the soils of Dzindi	64	40
Rehabilitate the irrigation system to improve access to water	40	6
Improve green maize production among farmers at Dzindi	36	16
Improve knowledge of the production of indigenous vegetables (Chinese cabbage and nightshade)	32	16
Improve farming at Dzindi	24	8
Construct overnight storage dams to improve access to water	20	6
Re-establish the dairy project at Dzindi	16	0
Resuscitate the Dzindi Farmer Co-operative	14	0
Provide information on fertiliser application in crop production at Dzindi	14	8
Establish a Guinea fowl and duck production enterprise at Dzindi	14	0
Improve produce marketing	12	0
Improve knowledge of farming among plot holders at Dzindi	12	6
Assist farmers with obtaining a second collectively owned tractor	10	0
Assist with the replacement of the scheme fence	10	0
Establish a money-lending scheme	8	0
Assist farmers in obtaining electricity and toilets at the plots	8	0
Improve access to poultry manure	4	2
Improve farmers' knowledge of the use of chemicals in plant protection	4	4
Establish a sheep and goat project at Dzindi	2	0
Establish a piggery project at Dzindi	2	0

The establishment of a poultry project at Dzindi had been achieved by the project and the production unit had been handed over to the framer collective. Income generated from selling the broilers used in the two broiler experiments had been transferred to the plot holder collective and they used it to purchase 800 day-old chicks. The remainder of the feed was also transferred to the collective and was sufficient to raise the chicks to market readiness. This explains the high response frequencies related to this objective shown in Table 10.3

Improving knowledge of the soils of Dzindi was achieved by conducting a soil survey and determining a selection of water-related properties of the main soil types. A set of laminated soil maps of the four irrigation blocks was handed over to the extension officer and these were displayed on the wall of his office. The team did not provide a formal explanation of the implications of the soil distribution for irrigation purposes to plot holders.

From the start it was explained to farmers that the project could not actively improve the irrigation system, but that it could assist the community with access to agencies that have the mandate to do so, i.e. through the RESIS programme. In 2005, representatives of this programme engaged with the community in the participatory planning of the rehabilitation of Dzindi. The RESIS representatives showed no interest in the work that had been done by the research team, preferring to use their own intelligence gathering processes and procedures.

Improving green maize production among farmers at Dzindi was actively pursued through the creation of an interest group among farmers. About 20 of the 102 plot holders actively participated in the interest group, which engaged in the conduct of farmer-managed on-farm experiments and the assessment of the plot experiments at the research site on Plot 1 (see section 9.3.3 of chapter 9). Interested farmers also received small amounts of seed of different hybrids considered suitable for green maize production to try out on their plots. The assistance of Pannar in supplying seed free of charge for distribution among farmers is gratefully acknowledged.

Improve knowledge of the production of indigenous vegetables (Chinese cabbage and nightshade) was actively pursued through the conduct of experiments at Dzindi. These experiments investigated the effects of planting date and soil water availability on biomass production of Chinese cabbage (see chapter 8, sections 8.3 and 8.4). Additional work was done in Pretoria, but farmers were not really aware of the green house experiments that were conducted at the University.

Improve farming at Dzindi was an overall objective of the project and was never identified as a specific objective. Relative to the frequency with which this objective was identified, the low frequency referring to active pursuit of this objective by the project suggests that farmers did not perceive the project as having focused on improving their farming.

Construct overnight storage dams to improve access to water was an objective which the team dealt with in a similar matter as the rehabilitation of the irrigation system to improve access to water discussed earlier.

Re-establishing the dairy project at Dzindi was an objective that was pursued during the first year of the project. The idea was to introduce a zero-grazing system, whereby all fodder would be cut and carried to the stables. The main reason for this choice of system was the problem farmers had experienced with cattle mortality, which was most probably related to tick-borne diseases. Three perennial fodder species were introduced and grown experimentally. Farmers with cattle were invited to cut the biomass and feed it to their animals. When Mr Van der Walt, the M Tech student responsible for this project, left the University of Pretoria and took up a new job in mine dump reclamation, this project was abandoned. It must be stressed that all three grass species thrived in the Dzindi environment and were ideally suited for planting on the bunds separating the irrigation strips.

The resuscitation of the Dzindi Farmer Co-operative was dealt with by Mr Letsoalo, who analysed the history of the Dzindi Farmer Co-operative and subsequently presented farmers with a number of options to either resuscitate the Co-operative or to create a suitable organization to improve access to farm inputs. However, farmers have not moved on the issue. An explanation of the social dynamics involved is provided in section 5.3 of this report.

The provision of information on fertiliser application in crop production at Dzindi received considerable research attention (see section 8.2) and considerable information has been collected on nutrient management for different crops grown at Dzindi. However, the knowledge that has been generated is still insufficient to provide definitive recommendations for use by farmers.

The establishment of a Guinea fowl and duck production enterprise at Dzindi was never adopted as a project objective, but this idea had been mooted to farmers as a potential expansion of the poultry enterprise.

Improving produce marketing at Dzindi was an identified objective that was pursued by the team, but actioning was limited. The analysis of the indigenous vegetable and maize commodity chains at Dzindi was completed and the research on green maize production is aimed at increasing the number of maize cobs per unit area that meet the quality criteria of hawkers, which the team identified as a critical issue (see section 3.2.3). Exploring distant urban markets for indigenous vegetables (Chinese cabbage and nightshade) was another strategy. It was established that there was a market for Chinese cabbage in Pretoria, but since the start of the project, farmers around Pretoria have started to supply the city with this crop, casting doubt that Dzindi farmers will be competitive on the Pretoria market.

Improve knowledge of farming among plot holders at Dzindi was an overall objective of the Project, not a specific objective. Of the 12% of plot holders who identified this particular objective half were of the opinion that it had been pursued.

Assist with the replacement of the scheme fence was an objective that was dealt with in a similar way as the rehabilitation of the irrigation system to improve access to water discussed earlier.

Establishing a money-lending scheme was never adopted as an objective by the project, but it did feature in the needs analysis conducted by the RESIS team that visited the scheme. Similarly, assisting farmers to obtain electricity (for lights) and toilets at their plots were part of the needs identified the RESIS team. These particular needs relate to the common practice of night irrigation.

Improve access to poultry manure was an objective that was linked to the establishment of the poultry enterprise at Dzindi. It was one of the benefits associated with this initiative. During the conduct of the two broiler experiments at Dzindi only a small amount of manure was produced, because of the relatively low number of birds (about 200 per experiment) that were used in the experiments.

Improving farmers' knowledge of the use of chemicals in plant protection was never raised as an issue, but research students based at Dzindi have been providing interested farmers with advice.

Establishing a sheep and goat project at Dzindi was never raised as an issue

Establish a piggery project at Dzindi was a goal that was raised by farmers when the situation analysis was conducted, but when the action plan was developed, all partners agreed to focus on poultry and to abandon the idea of pig production.

The survey results reveal three important issues:

1. Among plot holders, knowledge of the objectives of the project as they were captured in the joint action plan varied substantially. Indications were that some plot holders referred back to the initial needs analysis conducted by Van Vlaenderen (2003) when listing the project objectives. The lack of a shared understanding of what the project aimed to achieve suggests inadequate re-enforcement of what had been agreed upon.
2. Tangible change was the critical criterion plot holders used when assessing whether or not a project objective had been pursued. For example, the poultry project, for which the necessary infrastructure was established at the Scheme, was identified by most of the farmers as having been pursued actively.
3. Generally, plot holders did not consider knowledge generation *per se* as evidence of the active pursuit of a particular objective. This observation corroborates the tension that exists between research, which is a knowledge generating activity, and participatory action, which is farmer-driven.

Table 10.4 presents information on learning by plot holders in the domain of collaboration at Dzindi.

TABLE 10.4: Degree of learning among plot holders in the domain of collaboration

New knowledge acquired	**--------Proportion of farmers (%)--------**	
	Yes	No
Sharing of water among farmers	90	10
Maintenance of the irrigation infrastructure	84	16
Access input market	74	26
Access output market	88	12

The results presented in Table 10.4 suggest that the Project contributed considerably to knowledge development among farmers in the domain of farmer collaboration.

Learning is expected to lead to improvements. Table 10.5 presents the opinions of plot holders on how the project has impacted on the different aspects of farmer collaboration at the Scheme.

TABLE 10.5: Degree of improvement in farmer collaboration as a result of the project

Specific domain of collaboration	**Improvement as a result of the Project**	
	--------Proportion of farmers (%)--------	
	Yes	No
Sharing of water among farmers	82	18
Maintenance of the irrigation infrastructure	90	10
Access to input markets	68	32
Access to output markets	64	36

The survey results suggest that the learning by plot holders that occurred as a result of project activities had a positive impact on farmer collaboration. However, our results show that in reality little if anything has improved! The responses by farmers were, therefore, quite surprising.

Twenty of the 50 respondents indicated that they had acquired new knowledge and experience in relation to land exchanges. Table 10.6 shows the benefits these plot holders thought one could derive from renting out land to others.

TABLE 10.6: Benefits obtained by plot holders from exchanging land (n = 50)

Plot holder benefits of sharing land	**Frequency (%)**
Helps to keep the plot clean (free of weeds)	16
Improves livelihood by generating income	12
Exchange arrangements need to be reported to the extension officer	10
Improves relationships among plot holders	2

As the Project progressed, the research team started to pay attention to land exchanges, because a lot of land was found to be idle. Raising this issue with plot holders appears to have changed the views of some. In 2006 it became evident that exchanging land among farmers was no longer taboo (see also section 6.5.1). In the eyes of the research team, this development was a positive outcome of the project.

The terms of reference of the project has ‘best management practices for smallholder irrigators’ as its central aim. This implied that farming system improvements were a critical expectation. Table 10.7 shows the different system aspects about which plot holders gained new knowledge. The results in Table 10.7 indicate that the project had a positive aspect on learning among farmers as far as their farming systems was concerned. The high impact rate in terms of learning contrasted sharply with the low rates in relation to whether or not particular objectives were actively pursued by the project. This supports the earlier statement that farmers consider tangible interventions as most important.

TABLE 10.7: Proportion of farmers who said they acquired new knowledge on selected aspects of their farming system

System aspects on which new knowledge was gained	**Proportion of farmers who gained new knowledge** (%)
Selection of cultivars in maize	96
Use of fertilisers in different crops	96
Optimizing planting date in different crops	94
Planting density in maize	94
Land preparation	88
Marketing of different crops	88
Irrigation frequency in crop production	86
Enterprise budgets of different crops	82
Use of hired labour in crop production	64

One of the important outcomes of a participatory research project is that it improves the livelihood of the participants. In Table 10.8 the impact of the project on the livelihood of plot holders is presented.

TABLE 10.8: Impact of the project on the livelihood of plot holders (n = 50; 2006)

Impact of the Project on the livelihood of plot holders	**Proportion of respondents** (%)
Has improved my income	46
Has provided me with access to cheap broiler chickens	26
Has improved my knowledge of farming	22

Nearly half (46%) of plot holders indicated that their income had increased as a result of the project. Other livelihood benefits were improved knowledge and improved access to broiler chickens.

One of the important social impacts of a research project on a community is the way participants and researchers relate. Table 10.9 shows how plot holders perceived the research team in terms of relationships.

TABLE 10.9: Plot holder assessment of the relationship that was maintained between researchers active in the TUT-Dzindi Project and plot holders (n = 50; 2006)

Relational aspects of the Project	**Rating by farmers (%)**				
	Very poor	Poor	Average	Good	Very good
Involving me in the setting of priorities	0	8	24	44	24
Involving me in the setting of the project objectives	0	4	20	56	20
Involving me in project activities	0	8	28	44	20
Providing me with feedback on the results of activities	6	4	22	50	18
Exposing me to new ideas	4	8	20	42	26
Exposing me to new people	4	6	24	44	22
Treating you with respect	0	6	12	54	28
Providing you with information and training	6	4	14	48	28
Exposing young people to your way of farming	4	6	24	40	26
Overall assessment	**3**	**6**	**21**	**47**	**23**

Generally, plot holders had a positive perception of the relationships that were developed and maintained between researchers and farmers over the duration of the project. Overall, 70% of plot holders rated these relationships as good or better.

Plot holders were asked what any possible follow-up project should attempt to achieve. The responses are presented in Table 10.10. Plot holders were quite clear as to what should be the priorities of any follow-up project that may be launched. First of the list was the resuscitation of the co-operative, followed by improving access to produce markets and the finding of solutions to the land preparation problem and the infrastructural problem.

TABLE 10.10: Plot holder priorities to be considered by a possible follow-up to the TUT-Dzindi Project (n = 50)

Activities	**Proportion of farmers** (%)
Resuscitate the Farmer Co-operative for improved access to farm inputs	56
Improve access to produce markets	42
Donate a tractor to the collective of plot holders	26
Repair the canal	22
Donate seed (vegetables and maize)	10
Monitor impact of training provided	10
Encourage love among farmers	8
Build a dam to store water	8
Establish full-time production of chickens	8
Provide farmers with training on their plots	8
Provide farmers with information on the research results	6
Develop guidelines for spacing in green maize	6
Erect a structure to provide protection from the rain and for storage	6
Encourage collaborative farming among farmers	4
Erect a toilet and provide electricity for irrigation at night	4
Create job opportunities in poultry production	2
Renovate the scheme fence	2
Develop guidelines for the application of fertilisers and pesticides	2
Introduce the production of chillies	2
Re-introduce (dairy) cattle production	2
Encourage farmers to borrow money for farming	2

10.4 conclusions

Generally, the survey results indicated that the project has had a positive impact on the Dzindi community, particularly in terms of exposing plot holders to new ideas and information. However, the results also showed that plot holders expected tangible improvements to their personal and collective circumstances and in bringing this about the project was not particularly successful. The establishment of the poultry project was the only exception.

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11 CONCLUSIONS, RECOMMENDATIONS AND GUIDELINES FOR BEST MAMAGEMENT PRACTICES

11.1 Contextual issues

11.1.1 Best management practices for whom?

In his book, *The virtual farmer: past, present and future of the Dutch peasantry*, Van der Ploeg (2003) argues that the expert system concerned with agriculture in the Netherlands has failed to recognise the diversity that exists among farmers in that country. Instead, this system was preoccupied with the 'average farmer'. Van der Ploeg (2003) pointed out that the 'average farmer' was a construct created by the expert system, and that the 'average farmer' had characteristics that applied to few if any of the farmers encountered in the real world. This prompted Van der Ploeg to call the 'average farmer' a 'virtual farmer'. The problem according to Van der Ploeg (2003) was that policies and measures were being developed to support the virtual farmer and this caused interventions to be off target. For a long time, the South African expert system concerned with smallholder agriculture has also been guilty of reducing reality and this has resulted in constructs of rural people that do not resemble reality. In this context the question arises, best management practices for whom?

The analysis of plot holder livelihood at the smallholder irrigation schemes of Dzindi, Khumbe and Rabali showed that households engaged in a wide range of livelihood activities, both on-farm and off-farm. In addition, they obtained a substantial portion of their income from claiming against the state. Agriculture was an important livelihood activity among plot holders at the three schemes. At Dzindi, income derived from agriculture contributed about 30% to mean total household income in 2003 and was by far the most important local economic activity. Five main types of livelihood were identified among plot holder households at Dzindi using sources of income as the principal indicator for categorisation. Farming was central in the livelihood of about one in five plot holder households. The other 80% of households had livelihood activities that were more important than farming in terms of their contribution to total household income. It follows that for the majority of plot holder households at Dzindi, the productive use of the plot was a supplementary or complementary livelihood activity.

Among plot holders at Dzindi, the decision to live from farming was in some cases made when other livelihood options were closed. This indicated that the irrigated plot and farming represented a fall-back option to be exercised during a livelihood crisis, such as the loss of a job or the passing away of a grant holder. Many of the subsistence farmer households, which were the poorest group at Dzindi, were in a stage of livelihood transition. They used farming to survive, whilst exploring other livelihood options.

There were also homesteads that had deliberately elected to construct an agrarian livelihood. These included many of the market-oriented farmers who were shown to able to achieve reasonable livelihood outcomes from farming. Almost invariably market-oriented farmers sought to expand their operation but the prevailing circumstances at Dzindi were not conducive for this to happen. Strategies employed to expand their operations included the cultivation of non-scheduled parcels of land and the investment in other agrarian activities, such as providing land preparation services to others following the purchase of a tractor. Since inception of the Dzindi Scheme, market-oriented farmers have corresponded with the vision of policy makers because they make most effective use of the available resources from an economic perspective. However, the results of this study showed that on smallholder irrigation this type of farmers has always been a minority group, irrespective of the prevailing policy regime.

Diversity was also a feature of the way farming was conducted on smallholder irrigation schemes. The study at Dzindi identified three distinct farming styles, namely food farmers, profit makers and employers. Farmers in the different farming styles differed in terms of farming objectives and attitude to risk and this was reflected in their choice of crops, their production methods and their marketing strategies.

Food farmers, a farming style that largely corresponded with the concept of subsistence farmers, mainly farmed to supply their households with food. They were risk adverse and focused on the production of maize grain and African leafy vegetables. Their main concern was to limit the variable costs of production even when this compromised crop yield to an extent.

Profit makers fitted the profile of small-scale commercial farmers. They farmed for the market and were prepared to take risks. They typically produced maize for sale as green cobs and cabbages throughout the year. They elected to use high-quality services and goods instead of cheaper alternatives of lower quality.

Employers were a totally different category of farmers. They were farming at a loss because they employed one or more full-time farm workers. Recovering variable costs, which were particularly high as a result of the employment of full-time labour, was their main objective but most had to support their enterprises using income from other sources.

The implication of the observed diversity in livelihood and farming on the smallholder irrigation schemes that featured in this study is that the development of best management practices for farmers on smallholder irrigation schemes in Limpopo Province, needs to be clear for which type of farmers the development is being done. The important guideline is that the development of best management practices for farmers on smallholder irrigation schemes must be based on the analysis of the diversity in livelihood and farming of participants.

11.1.2 Domains for best management practice development

Three important domains were identified for best management practice development in the smallholder irrigation sector. These were the domain of the individual plot holder household and farm enterprise, the domain of the irrigation scheme (the group of plot holders) and the domain of the world outside the scheme.

In the past, the expert system concerned with smallholder development has focused mainly on the domain of the individual farm enterprise. Here technical issues related to production, storage, transformation and marketing of produce dominate and the development of best management practices is focused on finding ways to optimise the use of the available natural resources. The importance of agro-ecological diversity has long been recognised and over the years a considerable body of knowledge has been developed.

Much less attention has been awarded to the irrigation scheme as a whole, probably because in this domain social and institutional issues dominate. Yet, there is considerable interaction between this domain and the individual enterprises, as was amply demonstrated in this study. On smallholder canal irrigation schemes, the sharing of water and the maintenance of the irrigation infrastructure influence the availability of water for irrigation at the plots. Collaboration among farmers, or the lack thereof, also affects access to markets. Land tenure and farmers' interpretation of the prevailing tenure system influence land exchange among farmers, which is important for farmers seeking to expand their operations. Collaboration among farmers may also be important in terms of access to land preparation services, as was the case at Dzindi. The study of these social and institutional domains at Dzindi showed that there was considerable room to improve the management of shared resources. During the conduct of this project the activities of the research team were mainly limited to the analysis of these domains. No concerted attempts were made to improve the situation but feedback to the community on the research findings did have an impact on attitudes and social behaviour, as in the case of land exchange at Dzindi, suggesting that agency, probably in the form of action learning, could be used to improve the management of shared resources on smallholder irrigation schemes. The results also indicated that in these domains participants must be the drivers of development and that agency should be limited to facilitation of the action learning process.

Research into the domain of the world outside the scheme that was done under the auspices of this project was limited to the relationships between irrigation schemes and the surrounding settlements. Very little attention has been awarded in the past to these relationships. The study showed that demand for resources, such as land and water, in the area surrounding irrigation schemes can result in contestation, which, when not managed appropriately, can cause conflict. This, in turn, can have an impact on the operation of the scheme as a whole and on the individual farm enterprises. In the three schemes that were studied relationships between the schemes and their surrounds were generally cordial but evidence of a degree of resource contestation was found, particularly at Dzindi, which neighboured expanding urban and peri-urban settlements. When relationships between schemes and their surrounds are not managed appropriately, particularly at the local government level, there is a threat that farming on the schemes becomes compromised as a result of land invasion, unauthorised water extraction, theft of produce and vandalism.

11.2 Best management practices for smallholder irrigation schemes in Limpopo Province: general recommendations

11.2.1 The domain of the individual plot holder

The implication of the observed diversity at the level of the individual farm enterprises found on smallholder irrigation schemes was that, best management practices should be tailored to suit the specific objectives of farming households. Consequently, a 'one size fits all' approach is unlikely to be successful when developing and disseminating best management guidelines for use at the farm enterprise level. Categorising households in livelihood types and farming styles was shown to be a suitable approach to make sense of the diversity among them. The results of this study showed that households contained in the same farming style category tended to share the same farming objectives. Categorising plot holders according to their farming styles is, therefore, a suitable way to identify extension domains for the development and dissemination of technical management information.

11.2.2 The domain of the irrigation scheme

The domain of the irrigation scheme, more specifically the group of people who make use of this asset, is probably the most important and also the most ignored domain in the management of smallholder irrigation schemes in Limpopo and possibly also elsewhere in South Africa. It is this domain of management that determines access to irrigation water and land by individual farmers. Management in this domain can also improve access to markets and services, such as land preparation.

The **management of water and irrigation infrastructure** is of particular importance in smallholder canal irrigation. The findings of this study indicate that a system of simple rules that govern the sharing of water among farmers and the routine maintenance of the canal system can form the appropriate basis for sustainable water management by plot holders. However, the study also identified the need for an external agency to form part of the overall management system. The principal roles of this agency should be to participate in regular monitoring and evaluation of the management activities and to intermediate, and if necessary intervene, in conflict situations. Considering that the Limpopo Department of Agriculture is the legal owner of many if not all of the smallholder canal irrigation schemes in the Province, it is appropriate that this Department serves as the proposed external agency. Critical outcomes of a sustainable water and irrigation infrastructure management system for canal irrigation schemes are that water is being shared equitably among farmers and that canals are clean and in good condition.

An important weakness identified at all three schemes was the absence of adequate expertise to manage water flow in the canal system. As a result, gates and valves were not used to best effect, causing water losses and inequitable distribution of the water to the different parts of the scheme. Invariably, the extension staff assigned to the three schemes that featured in this study had never been trained in the regulation of water in canal irrigation systems. Considering the abundance of smallholder canal irrigation schemes in South Africa, particularly in Limpopo Province, the need to develop an appropriate training programme for extension staff working on this type of schemes was identified.

The results of this study showed that voluntary co-operation among farmers can improve **access to markets**. The results also suggested that institutional arrangements that are based on the value of mutual aid, in line with traditional forms of collectivism, are probably best suited when developing collective action among plot holders for improved market access. Intervention by the state should aim to support the initiatives of farmers and not to regulate voluntary collective action. When regulation does become prudent, it should be introduced in ways that allow smallholders sufficient time to internalise the new concepts and to adapt them to suit their own circumstances.

The results of this study show that *de facto* Trust tenure continues to apply on many canal irrigation schemes in Limpopo Province. Whereas most plot holders on these schemes do not cultivate their entire allotment at all times, there are others, primarily those that run farm enterprises with a strong market focus, who are in desperate need of additional land. **Land exchanges** among plot holders are the most obvious way for those in need to access more land. Opening the market for land exchanges on these schemes is expected to be assisted by the development of a simple rule system to govern exchanges, the development of a register of plot holders (usually in place), the demarcation of the individual plots in the field, and the appointment of an external agency to intervene when conflicts arise. As in the case of water management, the Limpopo Department of Agriculture is the most appropriate body to serve as the external agent. Lastly, there is also a need for mobilisation to encourage plot holders to consider land exchange as a way of deriving benefit from their plots.

Affordability and access to mechanised **land preparation** limit overall production on smallholder irrigation schemes. Poor households who are involved in subsistence farming are most affected by this constraint. The option of re-introducing animal draught on smallholder irrigation schemes as a way to reduce variable costs and possibly limiting the problem of soil compaction associated with the use of tractors warrants investigation. It is probably not practical for each plot holder to own the wherewithal to cultivate land using animal draught but there are no obvious reasons why selected households could not provide land preparation services to others on a commercial basis using animal draught equipment.

11.2.3 The domain of the world outside the scheme

Limiting recommendations for best management practices to aspects that were investigated empirically, the study identified two opportunities to distribute more widely the benefits associated with smallholder irrigation schemes.

One opportunity was to broaden access to irrigation land. Land is available at these schemes, particularly during winter, suggesting room for others to join production. However, at this stage plot holders tend to be reluctant to enter land exchanges involving outsiders.

Another opportunity to enable more people to benefit from the presence of a canal irrigation scheme was to allow outsiders to extract water from the canal, particularly during the night and storing this water in tanks. This opportunity would benefit people living within close vicinity of the canal by enabling them to access irrigation water for home gardening purposes. However, at Dzindi, existing extraction by outsiders, which mostly involved small quantities of water, already stirred up emotions among plot holders, suggesting that considerable negotiations would be needed before plot holders would allow for this to happen.

11.3 Selected best management practices for important commodity systems found on smallholder irrigation schemes in Limpopo Province

11.3.1 Improving green maize production

Several opportunities exist to improve green maize production on smallholder irrigation schemes in Vhembe. To maximise the number of marketable cobs per unit area, cultivar selection is important and ETZ 200 and SC 701 were identified as superior cultivars in terms of cob length and other important attributes. For September plantings at Dzindi, the optimum planting density for green maize production using the cultivar SC 701 was about 4.0 plants m^{-2}, but planting density has to be reduced to about 3.0 plants m^{-2} when using the PAN 93 cultivar.

11.3.2 Improving the production of selected African leafy vegetables

Optimising soil nitrogen availability was the most critical nutrient management concern in the production of Chinese cabbage and nightshade. Sufficient nitrogen needs to be available in the soil for the two crops to achieve optimum growth, but adding too much nitrogen adversely affects biomass production. Considering that smallholders produce these two vegetables under irrigation, which increases the likelihood of nitrogen losses due to leaching, maintaining optimum availability of N in field soils throughout the growing season is expected to be difficult to achieve. The use of split application of N, which is common practice among smallholders at present, is likely to be the appropriate strategy to achieve optimum availability of N but this needs to be investigated.

Production of Chinese cabbage and nightshade is also dependent on the adequate availability of phosphorus and potassium, but the adverse effects caused by applying these two nutrients in excess of the rate at which biomass production peaked were less distinct than for nitrogen.

Growers stand to benefit financially from optimizing fertiliser application rates in the production of Chinese cabbage and nightshade, but field experiments are needed to identify these rates.

The yield of Chinese cabbage peaks when the crop is planted during the period 25 May until 2 July. Postponing the planting date beyond the 2nd of July rapidly reduces yield and bringing planting forward to dates earlier than 25 May also reduces yield, but in a less extreme way. Consequently, the option of spreading the planting date of Chinese cabbage more widely, to avoid the period of excess supply on the local market, is seriously compromised by the important effect of planting date on the yield of this crop.

Full irrigation produces the highest yield in Chinese cabbage but this requires farmers to irrigate the crop at least twice per week. Considering that plot holders on canal schemes are only allocated water once per week, farmers can only implement full irrigation by practising night-irrigation or by negotiating access to additional water with other plot holders using the same supply furrow. Use of a deficit irrigation approach when producing this vegetable has limitations because compared to full irrigation, deficit irrigation reduces yield substantially.

11.3.3 Integrating crop and animal production systems

Assessment of the performance of a single-phase broiler diet obtained by on-farm processing of yellow maize grain and soya beans using a commercially available three-phase diet as the benchmark for comparison showed that birds fed of the commercial diet (C) grew faster and were ready for marketing one week earlier than birds fed on the on-farm diet (OF). From an economic perspective, the performance of the enterprises based on the use of the two diets was not very different. The experimental enterprise that used the three-phase commercial diet (C) provided a higher gross margin (R6.79 $bird^{-1}$) than the enterprise that used the on-farm single-phase diet (OF) (R5.38 $bird^{-1}$), a difference of R1.32 $bird^{-1}$. The main advantage of using the on-farm diet was that it provided the opportunity to integrate crop and animal production and to locate a larger part of the value chain within the local agrarian economy. The results obtained so far warrant further research.

11.4 Best management practices in participatory research and development

South African academics who are actively involved in the development of the smallholder sector and the students they supervise, quite readily convince themselves that their activities are for the benefit of smallholders. The research team that conducted this project was no different. Yet, despite being committed to the adoption of a participatory approach to conduct the project, which included the transfer of a high degree of power to smallholders when decisions were made on the project goals, as the project evolved, the team leader and his students were guilty of reverting back to the traditional practices of scientific enquiry and its associated methods of gathering, analysing and interpreting information.

One of the main reasons for the shift in paradigm of the team was the tension that existed between what was considered good research and what was most appropriate for farmer participation in development. This tension is acutely experienced in the domain of research product assessment, which typically employs the peer-review process. The desire of academics to satisfy the expectations of their peers is not conducive for methodological innovation within this community of practice. To allow and encourage academics and research students in the field of agriculture to adopt research paradigms that are participatory, there is a need for the academic community to change its views on what is considered ‘good research’. Progress with the methodological development and application of participatory research paradigms in the domain of agriculture is only possible when these paradigms find acceptance within the agricultural academic community.

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APPENDIX A

Improving capacity building with respect to students, farmers and other stakeholders

A1 Introduction

This report is based on the experiences of the project leader and a focus group discussion involving three senior students who were active in the project since its inception. One of these students was the resident extension officer at Dzindi, where the majority of the Project activities took place.

A2 Capacity building among students

Project K5/1464//4 has had considerable impact on capacity building among students registered in the Departments of Crop Sciences and Animal Sciences at the Tshwane University of Technology. This impact was made possible by exploiting the particular structure of the curriculum of students at Universities of Technology. The first qualification students register for at this type of universities is the National Diploma. In the context of this project the qualification students in the project were enrolled for was the National Diploma in Agriculture. The curriculum of this Diploma requires students to complete 20 subjects, which are offered by means of formal lectures and practicals during the first two years of study and in the third year, referred to as the experiential learning year, students acquire experience in practical farming by being attached to institutions active in agriculture. The project offered a large number of final-year National Diploma students with an opportunity to spend their experiential learning year working on different project activities. The project supported these students financially by paying them a stipend of R750 per week. Most were also accommodated at the centre, which the Project established at Dzindi Irrigation Scheme. Several students remained attached to the project after completing their Diploma studies. Some stayed just to gain more experience, but most sought to further their education by registering for the B Tech degree in Agriculture. The project supported them by paying a stipend of R1000 per month. In return, the students carried on assisting with the different project activities. A small group of students who obtained their B Tech in this way registered for an M Tech degree in agriculture and there were also three students who registered for the D Tech degree in Agriculture. Full-time M Tech students received a monthly stipend of R1500 per month and full-time D Tech students R2000 per month. An overview of student engagement in the Project is presented in Table A1.

TABLE A1: Student engagement in Project K5/1464//4 from start to end

Qualification	Number of students
Students who graduated	
National Diploma in Agriculture	14
B Tech in Agriculture	10
Industrial Engineer (Agriculture)	1
M Tech in Agriculture	2
M Inst. Agrar.	1
D Tech in Agriculture	1
Students who have not yet completed their studies	
National Diploma in Agriculture	0
B Tech in Agriculture	1
Industrial Engineer (Agriculture)	0
M Tech in Agriculture	5
M Inst. Agrar.	0
D Tech in Agriculture	2

At the official end of the project on the 31st of March 2007, the project continued to support 1 new B Tech student, 2 existing M Tech students, 1 existing D Tech students and 3 new M Tech students. The other D Tech student, Mr Letsoalo, is a staff member and does not receive a stipend. The two existing M Tech students, Mr Ralivhesa and Mr Netshithuthuni are expected to hand in their dissertations for examination during 2008 and the 2 D Tech students during 2008 or 2009. The three new M Tech students are expected to hand in 2009. Following the end of the project, these students are being supported with the funds that are left over, including the funds due to TUT after acceptance of the final report by the WRC (R120 000).

Several of the students who joined the project during the experiential learning year of their Diploma studies changed their perspective on furthering their studies and on research as a career option. Experiential learning students also appreciated their real-world experience of smallholder farming and the associated economic and social activities. When entering the B Tech course their exposure to research processes, including the writing of reports under the mentorship of senior students, assisted their performance at the B Tech level, and often they performed better than they did at the National Diploma level.

The B Tech year was some sort of transition year for the students. They remained involved in project activities during the time between the six block weeks of attendance which are spread over the academic year, but they also spent considerably time working on the course material and assignments, whilst still receiving financial support.

As indicated earlier some students, after obtaining the B Tech degree, remained attached to the project and registered for the M Tech degree, taking responsibility for particular projects within the overall project. Two of them, Ms TE Tshikalange and Ms KA Juma were awarded the M Tech degree, whilst another two are expected to complete in 2008.

Post-graduate students said that they appreciated being involved in the project because it exposed then new measuring techniques and instruments. Regular reporting and presentation of findings honed their writing and communication skills and build their confidence to provide critical contributions when participating in scientific events. They also appreciated the experience in management they acquired. They learnt to plan, implement and conclude in accordance with specified time frameworks and were responsible for the management and mentoring of junior students assisting in their projects. They acquired verbal communication skills through their interactions with farmers and benefited from working in a group environment which the Project provided. However, from a student perspective, the most outstanding contribution by the project was the financial support it provided to them, because most were from poor or very poor homes and would have had to end their studies after obtaining the National Diploma were it not for the financial support provided by the project. An estimated 75% of the WRC funding in the project was spent on supporting students, another 15% on purchasing equipment for transfer to farmers (e.g. the broiler unit) and about 10% for running costs. The National Research Foundation supported the project during 2004, 2005 and 2006, augmenting the available WRC funding with about R900 000 over the three year period. This funding was mainly in the form of bursaries to students in the project, but also added about R120 000 towards running costs. Overall, the financial support provided by the project was not overly generous, but without exception it enabled students to become financially independent from their parents and in some cases students even used part of their income to support their parents. An interesting comment made by students was that the modesty of the amounts they received helped them to develop financial management skills. The availability of accommodation at Dzindi was also a success factor in the capacity development of students.

A3 Capacity building among smallholders

The project had four main activities that were directed at improving existing practice. These were:

1. Improving collective action in the spheres of water sharing, infrastructural maintenance and access to markets;
2. Improving production of Chinese cabbage, the main winter crop, with particular reference to water and planting date;
3. Improving green maize production; and
4. Introducing broiler production based on the use of locally produced and processed grains to add to overall scheme activities, provide a new market for crops and to generate a source of plant nutrients for use in crop production, bringing about a degree of nutrient cycling.

The approach used to collective action was to analyse the way farmers organised themselves for the particular purposes where this type of institutional arrangements matter. A lot was learnt by the team, but little has been achieved in terms of bringing about improvements, even though important weaknesses have been identified.

The activities surrounding the assessment of the effects of planting date and irrigation strategy on the yield of Chinese cabbage was by means of field experiments on the research plot at Dzindi. Experimentation commenced from the start of the project and was carried through until the final year. Little was done in terms of involving farmers and the impact of this activity on farmer practices was negligible.

Research on green maize started during the third year of the project. From the start this project sought to involve farmers. The strategy that was adopted was to start a commodity group of green maize growers. Farmers joined on a voluntary basis and soon after commencement the group reached its current membership of 20 farmers or 20% of the farmers operating at Dzindi. All of them were growing green maize for marketing purposes. Since inception the members of the commodity group have diligently and consistently participated in all the activities, which involved the assessment of on-station experiments conducted on the research plot at Dzindi and the conduct of on-farm experiments on the plots of volunteer members. The group meetings are interactive events which encourage farmers to feed back their interests and perceptions into the research agenda. The assessment of the impact of Project K5/1464//4 emphasized the success of this approach. Another factor that has contributed to the success of the green maize improvement project was the participation of the seed company Pannar. This company has provided the project with new cultivars for testing and with advice on how to comprehensively assess the performance of green maize cultivars. The impact of the project activities on the practices of members in the group has been substantial. Within a period of two years farmers have adopted new cultivars and have reduced their plant spacing to increase the proportion of marketable cobs in their stands. As a result, participants have stated that they have been able to raise their income from green maize production but no quantitative evidence was collected to verify their claims.

The broiler production project was mainly concerned with implementing and assessing the idea of the project (producing feed on-farm) through the conduct of experiments in which the performance on-farm processed feed based on yellow maize grain and soya beans was compared with commercially available feed. For this purpose a high-quality fully-equipped broiler unit was built at Dzindi, which the farmers appreciated tremendously (see impact assessment report). At the end of each experiment the broilers were sold and profits were deposited in the Scheme account, which farmers also enjoyed. Training of three people from the Dzindi community designated by the farmers to take over production was also done. Since then farmers have taken over broiler production and the two batches they have produced so far were successful. The second component of the project, which involves the introduction of soya bean production at the scheme, still needs to be launched. Additional funding will be needed to achieve this. Farmers have indicated their interest in this phase of the project, which is of fundamental importance in terms of system development.

Other important experiences were that farmers find livelihood surveys extremely intrusive and do not like participating in them. They did enjoy the way we analysed farm enterprises financially using flip charts enabling farmers to see the results. Several farmers used the outcomes of these analyses to make changes to their farming system. More importantly farmers, particularly those with a profit maker farming style, adopted our approach to enterprise analysis to assess their different enterprises themselves.

Demonstration of new techniques in the field enabling farmers to observe and ask questions was found to be an ingredient of successful technology transfer. Farmers liked to see how things were done.

Feeding back research results in general meetings got farmers to think about issues and influenced their discussions on how to solve problems. This form of capacity building is not particularly tangible, but the impact assessment survey showed that these activities did influence people at the Scheme.

A4 Capacity building among other stakeholders

Three main stakeholder groups other than the Dzindi community were identified, namely other tertiary institutions, government and other smallholder irrigation communities.

The project had an active collaboration with other universities. TUT made use of expertise at other Universities, particularly the University of Pretoria and assisted students from other universities, particularly in terms of providing a setting about which a lot had been documented. These include the Universities of Venda, Limpopo and Pretoria.

The Project organised a workshop with the Department of Water Affairs and hosted the 2006 NIRESA meeting at Dzindi at which a range of people active in the irrigation sector were present, but the influence of the project on government has been negligible thus far. The District Office of the Department of Agriculture often uses Dzindi as a showcase when there are local events, indicating awareness about the research and development activities, but there has been no tapping into these results. It has been realised that the project should have targeted middle management of the Department at municipal level. The lack of a formal relationship between the project and the Department was a weakness, but the in-field water harvesting project in the Free State showed that even when the Department is partially funding technology transfer projects, committed participation is not guaranteed. Institutional location of action research projects within the system of government remains an area of great concern in South Africa. This was amply demonstrated by the Ruliv Project in the Eastern Cape, which was heavily supported by GTZ. Two years of inclusive participation with a wide range of stakeholders in the Provincial government were spent to embed the Ruliv Project institutionally, so that maximum benefit could be derived from the lessons learnt, but ultimately active governmental participation only occurred at the municipal level, where the project activities occurred.

The Project has had no measurable impact on other irrigation communities similar to Dzindi, even though several of these projects occur in its vicinity. There have been no farmer to farmer extension activities, mainly because the budget and time horizon of the project were too limited.

A5 Conclusions and recommendations

Whereas the project was successful in terms of capacity building among students, the success rate of students improved when the project introduced student selection. This involved a process of advertising positions, short-listing of candidates and interviews with the students that were short-listed. Senior students seeking junior students for use as assistants decided on who was to be appointed. This process of student selection by senior students improved the general standards of the research work. Senior students pointed out that junior students and particularly B Tech should be given small research projects to conduct on their own, because this would prepare them for what was expected at the M Tech level.

The concept of Project K5/1464//4 was to improve irrigated smallholder farming through participatory, adaptive research. The project succeeded in generating new knowledge, both contextual and technological. It was not particularly successful in transferring technology to end users. The experiences with the green maize project show that when technology transfer is an integral part of project design, it is possible to achieve an impact on farmer practices within the confines of a four-year project. However, not every project lends itself to this approach. Some research questions require a substantial period of research time to develop comprehensive understanding of the problem. The investigation into the response of Chinese cabbage (*Brassica rapa* L. subsp. *chinensis*) and nightshade (*Solanum retroflexum* Dun.) to nutrient availability and the broiler project are but two examples of this. This point was also amply demonstrated by the highly successful in-field water harvesting project conducted in the Free State. Therefore, the Water Research Commission should seriously consider second-phase funding of promising technology transfer projects.

Adaptive research in support of smallholder farming is extremely important for the development of this sector, because its circumstances differ substantially from those in the large-scale commercial farming sector. Adaptive research aims at generating and transferring knowledge to end users enabling them to farm better. Governmental interventions in the smallholder sector tend to focus on the transfer of assets to smallholders, such as land, infrastructure, equipment and inputs. Ways need to be found to better integrate these two approaches, but this requires commitment at senior governmental levels and appropriate institutional location of adaptive research projects. This cannot be achieved by people responsible for the conduct of individual research projects and should be dealt with generically by the Water Research Commission in collaboration with the relevant government departments and structures.

APPENDIX B

Research products that arose from the project

B1 Theses and dissertations

1. ADRIAENS, B. 2005. Evaluation of the chemical and the physical soil properties at the Dzindi Irrigation Scheme in Limpopo Province, South Africa. Ghent: Hogeschool Gent. 165pp.
2. TSHIKALANGE, T.E. 2006. Response of *Brassica rapa* L. subsp. c*hinensis* to nitrogen, phosphorus and potassium in pots. M Tech (Agric.) dissertation. Pretoria: Department of Crop Sciences, Tshwane University of Technology. 159pp.
3. JUMA, K.A. 2006. Response of *Solanum retroflexum* Dun. to nitrogen, phosphorus and potassium in pots. M Tech (Agric.) dissertation. Pretoria: Department of Crop Sciences, Tshwane University of Technology. 138pp.
4. MOHAMED, S.S. 2006. Livelihoods of plot holder homesteads at the Dzindi smallholder canal irrigation scheme. D Tech (Agric.) thesis. Pretoria: Department of Crop Sciences, Tshwane University of Technology. 285pp.
5. NTHAI, M. M. 2007. An evaluation of irrigation water supply infrastructure to improve conveyance efficiency and water availability at Dzindi Irrigation Scheme, Limpopo Province. M. Inst. Agrar (Rural Engineering Technology) dissertation. Pretoria: University of Pretoria. 79pp.

B2 Journal publications

1. LETSOALO, S.S. & VAN AVERBEKE, W. 2005. Sharing the water: institutional and organisational arrangements at Dzindi Irrigation Scheme in South Africa. *South African Journal of Agricultural Extension* 34 (1): 34-43.
2. VAN AVERBEKE, W. & MOHAMED, S.S. 2006. Smallholder farming styles and development policy in South Africa: the case of Dzindi Irrigation Scheme. *Agrekon*, 45(2): 136-157.
3. VAN AVERBEKE, W., TSHIKALANGE, T.E. & JUMA, K.A. 2007. The commodity systems of *Brassica rapa* L. subsp. *chinensis* and *Solanum retroflexum* Dun. in Vhembe, Limpopo Province, South Africa. *Water SA*, 33(3): 349-353.
4. VAN AVERBEKE, W., JUMA, K.A. & TSHIKALANGE, T.E. 2007. Yield response of African leafy vegetables to nitrogen, phosphorus and potassium: the case of *Brassica rapa* L. subsp. *Chinensis* and *Solanum retroflexum* Dun. *Water SA*, 33(3): 355-362.
5. VAN AVERBEKE, W. & MOHAMED, S.S. Smallholder irrigation schemes in South Africa: past, present and future. *Water SA*: Accepted 9 October 2007.

B3 Book chapters

1. LETSOALO, S. & VAN AVERBEKE, W. 2006. Water management on a smallholder canal irrigation scheme in South Africa. In: Perret, S., Farolfi, S. & Hassan, R. (eds.). *Water governance for sustainable development: approaches and lessons from developing and transitional countries.* London: Earthscan: 93-109.

B4 Papers published in conference proceedings

1. VAN AVERBEKE, W. & KHOSA, T.B. 2004. The triple-A framework for the analysis of smallholder food commodity chains. 3rd International Conference on Entrepreneurship: Sustainable Globalisation, 3-4 November, Pretoria: Tshwane University of Technology. *Proceedings*. [CD ROM]. Pretoria: Tshwane University of Technology: 292-299.
2. LETSOALO S.S. & VAN AVERBEKE, W. 2004. When water is not enough: Institutions organisations and conflicts surrounding the sharing of irrigation water at a smallholder irrigation scheme in South Africa. International Workshop on Water Resource Management for Local Development: Governance, Institutions and Policies, 8-11 November 2004, Loskop Dam Aventura. *Proceedings*. [CD ROM]. Pretoria: WRC & CIRAD: 362-373.
3. MOHAMED, S.S., VAN AVERBEKE, W. & FERRER, S.R.D. 2004. Farming styles on smallholder irrigation schemes: the case of Dzindi. International Workshop on Water Resource Management for local development: governance, institutions and policies, 8-11 November 2004, Loskop Dam Aventura *Proceedings* [CD ROM]. Pretoria: WRC & CIRAD: 374-386.
4. VAN AVERBEKE, W. & PERRET, S. 2004. The maize filière at Dzindi, a smallholder irrigation scheme in Limpopo Province. International Workshop on Water Resource Management for local development: governance, institutions and policies, 8-11 November 2004, Loskop Dam Aventura. *Proceedings* [CD ROM]. Pretoria: WRC & CIRAD: 387-400.
5. LETSOALO, S.S. & VAN AVERBEKE, W. 2006. Infrastructural maintenance on smallholder canal irrigation schemes in the north of South Africa. International Symposium on Water and Land Management for Sustainable Irrigated Agriculture, 4-8 April 2006, Cukurova University, Adana, Turkey. *Proceedings* [CD ROM]: no page numbers.
6. TSHIKALANGE, T.E. & VAN AVERBEKE, W. 2006. The cultivation of *Brassica rapa* L. subsp. *chinensis* in Vhembe, Limpopo Province, South Africa. International Symposium on the Nutritional value and Water Use of Indigenous Crops for Improved Livelihoods. 19-20 September, University of Pretoria. *Volume of papers (not edited)* [CD ROM]. Pretoria: The Centre for Nutrition, University of Pretoria: no page numbers.

7. TSHIKALANGE, T.E. & VAN AVERBEKE, W. 2006. Effects of nitrogen, phosphorus and potassium on the production of marketable leaves of *Brassica rapa* L. subsp. *chinensis* in pots. International Symposium on the Nutritional value and Water Use of Indigenous Crops for Improved Livelihoods. 19-20 September, University of Pretoria. *Volume of papers (not edited)* [CD ROM]. Pretoria: The Centre for Nutrition, University of Pretoria: no page numbers.
8. VAN AVERBEKE, W. 2006. How do poor South African irrigators cope without a public land preparation service? International Symposium on Water and Land Management for Sustainable Irrigated Agriculture, 4-8 April 2006, Cukurova University, Adana, Turkey. *Proceedings* [CD ROM]: no page numbers.
9. VAN AVERBEKE, W. & JUMA, K.A. 2006. The cultivation of *Solanum retroflexum* Dun. in Vhembe, Limpopo Province, South Africa. International Symposium on the Nutritional value and Water Use of Indigenous Crops for Improved Livelihoods. 19-20 September, University of Pretoria. *Volume of papers (not edited)* [CD ROM]. Pretoria: The Centre for Nutrition, University of Pretoria: no page numbers.
10. VAN AVERBEKE, W. & JUMA, K.A. 2006. Effects of nitrogen, phosphorus and potassium on the production of above-ground biomass of *Solanum retroflexum* Dun. in pots. International Symposium on the Nutritional value and Water Use of Indigenous Crops for Improved Livelihoods. 19-20 September, University of Pretoria. *Volume of papers (not edited)* [CD ROM]. Pretoria: The Centre for Nutrition, University of Pretoria: no page numbers.

B5 Complementary research reports

1. VAN VLAENDEREN, H.R.M. 2003. Developing a participatory framework for development research in the Dzindi Irrigation Project. Pretoria: Technikon Pretoria. 22 pp.
2. LAKER, M.C. 2005. Best management practices for small-scale subsistence irrigation farming through participatory adaptive research: Report on a visit to Dzindi Irrigation Scheme. WRC project K5/1464//4. Department of Crop Sciences, Tshwane University of Technology, Pretoria. 19pp.
3. VAN DER STOEP, I. & NTHAI, M.M. 2005. Evaluation of the water distribution system at Dzindi Irrigation Scheme. WRC project K5/1464//4. Pretoria: Water Research Commission. 34pp.