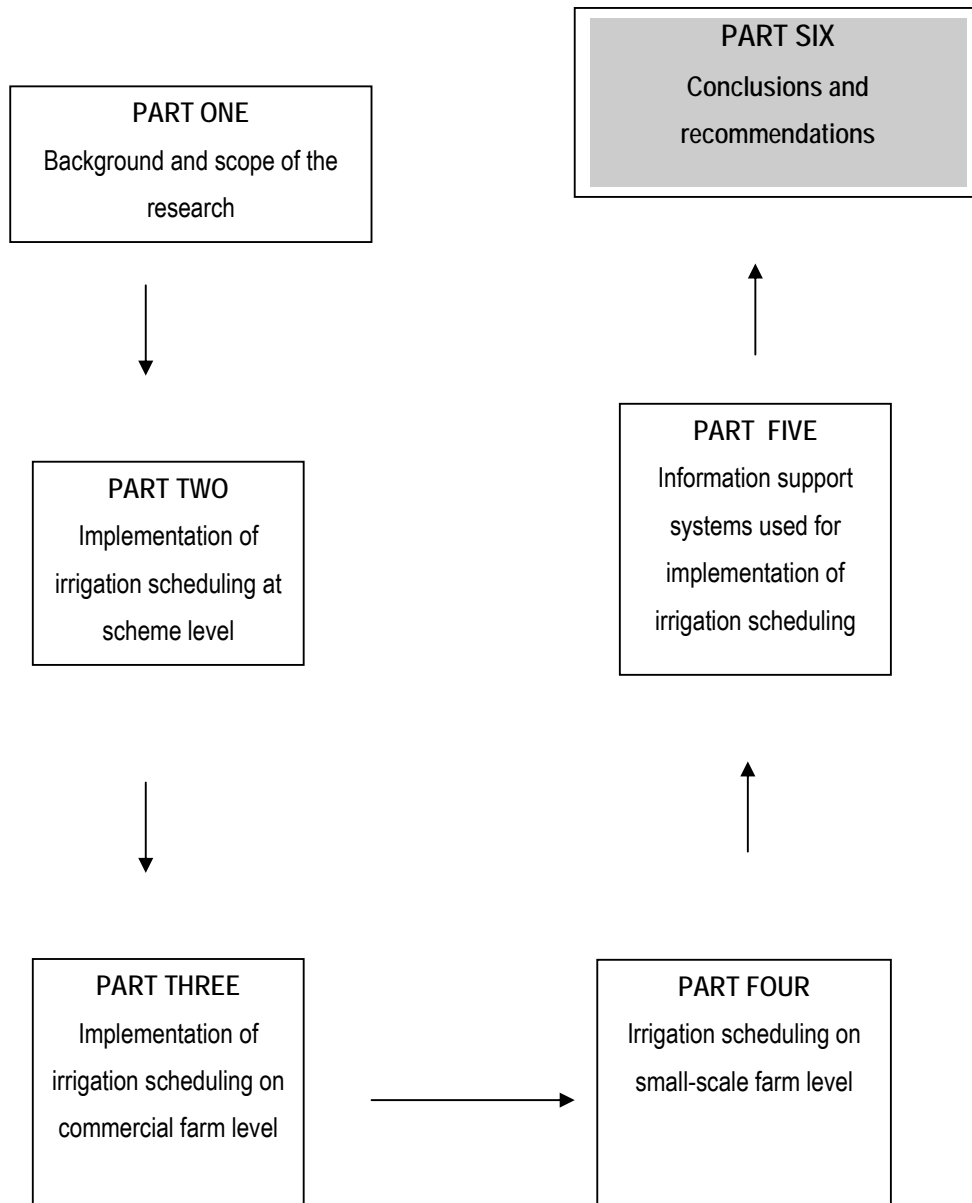


PART SIX

CONCLUSIONS AND RECOMMENDATIONS



CHAPTER 21

CRITICAL FACTORS THAT INFLUENCE THE ADOPTION OF IRRIGATION SCHEDULING

Irrigation scheduling, which implies the provision of the required volume of irrigation water at the right time, is widely recognized by agricultural scientists as being a prerequisite for efficient water management on the farm. Although a great variety of irrigation scheduling methods and models are available to irrigation farmers in South Africa, only 18% appear to irrigate according to this fairly strict definition, using objective or scientific irrigation scheduling methods. The majority of farmers regard the use of subjective methods, which is based on intuition, local knowledge and experience as gained over many years in irrigation farming, to be adequate for decision-making.

One interpretation of this low rate of adoption is that irrigation farmers generally have a negative attitude towards objective irrigation scheduling methods, and consequently prefer relatively subjective decision-making strategies. More likely reasons are that the information provided to irrigators through objective assessments does not meet their managerial information needs, and therefore not all the irrigators found the net benefit of the implementation of objective scheduling very positive.

Objective irrigation scheduling represents an attempt by scientist to intervene and improve the irrigators' management on the farm. However, what is not appreciated is that the successful decision and accommodation of a singular innovation in the total management system is much more complex than an isolated adoption (McCown, 2002). Farmers go through a hierarchy of decisions or judgements prior to the seeking of extra precision in his decision on irrigation timing. This gap of discrepancy between what sciences has to offer as a solution and what farmers expect and need or what they regard as appropriate represented the focus of this investigation. It is clear from the results from this study that an innovation like irrigation scheduling is composed of a technical dimension (technical device or procedure) but also of

an adapted human practice, including the condition that must prevail for such practice to happen (social dimension).

It was hypothesized that there is a significant difference among participant irrigation farmers in their irrigation scheduling techniques and practices use. Based on this assumption, several objectives were set. The objectives of this thesis are first to identify and classify the spectrum of soil-plant-atmosphere irrigation scheduling methods and techniques that are available for the use by irrigation farmers, researchers and extensionists in irrigation management, Secondly to determine the current adoption of irrigation scheduling methods and techniques by commercial and small-scale irrigation farmers on the irrigation schemes in South Africa, and to identify the human and socio-economic factors that influence the implementation of irrigation scheduling. The third objective was to identify the agricultural knowledge information systems that irrigation farmers use in their effort to learn more about irrigation scheduling to address these objectives. To address these objectives, the following assumptions were questioned that influence the adoption of irrigation scheduling practices.

- The implementation of irrigation scheduling practices on-farm is determined by independent and intervening variables. (Hypothesis 1)
- More precise irrigation scheduling offered by scientists is perceived to improve production efficiency. (Hypothesis 2)
- The technology level of farmers and the specific farm business characteristics determine irrigation farmers' approaches to problem solving and learning. (Hypothesis 3).
- Competent ground level support by research and extension professionals is conducive for the implementation of irrigation scheduling. (Hypothesis 4):

- Effective research-extension-farmer dialogue is necessary for the improvement of implementation status of on-farm irrigation scheduling practices. (Hypothesis 5):

Testing these five assumptions provided a framework for this thesis. This final chapter summarises how well the assumptions are supported by the empirical evidence found in this study. This study was embedded in a practical WRC research project (WRC Report TT 1137/1/05) and aims to contribute to the theory and practice of on-farm irrigation scheduling. Given this purpose, the study also concludes by posing some future research and extension challenges to improve on farm water use efficiency.

21.1 FACTORS THAT INFLUENCE THE ADOPTION OF IRRIGATION SCHEDULING

1. Differential perceptions regarding the concept of "irrigation scheduling"

As a concept, "irrigation scheduling" encompasses more than the restrictive definition recognized by agricultural scientists. Objective irrigation scheduling approaches represents a means for agricultural scientists to provide farmers and advisors with information for decision-making. The majority of irrigators perceive irrigation scheduling to include the use of intuition, local experience and observation in following "a schedule or time table for the application of irrigation." Irrigators thus tend to fall into one of the following categories:

- Some farmers have indicated a very strong belief in the use of more objective measuring of irrigation scheduling. Decisions are based on scientific indicators, and there is a general belief that technology provides an answer to their problems. For these farmers, objective measurement is ideal because data and measurements are repeatable and generally fit the paradigm of "scientific thinking".
- However, the majority of farmers use subjective irrigation scheduling, which is mainly based on intuition in adapting to fixed and semi-fixed

irrigation calendars. Little or no measured data is available, and therefore the decision taken by the farmer is hardly repeatable but rather based on the skills of a good manager and his specific mental model. Social researchers have shown that highly complex non-linear problems are often better solved by intuition than engineering. This is what a “good manager” means (Hayman, 2001).

It is clear from the findings that often the farmers’ mental model and the scientists’ scientific model of irrigation scheduling differs. Vanclay (2003) provides 12 reasons for non-adoption of scientific technology by farmers. Most of these reasons relate to the failure of scientists to understand the worldview of the farmer and the constraints under which they operate. The general tendency among agricultural scientists is to regard only empirical knowledge based on the biophysical system as being valid to deal with the complexities and variability of farming systems, and thereby often ignores decisions based on farmer experience and which is compatible with the specific social needs and situation of the farmer. This “technical-rationality” is often grounded as professional knowledge, but has often failed to resolve the dilemma of rigour versus relevance that farmers face in their daily decision-making.

These differences regarding the definition of irrigation scheduling were also evident within the discussions of the advisory committee members. Some members were convinced that irrigation scheduling referred only to the implementation of objective irrigation scheduling methods, while others also perceived the use of intuition as an alternative irrigation scheduling method, for which the concept, unless artificially delineated makes provision for.

It is clear that farmers and agricultural scientists have different perceptions regarding the definition of irrigation scheduling and this goes a long way in explaining the often-unsuccessful communication between scientists and farmers and the resulting low adoption rate. It is important that cognizance is taken of these differences and that more effective dialogue is pursued (between scientists and farmers) which is characterised by empathy and a

willingness to listen and to engage in co-learning. Irrigation strategies can only be efficient when designers, irrigation suppliers, and agronomists and farmers communicate effectively and on a regular basis.

2. The effect of situational variation on decision making regarding irrigation scheduling

Farming enterprises involved in the growing of high value crops are more prepared to make use of objective irrigation scheduling because of the large scope of perceived improvement in crop quality. The current trends adopted within a high technology level farm must keep up with the traceability of product, changes in fertilization strategies from feeding the soil to feeding the plant, new soil management philosophies, integrated crop management, use of softer pesticides and herbicides, the world of ISO standards and Eurepgap and also produce to improve margins. The new paradigm in which high value crop farmers are competing also made farmers more aware of precise irrigation scheduling.

Precision scheduling provides more accurate information for tactical decision-making that could help the farmer to minimize the risk and to deal with change and variability. The decision of the farmer whether or not to use precise irrigation scheduling for tactical decisions, will depend on the position of the farmer on an input-response curve (Figure 21.1). For many tactical decisions the response curve is steep and then flat. When the farmer is still on the steep slope of the curve (A), the relative advantages will still be visible and relatively big (large response to the introduction of irrigation scheduling on the total irrigation requirement for a specific crop). Furthermore it will be cost-effective to spend additional time and resources on fine-tuning the irrigation scheduling. However, when a farmer is confronted with situations that are marginal and where risk and uncertainty prevail because of the flatness of response (beyond the optimum point B), there may be less to be gained from implementing precise irrigation scheduling. Even though water is the primary constraint to production, it represents a very small percentage of the total input costs (as indicated in Part Three). Because of the uncertainty of the

location of point B and the fact that farmers in general are risk averse and fear of sliding down the steep response curve towards point A, a possible strategy is to apply more water than necessary (“insurance irrigation”). Therefore, operating on the flat part of the curve between points B and C as indicated in Figure 21.1 provides cheap insurance for a high value crop like horticulture. This study confirms the findings of Stirzaker (1999) that between points B and C, little financial incentive is perceived by farmers to reduce water application.

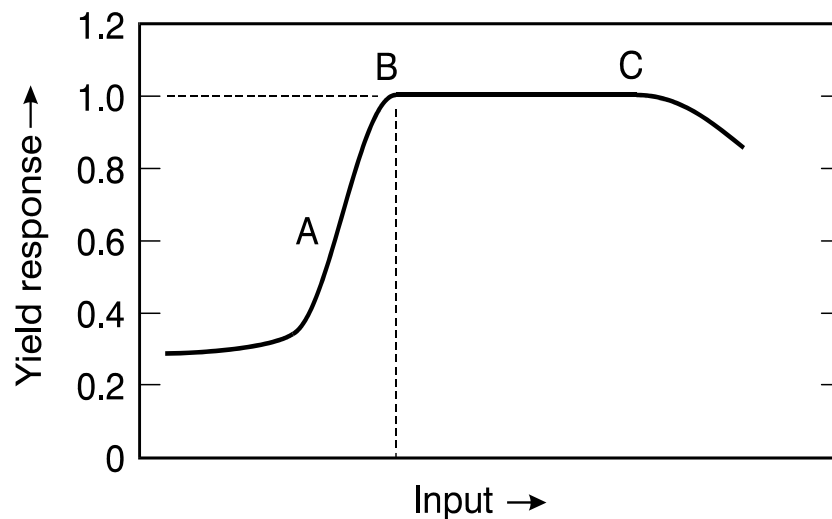


Figure 21. 1: Input -response curve for irrigation decisions

It is, therefore, imperative that agricultural scientists and extensionists should try to understand the difference between the real risk perceived by the farmer at farm level which are addressed with intuition most of the time, and the assumed risk by scientists in their modelling on a field level. Tactical decisions with regard to irrigation management refer to decisions taken everyday. These decisions are difficult for the farmer to take because of the uncertainty of their outcome. Furthermore, the farmer's position on the response curve should also be established through effective dialogue between the relevant stakeholders before recommendations regarding irrigation scheduling are offered. This dialogue implies effective two-way communication and continued, thoughtful exchange of ideas that matter most regarding irrigation management, and scheduling time.

3. Farmer's decision-making is limited by insufficient information

The irrigation farmer is in the first place a producer of crops. Therefore, according to Brookes (1948), the crop farmer is concerned with the integration of all the factors that determine plant growth and development, and it is the basic knowledge of this integration that is deficient. Rather than a shortage of information, many of the commercial farmers complain about “information dazzle” or information that cannot be readily integrated for use in decision-making regarding irrigation management.

For this to happen, it is essential that accurate, reliable, timely and appropriate information is developed, and effectively disseminated to extensionists, advisors and end users. However small-scale farmers experienced the opposite where appropriate and specifically adapted irrigation management information is often lacking. The majority of small-scale irrigation schemes are situated in extensive rural areas where modern communication technology like telephones, Internet and regular contact with professionals and the printed media is limited. This calls for creativity and special inputs in the development of appropriate training material to support small-scale farmers and extensionists.

This study indicated that the general technical knowledge and competence level of many of the men and women responsible for the support of the irrigation farmer are inadequate. Perhaps in the first instance it is the lack of regular self-reflection by scientists that had contributed to the adopting of a hard systems thinking as a common sense justification for their “scientific work” (Sebilotte, 1994). Unless scientists fully understand that irrigation farming systems are hierarchical systems, where what happens at one level is explained by what happens the level below, and is giving meaning by what happens at the level above, any research product will likely be trivial.

Furthermore, it is likely that the educational system responsible for the training and preparing of students to take up the relevant roles in water management is limited or inadequate. This shortcoming in training and competence of

extensionists and advisors was confirmed by 49% of the irrigation consultants who referred to recommendations made by some of the consultants, which are often not compatible with the farmers' practical management needs. If farmers are unable to perform uniformly and precisely, according to the irrigation water application recommended, they tend to follow a general tendency of applying rather an excess of water over the whole field than too little water ("insurance irrigation").

The challenge exists for extension and irrigation consultants to gain the necessary skills and competence, not only to transfer general knowledge and information, but also to support farmers with the identification and conceptualization of problems in irrigation management. Extension involves more than just the transfer of information, but requires effective co-learning between the relevant parties by following a learning based approach.

There is an urgent need for a study into the current status of training in irrigation management offered at all the tertiary institutions in the country. The curricula offered in irrigation management at tertiary institutions should be evaluated and shortcomings identified and addressed where possible.

4. Investment in irrigation scheduling

Experienced farmers in the use of objective irrigation scheduling methods indicated that it takes an enormous amount of work and time to get scheduling to be aligned as part of standard day-to-day irrigation management on the farm (Naude, 2002). Respondents perceive the implementation of objective irrigation scheduling methods as time consuming and costly and not practical enough for implementation on the farm. Therefore many irrigators do not perceive enough benefits (usefulness) for them to continue with the implementation of this scheduling approach and tend to revert back to subjective irrigation scheduling methods. Farmers are likely to continue with traditional irrigation scheduling technology until new irrigation scheduling technology is developed, which provides directly visible results or benefits with minimum cost or inputs time.

The benefits of the implementation of more precise irrigation scheduling methods tend to be more evident to producers of high value and intensive crops. The improvement of crop quality, saving on electricity costs, increased production yields and efficient use of fertilisers are perceived by this group of farmers as important motivational “driving forces” for the implementation of objective scheduling. However, for a large number of cash crop growers (cereals, cotton, etc), the possible financial advantages are not always evident and therefore these farmers generally are more willing to follow their meta-model based on intuition, experience and observation. This implies that the precision irrigation scheduling methods and procedures offered by research has limited value to offer to these farmers. This has not to say that in some years under certain conditions (for instance periods of drought), more precision will not make significant difference.

There is a great need that the risk that irrigators are prepared to take with the use of objective irrigation scheduling methods should be discounted against the possible benefits to gain from such implementation. Although this study identified certain trends, a more detailed analysis of the role of risk and uncertainty in the decision-making of irrigators is needed.

Seven percent of the respondents perceived absolutely no change in production efficiency since the introduction of irrigation scheduling on the farm. These include the number of irrigators that were newly introduced to the use of objective scheduling methods and some farmers involve in the production of pastures that raised certain concerns regarding the implementation of objective irrigation scheduling methods. A possible explanation for the relative low adoption rate of irrigation scheduling in the pasture industry is because of the requirements with regard to irrigation interval and amount as well as the large number of fields all at different crop growth stages. Therefore, for many in the pasture industry, it makes sense to follow a fixed or semi-fixed irrigation schedule in combination with the use of intuition. Although the use of conventional methods like the soil auger and shovel are still commonly use by these farmers, an urgent need exists to investigate the possible adaptation of real time irrigation scheduling models

into irrigation calendars for pasture production. The possible use of a soil probe and the wetting front detector should also be further investigated and demonstrated to farmers.

5. Wrong extension packaging of irrigation scheduling?

In the past the benefits of possible water saving was perhaps overemphasized, while other relative benefits like saving on electricity operational costs, improvement of nitrogen and nutrient management, improvement of quality of crop and the increase in production yields were often neglected or not properly highlighted by extension in the dissemination of information. Farmers perceived the relative advantages attached to the practising of irrigation scheduling rather as a “multitude of possible benefits” offered to address the complexities of a specific farming system and not as a single advantage such as the saving of water.

Future initiatives by extension and research should therefore be directed to ensure that irrigation scheduling is offered to irrigators in an appropriate and sensible manner. Instead of focusing only on the conservation of irrigation water through more precise irrigation scheduling approaches, irrigation scheduling should rather be recommended for “trouble shooting” in irrigation management. The additional benefits mentioned above are invariably more visible to farmers and will also help to change perceptions, beliefs and attitudes of farmers towards the implementation of irrigation scheduling.

6. Uncertainty regarding future irrigation water allocations

Although farmers in general perceive the conservation of irrigation water to be very important, the implementation of irrigation scheduling to ensure more efficient water use on the farm is perceived as more important than saving water per se. Farmers’ attitude towards the saving and efficient use of irrigation water is in general positive, however many farmers are apprehensive as to whether the practising of efficient irrigation practices on-farm may lead to a possible revisit of current allocations of irrigation water by

DWAF. The following statement by a very progressive irrigation farmer in Mpumalanga confirms that:

“Not many changes have taken place as far as an irrigation farmer in an irrigation scheme is concerned, except that if you do not keep on using the allocation of irrigation water, you will lose it. This makes farmers very much wary about the real value of irrigation scheduling”

It is therefore important that government (DWAF), as well as the relevant water management institutions, urgently address this concern or misperception of farmers appropriately to assure the necessary security of water allocations. If not properly addressed this misperception could act as a possible hindrance to the adoption of efficient irrigation management.

7. Potential role of WUA as a learning system in promoting efficient on-farm water use practices

The fact that 96% of the respondents also regard the implementation of irrigation scheduling by their fellow farmers as important, is a clear indication that farmers perceive irrigation water as a common property and therefore also support the use of sustainable irrigation practices not only at a farm-level, but also on scheme level. Often the assessment of water resources along with the planning and construction of the irrigation scheme is the responsibility of engineers. Usually the irrigation deliveries are set, and not specifically based or related to crop water requirements. Lack of cooperation and coordination between farmers and the administration staff on irrigation schemes contributes to the relatively poor water use efficiency experienced on some of the schemes.

The supportive role, which local water institutions should play with regard to the adoption and improvement of effective water management principles, emerged from the survey. Eighty percent of the respondents were of the opinion that the WUA could and should play a more definite role as a “learning system” for changing farmers’ behaviour with regard to efficient water use. As

Water User Associations in South Africa will implement the Water Demand Strategy (WDM) as adopted by the Department of Water Affairs (1998), through the implementation of appropriate Water Management Plans (WMP), one of the new expected roles, which WUAs and irrigation agencies should take up, is the empowerment of farmers through facilitation of appropriate training programs. For the implementation of the WMP, it is expected of the WUAs to interact effectively and regularly with farmers, who are expected to have a prominent say in the design and management of an irrigation scheme. To accomplish this it is important that farmers should be prepared and motivated to organize themselves for the purpose of water user associations. This will also imply that an organisation like the WUA have to change their current way of thinking and adapt to the needs as expressed by the environment. In order to adapt, WUAs must become learning organisations- where within and between hierarchical levels of the organisation they share experiences and learn from it (Senge, 1993). Also the necessary support (technical and managerial) and general awareness should be offered through efficient dialogue between the WUAs and irrigation farmers.

A practical example is the role that the water authorities in Hermanus played during the early 90's as indicated in Box 21.1.

Box 21.1: Making Water Demand Management work!

The town of Hermanus in the Western Cape Province of South Africa faced a serious shortage of domestic water in the late 1990's. An option to alleviate the problem was to build a storage dam- but the high construction cost of it did not make this an attractive solution. The water authorities then decided that they would attempt to convince users to use less water. Subsequently an escalating block tariff structure for water was instituted but no significant changes in water use were experienced. When the authorities started to show the tariffs with user-friendly graphs on the accounts, users began to realize the cost saving in using less water. The outcome was that the total water use for the town decreased far beyond expectations and the building of the dam will not be necessary for several years to come.

The current initiatives and activities of some WUAs, which were visited were found to be remarkable and were perceived favourably by farmers. However, there are many water institution managers that still perceive their role only as that of delivering bulk water and the general management of the scheme.

8. *The use of computer models for irrigation scheduling*

Ownership of computers is with the exception of the small-scale farmers, no longer an issue amongst commercial farmers. In this study, all respondents indicated that they have access to computers, but computers were used rather for general farm management and record keeping (largely for tax and labour management purposes) and not for irrigation scheduling purposes.

The perceived usefulness of irrigation scheduling models is confined and the majority of irrigators still rely on intuition or paper and pen for key irrigation scheduling decisions. Apart from the requirement of certain levels of skills, computer literacy and access to weather data, regular interaction between professional advisors and irrigation farmers will always be needed before it can be implemented efficiently. These findings illustrate that irrigation scheduling models and programmes are predominately advisor-driven rather than farmer-driven, which bring about their distribution largely being geographically bounded. It is therefore clear from the response of irrigation farmers that although computer models and programmes provide useful information for discussion in a face-to face interaction, it cannot function in a *stand-alone mode*.

As already been emphasised earlier in the document, it must be kept in mind that models are built mostly by agricultural scientists and therefore reflect the decision-making style of the developer. Therefore it is important that scientists need to understand the farmers' management of risk and enter into a co-learning adventure through effective dialogue with farmers. Only through dialogue the real needs of farmers (felt and unfelt) will be identified to unlock the local knowledge and intuition of the farmer.

It is clear from the investigation among farmers that make use of scheduling models, that modifications to the majority of available computer irrigation scheduling packages are necessary to meet the requirements of the end-users. This includes the addition of online help and more clear and easy to understand graphical simulation of irrigation requirements, as well as the modification of the “scientific language” used in the models.

It is recommended that an alternative to the use of simulation models for real time irrigation scheduling should be developed like a site-specific irrigation calendar for irrigation farmers. This approach is currently being tested in Taung amongst the small-scale farmers involved with barley production. Initial results appear to be very promising and farmers are eager to apply the recommendations.

9. Flexibility in irrigation scheduling

The implementation of objective irrigation scheduling techniques, which are based on field soil water balance, requires that farmers take an appropriate amount of water from the supply system timeously. The inability of the bulk conveyance and delivery system to deliver water at the farm gates with the necessary reliability and flexibility will hamper the implementation of objective irrigation scheduling. This was found to be common in the older irrigation schemes where water is delivered to farmers in a predetermined schedule. With predetermined scheduled delivering followed water stress periods, which occur when, the time intervals between successive water applications are too large.

The building of on-farm storage facilities can provide the farmer with more flexibility in terms of the water he/she receives and the applied irrigation practices. Economic factors like additional capital and operating costs required compared with the potential yield reduction or increase because of the additional reliability of water supply will influence the final decision made by the farmer.

Lack of flexibility in water delivery was also attributed to the limitations of the canal system. In many of the older irrigation schemes the relatively poor state of canals and long distances that water has to travel with relative high spillage, caused serious problems in terms of the supply of water to farmers, especially during peak growing periods. Although the majority of irrigators are aware of the use of Ruraflex, not all of them can irrigate only during the nighttimes or low demand periods. Due to certain canal capacity limitations they also have to irrigate during peak and standard demand periods that are less cost effective. Therefore although a farmer can select a certain irrigation system designed to apply a certain volume of water in a 24-hour period, certain shortfalls could be created because of limitations in the delivery of water and, therefore, it is common to find farmers irrigating 24 hours per day, for seven days per week during peak growing periods.

With existing bulk water conveyance systems it is recommended that the designer (engineer of the scheme) should determine whether cost-effective alterations can be made to increase the manageability and effectiveness of the canal system. It is important for extensionists, designers and planners of irrigation systems, farmers and irrigation scheme managers to communicate regularly and effectively to address situation specific shortcomings regarding the delivery and reliability of irrigation water. Water management institutions like the WUA should also employ all reasonable effort to:

- Calculate the irrigation requirements for each crop grown in the WUA district
- Estimate as closely as possible, the area of each crop grown, preferably the average over more than one year in the WUA district, and
- Use the above to calculate the monthly and annual irrigation requirements for the WUA.

This information plus the use of a computer program like SAPWAT can assist irrigation scheme managers with the planning and management of an

irrigation scheme. Appropriate training in the use of SAPWAT and to calculate the net irrigation requirements of an irrigation scheme, is essential.

10. Distribution uniformity of irrigation systems

The ability of an irrigation system to apply water uniformly and efficiently to an irrigated area is a major factor that influences the agronomic and economic viability of a production system. The awareness and regular evaluation of distribution uniformity and application rate of an irrigation system is an important managerial function required from an irrigator.

The distribution uniformity of an irrigation system depends both on the characteristics of an irrigation system and on the managerial decisions of farmers (Pereira, 1999). Surface irrigation is influenced primarily by the soil intake characteristics, while overhead irrigation is influenced by the condition of sprinkler packages and the pressure variation within a system (Reinders, 2003). These factors of an irrigation system need to be correctly managed to ensure that the distribution uniformity is at an acceptable level, which will ensure the optimal use of water resources.

It is a concern of many of the irrigation advisors and professionals that many farmers do not regularly evaluate the distribution of uniformity and application efficiency of on-farm irrigation systems. Although 64% of the respondents indicated that they measure distribution of uniformity of their irrigation systems on a regular basis, these practises were not validated on the farm. From discussions with extensionists and irrigation consultants it appears as if this figure is inflated. Eighteen percent of the respondents admit they do not pay attention to this aspect of irrigation management. If a farmer does not regularly measure the distribution uniformity of an irrigation system, he/she cannot calculate the mean application rate of irrigation, and is therefore not aware of the variability of application of irrigation. A critical factor often neglected by designers and planners of irrigation systems is the ease of management and operation of the irrigation system. The easier the system operation instructions are, the more likely the operators will carry them out.

Irrigation systems should be robust and easy to maintain by semi-skilled persons.

It is recommended that a comprehensive operation and maintenance manual always form part of any designed irrigation system. Extensionists, advisors and water institutions should play a more distinctive role in increasing the awareness of irrigators in this regard and also become more active in the evaluation of irrigation in the field. Currently, only the ARC ILI is offering this service countrywide with the help of a field laboratory unit. It is recommended that more extensionists and advisors responsible for the support of irrigation farmers should be equipped with a field laboratory that could be used for the field evaluation of irrigation systems and for regular on-farm demonstrations.

Although drip irrigation is generally efficient when it is well managed, flood irrigation should not be dismissed as a matter of principle. Properly designed, constructed and operated flood irrigation systems are very efficient in terms of water use, with the benefit of low running costs. Laser planning devices enable performance improvements in the infiltration system for level basins and level furrows found in the Lower Orange irrigation area. The impact of levelling accuracy on distribution uniformity and on yield was perceived to be highly significant. This was therefore adopted by the majority of farmers in the Lower Orange as a standard approach for new irrigation development. The need for appropriate maintenance and precision of land levelling is important as it facilitates irrigation scheduling and induces higher yields.

Incentives (like soft loans, rebates, etc) should be considered for those farmers who are prepared to use efficient irrigation management. Even on the farm these incentives could be introduced where the farmer awards his/her block manager for the efficient water utilization on the farm.

11. Irrigation water tariffs

On the majority of schemes the individual abstraction of irrigation water is not measured. Irrigators generally pay water tariffs that are based on irrigated

area, and not on actual water volumes used. Consequently there is little financial and social incentive for the implementation of efficient water use.

It was generally found that farmers have a positive attitude towards the implementation of volumetric water tariffs, where a flow meter is installed to measure individual abstractions. The introduction of water tariffs based on volumetric allocations instead of on a flat rate based on area listed for irrigation is acknowledged by the majority of farmers (85%) as being an important condition for more efficient water use. This, however, requires proper water measurement at the intake of the bulk water conveyance system and at each outlet. The findings of a WRC research project (vd Stoep *et al.*, 2005) on the evaluation of different flow meters available for the irrigator indicated that commercially mechanical meters are available at relative low costs. These authors also identified the need for greater awareness by WUAs with regard to the availability and suitability of devices, especially as far as new technological development is concerned. However, from a farmers' point of view, it was identified that these measuring devices should be accurate and the users should trust the readings, which are generated.

The report by vd Stoep *et al.*, (2005) identified the need for the developing of a water measuring policy as a matter of urgency to guide WUAs in the selecting of appropriate devices and procedure for implementation. The use of volumetric measurement will mean that irrigators pay in proportion to their use of water services. Based on the findings of this research, the success of such a proposed policy will depend on the effectiveness of the communication between WUAs and farmers with regard to the process of measuring and interpretation of measured data. A visible and simple understandable way should be followed on a monthly basis to inform irrigators about their position regarding the water allocation. Financial incentives should be put in place for the farmer who is willing to schedule more accurately and prepared to use water more efficiently on the farm. Water trading is such an exciting mechanism to encourage the judicious use of water. The current tariff system does not provide incentives for farmers who use water wisely and should be revised.

12. Required attributes of extensionists and consultants for efficient knowledge support in irrigation management.

Several attributes of consultants and extensionists were identified in the study, which are critical for the building of trust and credibility between irrigators and the advisor or consultant. These are the following: technical competence; timely and focused support; integrity and credibility; understanding the context of the farmer and the industry; ability to interpret measured data and communicate effectively; availability, empathy and interpersonal sensitivity; and a preparedness to learn from each other.

Advisors and extensionists should be able and prepared to learn from each other, and from the farmer as well through effective dialogue between relevant stakeholders. This approach requires a paradigm shift from extensionists, as they should be prepared to take responsibility for their recommendations, but also be prepared to listen, observe and interpret what farmers are saying. It is important that advisors, consultants and extensionists involved in the dissemination of information regarding irrigation technology, should take cognizance of these attributes that were identified by the farmers for successful interaction with extension.

13. Knowledge support system

Irrigation consultants, cooperative extensionists and professionals from the industry are responsible for supporting commercial farmers with information regarding irrigation management. These professionals are usually used where farmers implement objective scheduling methods. The necessary skills and competence to interpret data and technology into useable information for the farmer is of paramount importance. Unfortunately many of the irrigation scheduling consultants and advisors operating as knowledge support system to commercial farmers are not properly trained in irrigation management and equipped to fulfil this responsibility. They also don't allow themselves enough time to spend and help farmers with the interpretation and possible recommendations concerning the measurements. Farmers perceived the

regular visits of consultants (face-to-face interviews) as important in the dealing with feedback from irrigation farmers on the current trends of soil water balance in the field and the building of trust between parties.

It is recommended that a professional association like SABI could assist with the development of ethnic standards and competence requirements for accreditation and licensing of irrigation consultants and advisors. Although SABI is currently offering some short courses in irrigation management and design, the successful completion of such training is not stated as a prerequisite for the delivering of irrigation consultancy services.

14. Relationship between farmers, researchers and extensionists

A great obstacle to the adoption and use of objective irrigation scheduling is the lack of interactive communication between researchers, extensionists and farmers. Reviews of the World Bank and USAID experience in research have all identified research-extension linkages as constraint in realizing the full benefits of research (World Bank 2003, USAID, 2003). Although this relationship between research, extension and farmers seems ideal in theory, it has not been successful implemented in agriculture. As agriculture becomes more knowledge intensive, these linkages are found to become even more critical, demanding target and user-driven research and technology development.

Poor adoption rates of irrigation scheduling technologies demonstrate that linear, reductionist and positivist perspectives, or the 'Transfer of Technology' approach (TOT) familiar to scientists (Röling, 1994) do not work well for this particular problem. The TOT perspective does not easily accommodate the dialogue and negotiation among stakeholders necessary for working through a complex issue like irrigation management with many variables. It is important to harness the local knowledge and experience of farmers into the development and implementation of irrigation scheduling methods through participatory action research. This partnership between research-extension-farmer suggests a learning process of investigation, assimilation and of

sharing as based on the experiential learning cycle of Kolb (1983). Essential to the partnership is ownership by all stakeholders of the learning and sharing paradigm. This approach entrenches the importance of mutual or co-learning between stakeholders. According to Cox *et al* (1995), the metaphor of a “*dance*” is used to describe the true participation where farmers and agricultural scientist engage in an effective dialogue and learning of each other’s dance steps. This involves improvising, where dancers improvise as they go, testing each new step for its fit with other steps and with the whole dance pattern (Hayman, 2001). Essentially this demands for a paradigm shift from many researchers and extensionists, as new roles are required from these professionals.

15. Institution building

Farmers are keen to take up information and technology once they can perceive that it will improve their on-farm results, especially productivity levels. The overwhelming response in terms of the role that farmers themselves play as a recognised learning source in terms of irrigation scheduling, emphasises the important role that study groups (farmer directed groups) and agricultural institutions (WUAs, irrigation board, farmer unions) could play to deliver and provide the many features which make learning and training effective for adult learners. The “shared identity” to the learning network will establish tacit and explicit rules of coordination between individuals and different groups, which will generate social capital as an important step in the process of learning.

Therefore the following actions are important:

- Establishment of well-organised and well-facilitated farmer directed groups.
- Support of institutions in the creating of a network that will induce the building of a “shared identity” of network members, since this will increase the opportunity for learning to be shared.

- More emphasis on delivering irrigation management and irrigation scheduling training through agricultural institutions and organizations.
- Farmers should place more emphasis on the agricultural institutions to identify training needs to help improve participation

16. Learning cycle of irrigation farmers

As farmers proceed through the learning process of evaluation, trialling, and determining whether a specific irrigation scheduling method was appropriate for a specific farming system and their personal goals, some either adopted or rejected the scheduling method. Fifty nine percent of the respondents changed their perceptions regarding the most appropriate irrigation scheduling method since the inception of irrigation scheduling. The majority of respondents who changed their practices were not satisfied with the accuracy of the scheduling technique or with predictions offered by an irrigation scheduling model. Many expressed difficulties with the implementation and use of the tensiometer in the past, which also reflect the fact that certain irrigation scheduling approaches require a very steep learning curve to be achieved before it could be successfully implemented. From the findings it is clear that many farmers did meet these requirements but were disappointed with the results of implementing these methods of irrigation scheduling.

The majority (69%) of the respondents who discontinued objective irrigation scheduling took the decision because they were of the opinion that they had gained enough knowledge, confidence and experience to continue with the use of subjective scheduling methods. There is a clear tendency for farmers to initially prefer objective irrigation scheduling methods up to a stage where they feel that they have the situation under control, and will then move on to another phase of the production cycle which may include marketing, changing fertiliser management or labour management, etc. During this phase of production, farmers will implement subjective irrigation scheduling methods based on their local experience and knowledge gained.

The more experienced farmers often only use the objective irrigation scheduling methods as a monitoring system to re-assure them that they are still heading in the right direction. If necessary they will revisit the irrigation scheduling practice, which they have adopted. This “experiential learning cycle” which many farmers are following should be acknowledged. The extensionists and researcher should identify the position of a farmer on this learning cycle in order to render efficient support to the basic steps and translating that takes place during learning and by offering new learning opportunities. The understanding of the learning cycle that farmers are following also helps us to identify the different learning styles that farmers adopt. This will only be possible if efficient communication between the farmer and the professionals is developed.

Understanding the irrigator’s perceptions, needs and knowledge is critical for the successful implementation of efficient irrigation scheduling practises. The study has shed much light on these behaviour determinants, but follow-up investigations are necessary regarding the following:

- Establishing how perceptions and needs change over time and how they influence the pattern of implementation (approach of irrigation scheduling). This could be achieved through follow-up surveys involving, as far as possible, the same respondents or through more qualitative and case study approaches.
- Accurately quantify the various behaviour determinants in order to determine which individual determinant, in comparison to a cluster or multitude of them, explains variation in behaviour.
- A more detail assessment of the role of risk and its quantification as it pertains to probability of success as well as probability of failure and an evaluation as to whether and to what degree this encompassed in the valence perception of both advantages and disadvantages.

- Monitoring whether and to what degree needs (as reflected in problem perceptions) and their compatibility change as the adoption behaviour changes.

17. Learning and information sources used by irrigation farmers

A variation in styles, preferences and motivation for learning exists between the commercial and small-scale farmer, as well as between those farmers who are more progressive and those who are less business-oriented. Learning of the progressive commercial irrigation farmers was identified to be more self-directed, action-oriented and experiential in nature. Therefore, farmers in general indicated preference to informal learning opportunities as part of their farmer networks rather than the delivery of formal training. Networks with fellow farmers are particularly important for the commercial irrigator. Other learning sources, which include both social and expert sources, are the local cooperatives, private consultants and industry experts. Farmers involved in objective scheduling are more willing and prepared to seek additional “external” learning sources. The general expectation that the technological level of the farm determines the choice of irrigation scheduling method as well as the information sources used is supported.

Generally the small-scale irrigators also use farmer networks but rely very much on information from the departmental extensionists in regard to irrigation management. The isolation experienced by many of the small-scale irrigators due the remoteness of the areas where they are farming, often reduces the opportunity to build information and support networks conducive to sustainable irrigation management.

Access to different sources of technical knowledge and information is likely to improve the value of the initial trial period through the possible impact regarding the farmers’ knowledge and will in turn influence the rate of adoption. Extensionists and irrigation advisors/planners responsible for the design and dissemination of irrigation scheduling information should recognise the adoption factors based on the age, farm size and level of farm

management towards the methods of receiving information on irrigation scheduling. It is important to ensure that the necessary “information and learning networks” exist to ensure full participation of all the stakeholders. The role of informal farmer networks needs to be appreciated by irrigation extensionists and advisors in the dissemination of information.

Basic knowledge of the plant-soil-climate system is an essential requirement for the effective implementation of irrigation scheduling. Unfortunately many farmers (even experienced farmers) are lacking knowledge about the basic principles involved in irrigation management. Water-use efficiency on the farm does not only entail the implementation of irrigation scheduling but also requires a holistic view of the critical management aspects that will ensure optimal water use on the farm (i.e. cultivation, crop management and soil conservation practices). It is therefore not adequate that farmers are trained only in terms of irrigation management without upgrading the necessary knowledge and skills required on the basics of the soil and plant system.

The development and offering of basic courses in the introduction to irrigation principles and irrigation management similar to the “Waterwise on the farm” program offered in Australia should be considered and investigated. A training program, which includes activities like experiential learning, on-farm training, workshops, and field days, benchmarking of best management irrigation practices and studying of case studies in irrigation, could be considered. An attractive incentive scheme should be attached to this program, and the program should be planned and developed to incorporate both commercial and small-scale irrigators.

The possible extrapolation of the Water Care Training offered in the Limpopo Province under its revitalisation initiatives on small-scale irrigation schemes to the rest of the small-scale irrigation schemes in the country should be investigated.

In Chapter 2 (Part One) an overview and classification of the irrigation scheduling methods and computer programs available to irrigators in South

Africa was presented. This information could possibly be used in the development of information brochures and training material to serve the needs of commercial and small-scale irrigators. Especially new irrigators are not always aware of the possibilities (technologies and methods) available to them regarding irrigation scheduling, and currently no concise but also comprehensive manual is available.

21.2 FACTORS THAT INFLUENCE THE PROPAGATION OF IRRIGATION SCHEDULING AMONG SMALL-SCALE IRRIGATION FARMERS

There is no dispute that the extension efforts on the majority of the small-scale irrigation schemes have not achieved the desired results. Farmers often referred to the general lack of technical skills (particularly irrigation management) and the competence level of many of the extensionists.

The following recommendations and conclusion are proposed regarding the propagation of irrigation scheduling amongst small-scale farmers:

1. Ground level support for the implementation of sustainable irrigation practices

The majority of small-scale irrigation farmers perceive irrigation management as “new technology”. The innovation processes of irrigation scheduling techniques with its three main components namely, creating a technique, dissemination of the idea and the adoption of it form a whole. The three components cannot therefore be allocated to different role players namely research who design the technique, extension services to disseminate technology and farmers to adopt it, without effective interaction between the relevant parties. Small-scale farmers, as illustrated in the case study at Bethlehem should also be included in the process of innovation and conditions should be created for them to participate. Therefore an interdependent partnership of researcher-extension-farmer should be developed. The success of the interface between farmers and extensionists

will depend on the credibility of extensionists as illustrated through his technical competence in irrigation management.

The important role to be played by a mentor in the daily support of small-scale farmers was emphasized with the case studies of small-scale irrigation farming. According to the definition of de Beer (2005), a mentor is simply “someone who helps someone to learn something the learner would have learned less”. Therefore, with this definition in mind, extensionists and selected farmers with the necessary experience in irrigation management can play an important role to help small-scale irrigation farmers with the improvement of on-farm water use efficiency.

2. Sharing of irrigation equipment like the centre pivots at Taung is only possible with good cooperation between farmers.

Small-scale farmers need to be well organized, and be able to manage and maintain their shared equipment. Local formal and informal farmer organisations are essential for proper cooperation and coordination of activities on an irrigation scheme. The positive interventions of farmer groups and organizations like the Farmer Support Units at Taung, local commodity farmer groups at Nkomazi and Tshiombo, block committees at Bethlehem as well as the role of management committees to steer the irrigation management on a scheme or project emphasize the necessity for the establishment of effective farmer organizations where the beneficiaries could take responsibility for their own development. Training and capacity building of farmers in this regard is needed, and should be the responsibility of extensionists and water institutions.

3. Strong institutional arrangements

A number of grants are available from DWAF (vd Merwe, 2004) to assist small-scale irrigation farmers, but two important conditions that have to be met before the applications can be made, is firstly that farmers have to form a legal entity (preferably a WUA) and secondly, that they must have applied for

a water use license. The importance of the capacity building of farmers to enable them to form and effectively manage Water Use Associations as a legal entity on the irrigation schemes, is but one of the several challenges that faces extensionists and other key stakeholders in the development of small-scale irrigation.

4. External management of an irrigation scheme

Clarification of land tenure arrangements of irrigation farmers could increase the incentive to invest in their land and irrigation systems. This factor influences the general operation and attitude of farmers to maintain infrastructure and willingness to spend on inputs like fertilisers and irrigation scheduling equipment and practices. External management is not conducive to farmers' taking responsibility for their farming enterprises. The farmers tend to neglect the maintenance of equipment if they do not see it as their responsibility.

5. Knowledge support system

Farmers need to understand the basic principles regarding the biological functioning of plants and gain the necessary insight into the complexity of the soil-plant-atmosphere systems before entering into a complex farming system like irrigation. For most of the small-scale farmers the expected learning curve to be achieved is too steep, and unachievable without proper and effective knowledge support. The ideal situation will be for small-scale farmers to start off with rain fed production on a limited scale, where the basic principles of crop production are learned, and then gradually move on to the more complex situation of crop production under irrigation. However, because the latter is not possible, an efficient and committed extension service is imperative for the successful development of small-scale irrigation farmers. Government should therefore ensure that such a service is put in place where required. The urgent need amongst small-scale irrigators regarding the necessary skills to manage irrigation systems should receive the required attention by all relevant role players.

6. Introduction of objective irrigation scheduling methods to small-scale farmers

It was observed that many of the small-scale irrigators are not at this point in time ready to be introduced to more sophisticated irrigation scheduling practices. This is mainly because many of them are still preoccupied with barriers like infrastructural problems emanating from inappropriate planning and design of irrigation systems, general lack of knowledge and skills in the maintenance and management of their irrigation systems. Therefore, the development of a site-specific irrigation calendar, as illustrated in the two case studies, namely, Taung and Bethlehem, seems like a possible approach to be followed in the development of small-scale irrigators.

7. Ageing and maintenance of infrastructure and irrigation systems

Ageing of infrastructure and irrigation equipment is inevitable. If no maintenance is done on the bulk water conveyance systems (canal systems) as observed in Tshiombo, Zanyokwe, Taung and Tugela Ferry small-scale irrigation schemes, it tends to break down completely and must be replaced at a very high cost. Regular monitoring and evaluation of the system for leaks, cracks, vegetation invasion and build-up of silt is important. The raising of awareness and support offer regarding the development of effective farmer organisations are essential roles to be played by extensionists and supportive role players.

8. Absence of stakeholders

In Nkomazi the general absence of stakeholders and inappropriate participation of farmers caused many problems regarding the role that extensionists and experts from the sugar industry can play in the training and support of farmers. The latter refers to the many landowners from Nkomazi who are staying in Johannesburg and Pretoria, and who rely on their families to manage and irrigate their lands. Stakeholders or their farm managers should be motivated to regularly attend meetings and training opportunities

arranged by extension. Alternative communication channels for the dissemination of information should be identified and put into place where needed.

9. *Breaking the “dependency syndrome”*

Extensionists and irrigation professionals referred to the “dependency syndrome” that the majority of small-scale irrigators are suffering from. In an effort to break with this syndrome, farmers need to take responsibility and ownership for their own development. This can only be done through proper institutionalization and the establishment of farmer representative bodies, like, for instance, the Farmer Support Units found in Taung, commodity groups in Tshiombo and the irrigation block committees operating on the Bethlehem project. Farmers need to perceive the support from advisors and extensionists as being of a temporary nature and must accept the responsibility to develop the necessary urgency and motivation to be capacitated and empowered through the regular interaction with farmers and extensionists.

Communication networks, trust, commitment and shared values are some of the important elements of social capital that should be developed in order to foster a climate of co-learning. This study again confirmed that small-scale farmers do not operate in isolation, but rather in a social and business relationship situation in which the individual’s position is progressively influenced as a result of others.

10. *Enthusiastic and committed extension support - a prerequisite for sustainable small-scale irrigation development.*

Small-scale irrigation farmers need intensive extension support to overcome their relatively low managerial capacity. Small-scale farmers in general are in desperate need of comprehensive extension support to inform them about new innovations and practices and to help them to become “aware” of the potential use of irrigation scheduling practices. However the needs and nature of the small-scale farmers are diverse and integrated with the broader society

and economy. By assuming a linear, homogeneous approach of technology dissemination to research technology will downplay the boundaries of this diverse environment in which the small-scale farmer operates. Therefore a new strategy in technology development and transfer such as participatory action research will not only incorporate the collective knowledge of all the key role players, but will also increase the farmer ownership over the research and extension process. The science of irrigation is however complex and comprehensive, and therefore competent extensionist with a good working relationship with farmers and other irrigation professionals are needed.

The traditional approaches adopted to organize farmers and farming cooperatives, needs to be revised to meet the development challenges of the twenty first century. The main extension roles to help rural communities to become organized are as follows:

- Empowerment and ownership role - this can be a cornerstone of the new approach to extension. The extension staffs needs to help farmers and rural communities to organize themselves and take charge of their own growth and development.
- Community organizing role – extension officers must learn the principles of community–organizing and group management skills in order to help the community, especially the poor or weaker sections to organize itself for development.
- Human resource development role - the human resource development approach empowers people and gives new meaning to all other roles. Development of technical capabilities must be combined with the management capabilities.
- Mentorship role- the important role that mentors could play in helping farmers to overcome constraints in the steep learning curve many have to complete.

- Problem-solving and education role - problem solving is an important role, but is changing from prescribing technical solutions to empower farmer organizations to solve their own problems. This is achieved by helping them to identify the problems and seek the right solutions by incorporating their indigenous knowledge with improved knowledge and by using their resources properly.

11. Experiential learning or “learning by doing” approach

The importance of stimulating efficient interaction and dialogue between farmers, extensionists and researchers through experiential learning proved to be successful in the building of capacity amongst small-scale farmers. The opportunities for regular feedback from farmers to mentors and extensionists are numerous, and it also address the general problems that are often experienced regarding articulation of complex concepts like irrigation scheduling and other relevant issues applicabel to irrigation management. Extension officers should however be equipped with the necessary skills and knowledge to fulfil this facilitating role in starting a dialogue with farmers and must be prepared to listen sympathetically to what farmers have to say. This does not only expect a new approach to training of extension officers but also needs a change of attitude and perception by some extensionists.

The experiential learning approach followed in the projects, as indicated in the case studies of Bethlehem and Taung, reflects four main elements as proposed by Kolb (1995): concrete experience, observation and reflection, generalization and conceptualization and then active experimentation. Farmer Field Schools (FFS), which are based on these elements of experiential learning, can be used as a possible “extension vehicle” where the training and development is organized around a season-long series of weekly meetings focusing on agronomy, soil preparation, irrigation principles and irrigation and other farm management issues. With FFS the focus is on capacity building of the individual and the group of farmers. The experiential learning processes require people with the necessary skills and knowledge to

help and support farmers, but also important facilitating skills to be able to ask the right questions at the right time.

The implementation of irrigation scheduling technology on the farm is important for the sustainable and efficient use of irrigation water. However, to enable farmers to implement recommended irrigation scheduling approaches and principles an environment conducive for “learning” should be developed. Learning assist farmers to receive decode and understand the information provided on irrigation scheduling, and hence help to make better-informed decisions regarding irrigation management. The change of irrigation practices is, however, a cumulative process, which builds on existing knowledge and practices through interactive learning in which effective dialogue between the farmer, extensionist and researcher plays a crucial role.