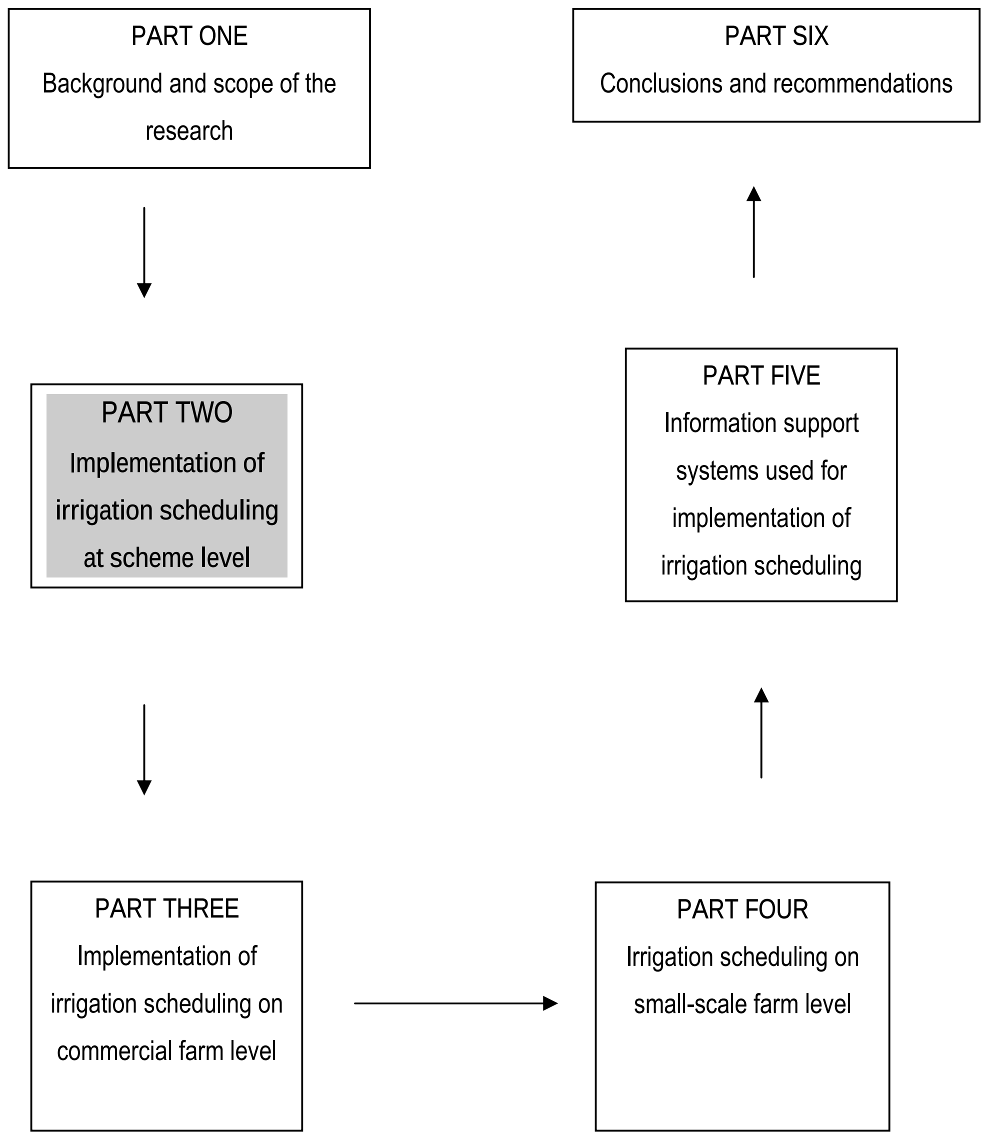
PART TWO

IMPLEMENTATION OF IRRIGATION SCHEDULING AT SCHEME LEVEL



CHAPTER 3
INTRODUCTION AND RESEARCH METHODOLOGY

3.1 INTRODUCTION

Part Two of this report presents the results of a quantitative assessment of the implementation status and distribution of irrigation scheduling methods and models in the nine provinces amongst irrigation farmers. This provides an overview of the implementation and distribution of different methods and techniques of irrigation scheduling by commercial and small-scale farmers on a scheme level (macro level). It also reflects the internal and external factors that influence the implementation of irrigation scheduling on a scheme level.

3.2 RESEARCH METHODOLOGY

3.2.1 Profile of respondents, data collection and analysis

The findings in Part Two are derived from a national survey that was conducted in the nine provinces involves approximately 332 operational irrigation boards and government schemes. Surveys and structured interviews were the main tools for gathering information and assessing the implementation of irrigation scheduling by irrigation farmers.

The respondents involved in this part of the survey were irrigation scheme representatives or spokesmen providing information regarding the respective irrigation schemes. The number of respondents, therefore, corresponds with the number of the irrigation schemes (irrigation board and government schemes). Thirty eight percent of the respondents had access to records and responded by providing actual figures on the situation within the irrigation schemes, which will be referred to as "recorded figures or data". The rest (72%) of the respondents gave estimates based on consensus figures after consultation with other executive members or the leading irrigation farmers from the specific irrigation scheme or the opinion irrigation farmers in the area (“reported figures”). This is therefore a fairly accurate reflection of the conditions on the different schemes. For the irrigation scheme boards with relatively small numbers of participants, the task of collecting the actual figures was comparatively easy.

The total population of registered irrigation board schemes, government schemes and Water User Associations were considered, to ensure accuracy and representation of the current irrigation situation. An address list obtained from the Department of Water Affairs and Forestry (DWAF) was initially used to identify the 332 existing irrigation board and government irrigation schemes. However, the address list was found to be outdated and alternative ways were subsequently selected. Methods used for collecting data included telephonic interviews, face-to-face interviews and questionnaires (with instruction letters) faxed or e-mailed to clients *(Appendix 1*). While telephonic interviews proved to be very effective, responses to the latter two (faxed or e-mailed questionnaires) were initially disappointing, presumably because of the effort involved and the reluctance among respondents to release information.

The main objective guiding this part of the investigation was to obtain a broad picture of the implementation and distribution of irrigation and irrigation scheduling methods in the nine provinces by commercial and small-scale farmers. A structured questionnaire was compiled which consisted of four parts:

- The first part dealt with information on the number of irrigation farmers and area under irrigation in the scheme, the irrigation methods applied, the implementation of irrigation scheduling by farmers, irrigation allocation (m^3/ha/annum), and irrigation tariff applicable.

- The second part was concerned with the major crops grown in the irrigation area (an estimation of the proportions of each crop) and the type of farming business enterprises, viz. a one-man or owner-managed enterprise or a corporate (or estate farming) enterprise found in the specific scheme.

- The third part of the questionnaire was aimed at an appraisal of the irrigation scheduling methods generally used in the specific irrigation scheme as well as the support systems or information sources that farmers in general use to make decisions specifically in terms of water management and irrigation scheduling.

- The fourth part referred to the perceptions and attitudes of irrigation consultants regarding irrigation scheduling, with specific reference to important attributes regarding competency, training and experience.

Eventually a relatively high response (74%) was obtained in the survey due to special follow-up efforts made by the project team to contact respondents again where necessary. DWAF officials, irrigation board officials, extensionists, and irrigation advisors also assisted in the collection of information especially in the provinces of Kwa-Zulu Natal, Western Cape, Mpumalanga, Northwest and Limpopo. Two hundred and forty six usable surveys were returned from the commercial farming sector with the distribution frequency as indicated in Table 3.1.

Table 3. 1: The response rate from irrigation schemes in the different provinces (N=332)

	Limp	NW	GP	MP	KZN	EC	WC	NC	FS	Total
No of irrigation scheme boards	25	36	7	43	33	32	109	32	15	332
Returned Questionnaires	20	33	6	34	25	14	67	32	15	246
% Response	80	91	86	79	76	44	62	100	100	74

Limp=Limpopo; NW= Northwest; GP= Gauteng; MP= Mpumalanga; KZN= KwaZulu Natal; EC=Eastern Cape; WC=Western Cape; NC= Northern Cape; FS= Free State provinces

Fifty one small-scale irrigation schemes, encompassing 40 irrigation scheme boards and 11 community food gardens were also included in the survey. The data regarding small-scale farmers was collected by personal structured interviews with farmers, as well as from discussions held with local extension officers and advisors involved with the support of these farmers.

The analysis of the data involved the use of statistical package for social science (SPSS version 10). Before analysis, data was captured into a computer readable format, which involved coding, editing, data cleansing. Where necessary modifications were made regarding the collapse or creation of new variables.

3.2.2 Irrigation area and number of irrigation farmers

The 297 surveys returned (246 surveys from commercial irrigation schemes and 51 from small-scale irrigation schemes), represent 759 019 ha (59%) of the present 1 290 132 ha currently irrigated in South Africa, and they relate to perceived representative opinions of 15 789 (60%) of the commercial irrigation farmers and 18 639 of the small-scale farmers as recorded by MMSA (1999).

Table 3. 2: Total area reported for the survey under irrigation and the number of irrigation farmers per province (N=297)

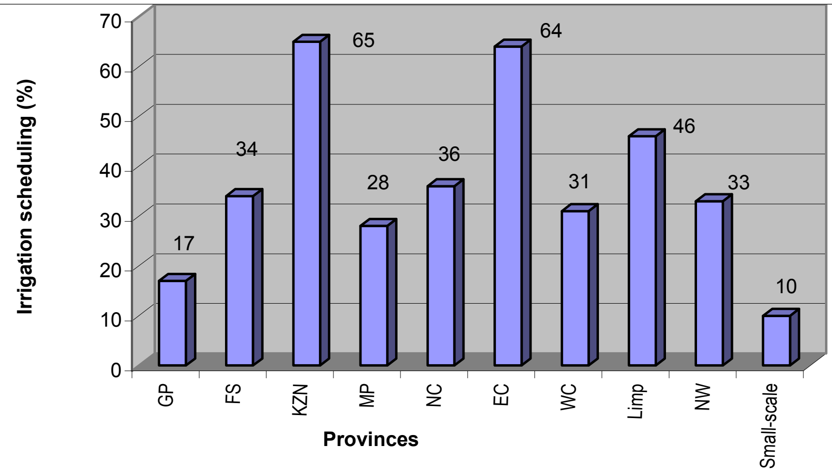
Province	Area under irrigation (ha)	Number of irrigation farmers accounted per province (n)
Gauteng	1 586	100
Free State	44 925	1 710
KwaZulu Natal	74 431	886
Mpumalanga	70 196	1 081
Northern Cape	155 193	2 894
Eastern Cape	44 049	929
Western Cape	116 271	3 833
Limpopo	49 779	1 107
North West	93 241	3 349
Small-scale	109 347	18 639
Total	**759 019**	**34 528**

CHAPTER 4
IMPLEMENTATION OF IRRIGATION SCHEDULING ON IRRIGATION SCHEMES

4.1 CURRENT STATE OF ON-FARM IRRIGATION SCHEDULING

The implementation of irrigation scheduling does not appear to be complicated. There is field capacity point, a refill point and many monitoring tools or computer models are available that can assist the irrigator with decision-making when to irrigate and how much to irrigate.

Respondents were requested to indicate the implementation of irrigation scheduling practices on irrigation schemes. The question invited farmers to indicate more than one method of scheduling, as farmers usually make use of a combination of scheduling methods. According to the survey results the mean percentage farmers implementing irrigation scheduling is 33 on the different irrigation schemes while the median is 18 percent. This indicates a huge variation in irrigation scheduling figures as reported by respondents for the different provinces (Figure 4.1).



Limp=Limpopo ; NW= Nortwest; GP= Gauteng; MP= Mpumalanga; KZN= KwaZulu Natal; EC=Eastern Cape; WC=Western Cape; NC= Northern Cape; FS= Free State provinces

Figure 4. 1: The perceived percentage implementation of irrigation scheduling as indicated per province (N=297)

Figure 4.1 shows that there are significant differences in the perceptions between farmers regarding the commonly used terminology of “irrigation scheduling” (F=2.16; p=0.000). The highest implementation of irrigation scheduling methods was reported for KwaZulu Natal (65%) and the Eastern Cape (64%). This however, is not a true reflection of the implementation of objective irrigation scheduling methods for these provinces as 68 percent of the respondents of KwaZulu Natal and 71 percent the respondents in the Eastern Cape, perceive subjective irrigation scheduling methods like the use of intuition and local experience to fit their definition of “irrigation scheduling”. Subjective irrigation scheduling methods were not perceived as belonging to the definition of “irrigation scheduling “ to the same extent in the other provinces, where continuous monitoring instruments for soil water content, or the use of computer models for calculating long-term ET figures and real–time ET were perceived as fitting the terminology “irrigation scheduling”.

The figure reported for the implementation of irrigation scheduling by small-scale irrigation farmers (10%) represents mainly the perception of extension officers and irrigation scheme officials responsible for serving these farmers in agricultural development, which fits more the definition as used by scientist namely, objective irrigation scheduling.

4.2 DIFFERENTIAL PERCEPTION REGARDING THE IMPLEMENTATION OF IRRIGATION SCHEDULING

Perception, according to Atkinson *et al.*, (1985), is the process by which human beings organize, integrate and recognize patterns of stimuli. Perception is not merely a passive reception and automatic interpretation of stimuli, but rather an active process in which incoming data are selectively filtered to the existing cognitive structure and therefore a key dimension in the process of behaviour change. “Perception refers to the world of immediate experience - the world as seen, heard, felt, smelled and tasted” (Morgan & King, 1966). This finding illustrates that different perceptions exist between farmers but also between irrigators and scientists regarding the commonly used terminology of "irrigation scheduling", which influence the adoption of scientific or objective irrigation scheduling techniques.

According to Düvel (1975), all causes of negative decision making as well as all the forces or potential forces of change, can be directly traced back to the psychological field. Several studies (Düvel, 1975; Koch, 1985; Botha, 1986; Koch, 1986; Louw & Düvel, 1993; Botha & Stevens, 1999) provide evidence of this, and this has led to Hypothesis 1.2, stating that the implementation of irrigation scheduling practices is determined by an intervening variable namely the perception of the user of irrigation scheduling methods.

Based on the response by respondents on the state of on-farm implementation of irrigation scheduling and because of the large variation in the perceptions of irrigation scheduling that exist, respondents were divided into five groups of reported irrigation scheduling implementation as indicated in Figure 4.2.

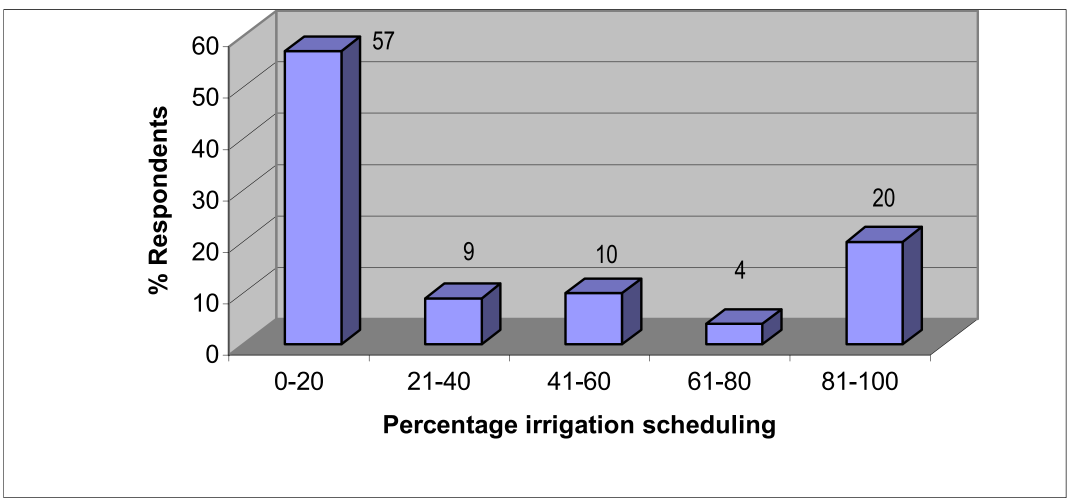


Figure 4. 2: Percentage distribution of irrigation groups (schemes) according to the reported percentage implementation of irrigation scheduling (N=297)

The majority of respondents (57%) reported the implementation of irrigation scheduling to be between 0-20 percent. Twenty percent of the respondents perceived the implementation of irrigation scheduling on the irrigation scheme level between 80-100 percent. The reasons for this huge variation in opinion regarding the implementation of irrigation scheduling on an irrigation scheme level is because of the differential perception amongst many respondents regarding the terminology of "irrigation scheduling" and lend evidence in support of Hypothesis 1.2.

The degree to which intuition fits the definition of irrigation scheduling as perceived by irrigation farmers was further investigated. Figure 4.3 reveals the percentage of respondents who use intuition and those who use objective scheduling methods within each category of reported percentage scheduling.

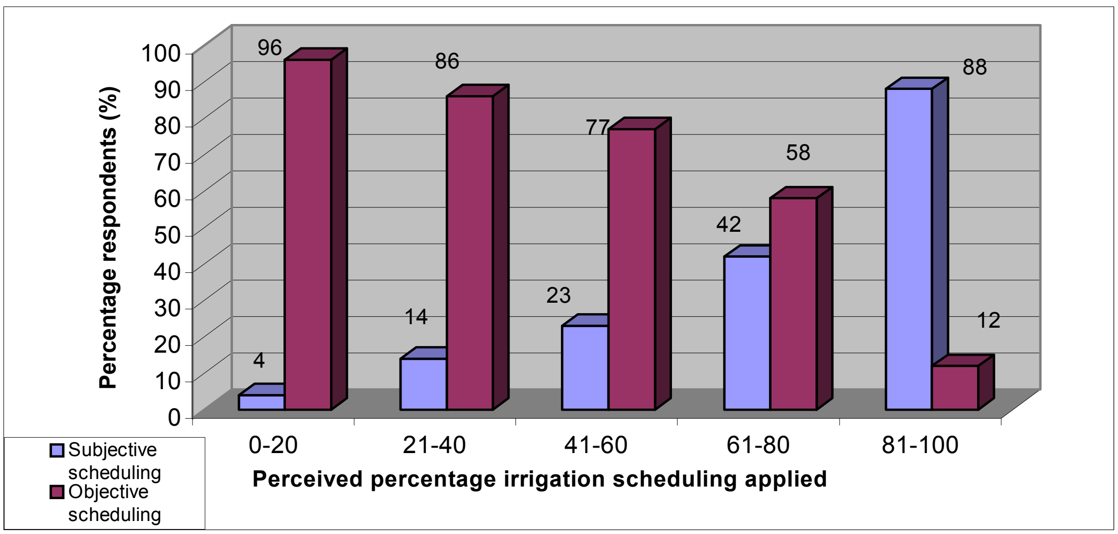


Figure 4. 3: Percentage distribution of respondents according to the perceived percentage irrigation scheduling applied and the percentage ratio between subjective and objective irrigation scheduling (N=297).

The fact that the percentage of respondents who regard the use of subjective scheduling methods (intuition) as part of irrigation scheduling increases dramatically (4% to 88%) with the increased percentage of reported irrigation scheduling, clearly shows that variation in reported irrigation scheduling figures can be largely attributed to the variation in the irrigation farmers' understanding of the terminology "irrigation scheduling". A highly significant negative relationship exists between the reported percentage of irrigation scheduling and the use of subjective irrigation scheduling methods (r=-0.605; p=0.000). This implies that the higher the reported percentage of irrigation scheduling is the more farmers make use of intuition, observation and local experience as a form of irrigation scheduling. This finding supports Hypothesis 1.2, namely that intervening variables like perception, knowledge and needs influence the adoption behaviour of irrigation farmers with regard to the practicing of irrigation scheduling.

These findings are important, especially for irrigation consultants and the extensionists with regard to the planning and implementation of appropriate communication strategies to promote awareness and adoption of objective irrigation scheduling among farmers. Farmers from the group associated with the use of subjective irrigation scheduling are likely to have different needs for their irrigation management decisions, than farmers from the group using objective irrigation scheduling in their decision making. The needs and aspirations of the five different irrigation scheduling groups are compelled to clear differences, which must be taken into account by irrigation advisors and extensionists in their future support strategies.

The reported figures of irrigation scheduling reflected in Figure 4.3 reveal three distinguishable groups of respondents' perception regarding the implementation of irrigation scheduling:

- For some of the respondent's irrigation scheduling is perceived as the use of intuition and experience which fits the model of subjective understanding of irrigation scheduling and was correspondingly included in the figures reported on the implementation of irrigation scheduling. This group therefore recorded relative high figures of irrigation scheduling application on the different schemes (up to 100%).

- Some respondents considered continuous monitoring of soil water content, or the use of computer models for calculating long-tem ET figures and real time ET to be objective or scientific scheduling methods. This group of respondents therefore recorded implementation figures of irrigation scheduling that reflect solely the use of objective irrigation scheduling methods on a scheme level. These recorded figures are therefore relatively lower because of the differential perception that exists. The median figure of 18% reported for the implementation of irrigation scheduling is therefore accepted as a more accurate reflection of the application of objective scheduling by farmers.

- The third group of respondents uses a combination of both scientific (or objective) and subjective irrigation scheduling methods. Although this group acknowledges the role of intuition in irrigation management decisions, they perceive intuition-based decisions alone as not adequate to ensure efficient irrigation management and therefore also make use of objective irrigation scheduling methods to help them with decision-making.

4.3 STATE OF IRRIGATION SCHEDULING ON DIFFERENT TYPES OF IRRIGATION SCHEMES

South Africa has four general types of irrigation schemes that are linked to the different economic development phases experienced in the country (FAO, 2000):

- Private irrigation schemes (approximately 450 000 ha). Private schemes exist where the water source can be privately owned and owners extract water directly from weirs, boreholes, and farm dams. The farmer carries all costs and the registering of these water sources are currently in process.

- Irrigation board schemes (approximately 400 000 ha). They statute under the earlier water legislation established irrigation boards. They are autonomous, democratically run institutions elected by participating irrigation farmers from within their own ranks. They are empowered to provide their own infrastructure and levy fees to cover full costs. Historically they had access to subsidy in respect of capital works and also state loans. This facility is no longer available (Pretorius, 2003). Under the National Water Act (No. 36 of 1998), all irrigation boards will be converted to WUAs.

- Government (state) schemes: 350 000 ha where the infrastructure was provided by the state. Management and maintenance of the distribution system is a state function and farmer involvement is limited to the participation on advisory committees. Water charges are levied for operation and are charged to farmers. Membership of these schemes will also be transferred to WUAs in due course.

- Small-scale schemes: 100 000 ha distributed among small-scale farmers and include:

  - Bureaucratically managed schemes fully administered by the state or an agency of the state.

  - Jointly managed schemes, where the irrigation development agency and project participants jointly are responsible for the functions on the irrigation scheme.

  - Community schemes, usually small in size, operated by water users themselves.

  - State or corporation financed schemes, such as in sugar cane production, where farmers are selected and infrastructure is provided to field edge.

  - Large estate schemes state or privately financed, managed by agents producing high value cash crops.

Following budgetary reprioritization and maintenance that was withdrawn, many small-scale schemes collapsed or are in a poor physical state (Maritz, 2004). The operating costs are charged to farmers at a subsidized rate.

In the survey three types of irrigation schemes were included namely government irrigation schemes, irrigation board schemes and the newly established WUAs as summarized in Table 4.1.

Table 4. 1: Frequency distribution according to the types of irrigation schemes included in the survey (2003) (N=297)

Type of scheme	n	Percentage (%)
Irrigation board schemes	214	72
Government scheme	48	16
WUA	35	12
Total	**297**	**100**

The new National Water Act (NWA) (Act 36, 1998) promotes integrated and decentralized water resource management and is to be implemented through the National Water Resources Strategy (NWRS). Social development, economic growth, ecological integrity and equal access to water are key objectives of the new water legislation. The NWRS makes provision for, amongst others, the establishment of Catchment Management Agencies (CMAs) and Water User Associations (WUAs) in each of the 19 water management areas in the country, as declared in Government Notice 1160, October 1999 (DWAF, 2000). These institutions are in the process of being established at the regional and local level, pursuing a more participatory approach to water resource management.

The CMAs are statuary bodies, established by Government Notice, with jurisdiction in a defined water management area. The functions and responsibilities of the CMAs include the development of catchment strategies, management of water resources and coordination of water related activities.

WUAs are cooperative associations of individual water users who wish to undertake water related activities at a local level for their mutual benefit. The WUAs usually operate in terms of a formal constitution and are expected to be financially self-supporting from water use charges paid by the members (Knoetze, 2003). A WUA falls under the authority of the CMA in whose area it operates, if the agency has received powers from the Minister to operate the WUA's activities. According to Schedule 5 of the NWA, one of the functions of the WUA can be "to regulate and supervise the distribution and use of water from the water resource according to the relevant water use entitlements, by erecting and maintaining devices for measuring and dividing, or controlling the diversion of the flow of the water". Through the constitution and business plan of the WUA, it must be shown how "the WUA makes progress towards measuring the quality and quantity of inflows and outflows, losses and water supplied to its customers, and towards the use of acceptable devices and techniques. The strategy and business plans are currently being tested through three pilot studies on the development of water management plans for the Gamtoos, Oranje-Riet and Orange-Vaal WUAs (Knoetze, 2003).

Some of the irrigation board schemes and government schemes have already been transformed into WUAs. The transformation of the irrigation boards into Water User Associations (WUA) has progressed very slowly, and during 2003, when this part of the study was completed only 23 WUAs had been established (Karar, 2003). The relatively high number of WUAs reflected in the survey is misleading because of duplication in the nomination, and therefore the reflection of 35 instead of 23 WUAs indicated by Karar (2003). As in the case of the Oranje Riet Water Users Association, the irrigation schemes of Scholtzburg, Modderrivier, Rietriver, and Oranje Riet River are regarded as four different WUAs for statistical reasons while they are incorporated into one WUA.

Respondents belonging to the three types of irrigation schemes have different perceptions with regard to the definition of "irrigation scheduling" as indicated in Figure 4.4.

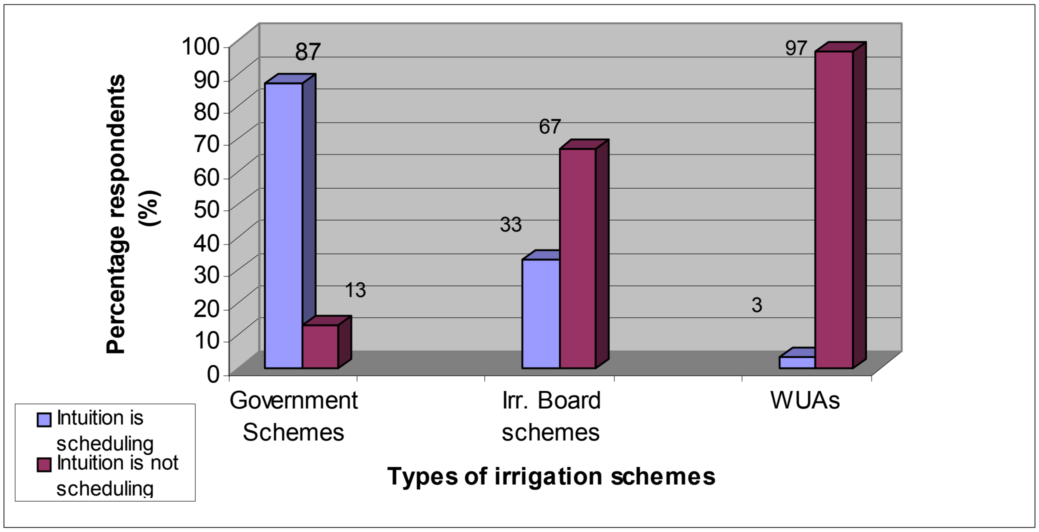


Figure 4. 4: Percentage distribution of respondents according to the percentage ratio between subjective and objective irrigation scheduling implemented on the different types of irrigation schemes (N=297)

Figure 4.4 illustrates that farmers irrigating on the three different types of irrigation schemes differ in their perception with regard to the understanding of the terminology “irrigation scheduling” ($F=3.46$; $p=0.044$). The majority (87%) of respondents farming on government irrigation schemes are of the opinion that subjective scheduling fits the general definition on irrigation scheduling, while only three percent of respondents from WUAs and 33% of irrigation board schemes respectively share the same opinion. This finding indicates that farmers irrigating on irrigation schemes that were transformed into WUAs, are in general more aware of the scientific definition of irrigation scheduling. This relationship is supported by the highly positive correlation coefficient ($X^2=28.26$; $df=8$; $p=0.001$), which is in accordance with the expectations (Hypothesis 1.2), namely that environmental factors in the form of proper structured and functioning irrigation management institutions (WUA) influence the implementation of irrigation scheduling.

4.4 ADOPTION OF ON-FARM IRRIGATION SCHEDULING METHODS

Field water use efficiency is defined as the amount of irrigation water that replenishes the rooting zone as a function of the amount of water supplied to the field. The challenge to the irrigator is to fill the root zone depleted by evapotranspiration. Central to this task is the ability to predict or measure the depletion of water in the root zone so that irrigation water can be applied according to the crop requirement.

In Chapter Two various irrigation scheduling approaches used by irrigators have been quantitatively described and classified. The spectrum of soil-plant-atmosphere irrigation scheduling methods commonly used by irrigation farmers as captured by the survey are clustered into seven groups:

- Use of long term evaporation figures like the use of evaporation pans (Class A pan), pegboard and the Green Book.

- The use of real time ET calculations as collected by automatic weather stations and distributed by fax modem or Short Message System (SMS).

- Plant based monitoring like sap flow, leaf water potential, and phytomonitoring.

- Measurement of soil water content and potential with soil water sensors: tensiometers, neutron probes, capacitance sensors (Diviner, Enviroscan, etc), and dielectric sensors (gypsum blocks).

- The use of irrigation scheduling models is used within the integrated soil water balance approach where irrigation scheduling is based upon either using soil water balance models and/or crop growth models to calculate evapotranspiration.

- Feel and appearance method: where a tile probe, soil auger or spade is used to determine the status of the soil water content.

- The use of intuition based on local experience, knowledge, observation and feeling as part of the farmers' repertoire or mental model for decision-making.

Figure 4.5 summarizes the percentage implementation of different irrigation scheduling methods as reflected by (a) recorded figures (38 percent of the irrigation schemes) and (b) as reported by representative respondents but supported by consensus opinion of a smaller reference group. These figures indicate that the reported and recorded figures regarding the implementation of the different irrigation scheduling methods do not differ substantially.

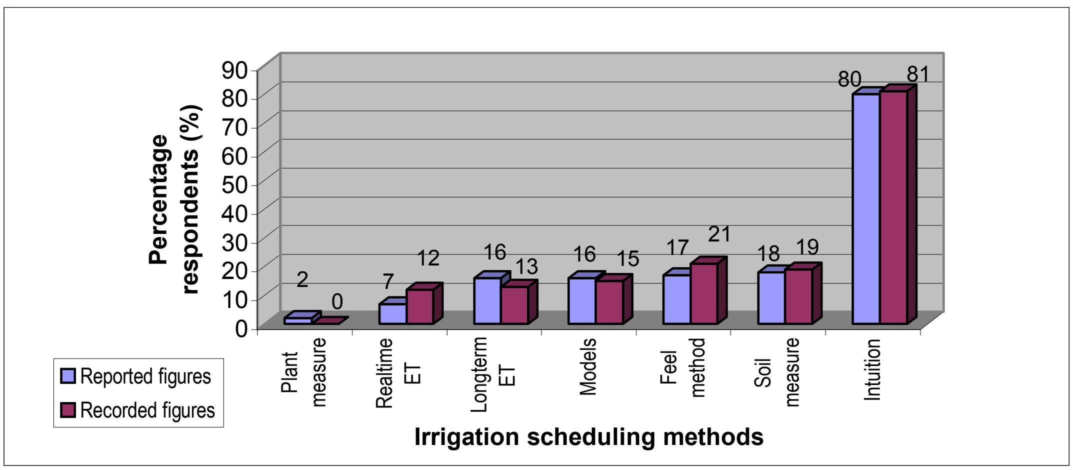


Figure 4. 5: Implementation of different irrigation scheduling methods by irrigation farmers according to figures recorded and figures reported by representative respondents from the different irrigation schemes (N=297).

The majority of respondents (81%) make use of subjective irrigation scheduling methods (intuition), while the reported implementation figures of objective scheduling methods vary between 2% and 18%, as indicated in Figure 4.5, with the median 14%. The recorded percentages vary slightly more. Only a few commercial fruit and wine grape growers in the Western

Cape reported the use of plant based monitoring (2%) for example the measurement of leaf water potential, sap flow and phytomonitoring.

The use of subjective irrigation scheduling methods by irrigation farmers entails the incorporation of fixed or semi-fixed irrigation calendars based on intuition, local experience, knowledge, observation and feeling. Intuition forms part of the farmers' repertoire or mental model, which brings "reflection" into the centre of understanding of what irrigation farmers do and is also sometimes described as "thinking on the feet". According to the Webster New International Dictionary of the English Language, intuition is a looking upon, a seeing either with the physical eye or with the "eye of the mind". This knowledge used for decision making is usually obtained without recourse to interference of reasoning, and is often referred to as innate or instinctive knowledge, insight, familiarity, a quick or ready insight or apprehension (Rowan, 1986).

4.4.1 Interrelationship between irrigation scheduling method selected and the implementation of irrigation scheduling

Figure 4.6 shows the relationship between the different irrigation scheduling methods selected by farmers with the implementation of on-farm irrigation scheduling.

As depicted in Figure 4.6 there are significant differences between the different irrigation scheduling groups ($F=165.1$; $p=0.000$). It is illustrated that farmers that fall within the bracket of 0-40% irrigation scheduling applied (scheduling groups 1-2), are more prepared to rely on the use of objective irrigation scheduling methods viz. monitoring of soil water content and the use of computer models or programs to schedule irrigation on the farm than the use of intuition. The use of intuition was restricted to less than 10% amongst these irrigation farmers. Figure 4.6 also indicated that as the respondents reported relatively higher figures of implementation of irrigation scheduling, the contribution of intuition (subjective scheduling methods) also clearly increased (scheduling groups 3-5). These findings provide evidence in support of Hypothesis 1.2, namely that higher reported percentage of irrigation scheduling is correlated with the use of intuition as a form of irrigation scheduling.

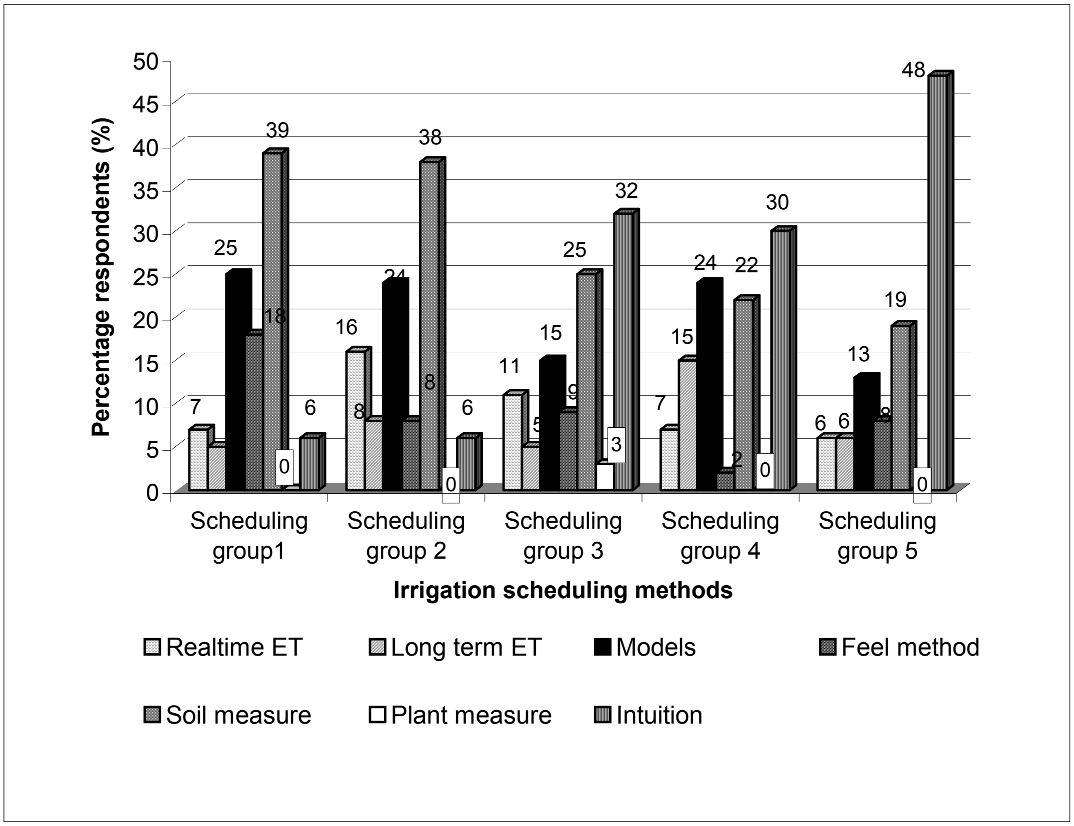


Figure 4. 6: Implementation of different irrigation scheduling methods by scheduling groups 1- 5 (N=165)

4.4.2 Computer irrigation scheduling models and the interrelationship with on-farm irrigation scheduling

Computer usage for farm management decisions becomes more popular, as there is a growing need amongst farmers for intensive physical and financial planning of farming operations where information is used for everyday management decisions. However the use of irrigation scheduling models among irrigation farmers is still limited and the majority of irrigation farmers (72%) who reported engagement in irrigation computer software also referred to the necessary help and support required from irrigation consultants and extensionists in this regard.

The majority of irrigation scheduling programs and models are used to generate advice, and are referred to in management literature as decision support systems (DSS). The complexity of farming systems is commonly used as the justification for modeling and decision support systems ”Never before have we been able to analyze so much data relating to a specific situation, and arrive at a solution to a complex problem “ (Hamilton *et al.*, 1991) or “to deal with complexity we need more sophisticated decision aids” (Hochman, 1995). Some of the irrigation scheduling models are relative simple and contain trivial calculation models, while others are much more complex and make analytical predictions with the help of simulation models. Figure 4.5 indicate that 16 percent of the irrigation schemes referred to the use of computer irrigation scheduling models by farmers.

As discussed in Chapter Two, numerous irrigation scheduling models and computer software programs have been developed and are available to farmers, consultants and researchers. These models are based on integrated soil water balance principles, with various degrees of sophistication, including mechanistic approaches to crop growth. A model like SAPWAT was developed with the main aim to help with strategic decisions on a scheme level while models like SWB, Irricheck, PRWIN, etc are real time irrigation scheduling models. These irrigation scheduling models were developed to help the farmer towards better-informed decisions in on-farm water management. The real time irrigation scheduling models and programs are based on actual daily conditions, usually soil water content and atmospheric demand, and therefore need regular measurements and monitoring of the soil-water-atmosphere conditions prevailing. Figure 4.7 illustrates the implementation of the different irrigation scheduling models as reported by the respondents.

PRWIN was found to be most popular among the irrigation farmers, as 18% of the respondents either referred to the use of this programme by an irrigator within the irrigation scheme or were using it themselves. The reported figure on the use of Probe Sched (8%), also includes the implementation of computer programs *Add Sched* that consultants and farmers generally use together with soil measurement devices like the Diviner and *Waterman Sched* generally used together with neutron probes supplied by Geoquip.

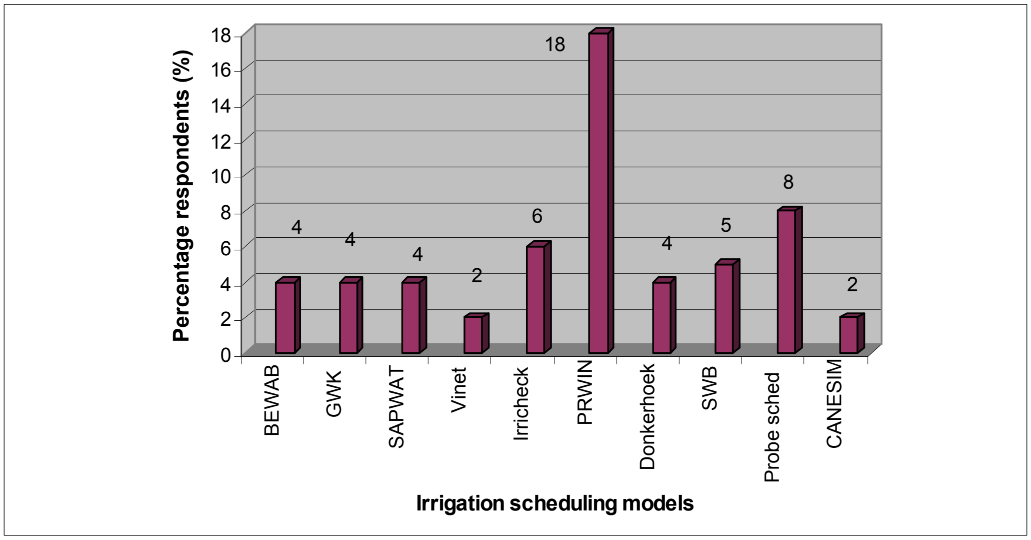


Figure 4. 7: The implementation of irrigation scheduling models by farmers (N=297)

From the responses received from respondents and field experience it appears that farmers need appropriate technical support of extensionists and irrigation consultants with the implementation of soil water balance models and programs, as it is often perceived to be complex and therefore difficult to apply on the farm. Literature reveals a positive association between extension and the adoption behaviour of farmers (Koch, 1985; Frank & Chamala, 1992; Chamala, 1996; Botha *et al.*, 2000; Leeuwis, 2004) and this led to the hypothesis that competent ground level support by research and extension is imperative for the adoption of irrigation scheduling on the farm (Hypothesis 4).

As depicted in Table 4.2 a highly significant negative relationship exists between the implementation of computer models or programs on-farm and support rendered by fellow farmers (Cramer's V value=0.940; p=0.000) or farmers themselves (Cramer's V value=0.610; p=0.020). These findings illustrate that the implementation of computer irrigation scheduling models and programs are predominately advisor-driven and not farmer-driven, which provides evidence in support of Hypothesis 4, namely that competent ground level support by irrigation advisors and extensionists is conducive for the implementation of objective scheduling practices on-farm.

Table 4. 2: Relationship between the adoption of computer irrigation scheduling models and programs and ground level support as reflected in a test of association (N=297)

Ground level support offered	Cramer's V	
	Value	p
Cooperative extension and industry support	0.238	0.050
Private irrigation consultant	0.592	0.080
Fellow farmers	0.940	0.000
Farmers themselves	0.610	0.020

Advisors and service providers who are in regular contact with farmers have considerable influence on farmers' decision making (Daniels & Chamala, 1989). Irrigation consultants and advisors usually select and use irrigation scheduling models and software packages, which fit their specific business needs and style of service delivery. The differences between the provinces regarding the rank order of irrigation scheduling models and programs implemented by farmers are significant (F=3.5; p=0.046). The difference lies in the fact that it appears that the adoption of irrigation scheduling models and programs appears to be advisor specific, and therefore the implementation of specific scheduling programs and models by farmers are also geographically bounded as indicated in Table 4.3. This clear relationship finds expression in the significant Cramer's V value (Cramer's V=0.576; p=0.004).

Table 4. 3 Distribution of irrigation scheduling models and programs in the nine provinces according to their adoption as indicated by respondents (N=297)

Computer models and programs	Distribution of implementation of computer models in various provinces per ranking order*				
	1	2	3	4	5
BEWAB	Free State	Northern Cape	Northwest		
Irricheck	Limpopo	Free State	Northern Cape	KwaZulu Natal/ Mpumalanga	Northwest
SAPWAT	Northern Cape	Free State/ Eastern Cape	Mpumalanga	KwaZulu Natal	Northwest
SWB	Limpopo	Mpumalanga	KwaZulu Natal	Eastern Cape	
PRWIN	Western Cape	Mpumalanga	Northern Cape	KwaZulu Natal Eastern Cape/ Limpopo	Free State/Northwest
CANESIM	KwaZulu Natal	Mpumalanga			
Probesched	Western Cape/ Northern Cape	Mpumalanga	Eastern Cape		
Donkerhoek	Western Cape	Eastern Cape			
GWK	Northern Cape	Northwest			
Vinet	Western Cape	Northern Cape			

**) 1= Highest implementation, 5= Lowest implementation*

4.5 SUMMARY

Although a large number of irrigation scheduling tools and methods have been developed for South African irrigation farmers, the implementation of objective irrigation scheduling methods are below expectation. Only 18% of the respondents confirm the use of objective irrigation scheduling methods and thereby adhere to the strict definition of scheduling. The majority of farmers do not monitor the status of soil water content, but rather use subjective irrigation scheduling methods.

Different perceptions exist between irrigators regarding the definition of “irrigation scheduling” and its implementation on the farm. This differential perception was clearly illustrated in the reported figures regarding the implementation of irrigation scheduling on an irrigation scheme level. A strong negative relationship exist between the use of subjective scheduling methods like intuition and the irrigation scheduling figures reported by respondent. This implies that the higher the reported percentage of irrigation scheduling the more the farmers make use of intuition and observation as subjective scheduling methods.

Although the computer models used for irrigation management decisions incorporate and link formalised knowledge from different disciplines, and allow for the making of complex calculations that would otherwise never be realistically carried out, the implementation of irrigation scheduling models, especially real time models, has proved to be restricted due to their complexity. The use of real time irrigation models amongst farmers is mainly restricted to regions where private consultants or advisors support their implementation. User-friendly and understandable models like BEWAB, which can be used for the development of irrigation calendars, seem to be more easily adopted by farmers especially where limited support by extensionists and private irrigation consultants is available.

CHAPTER 5
THE INFLUENCE OF INTERNAL FACTORS ON IMPLEMENTATION OF ON-FARM IRRIGATION SCHEDULING

5.1 TYPE OF FARMING BUSINESS ENTERPRISES

Two major types of farming business enterprises are often found on irrigation schemes, namely:

- One-man enterprises (owner-managed): These are farming units where the individual farmer, usually the owner, is responsible for all the management activities on the farm.

- Corporate enterprises: These are usually of a much bigger scale with the irrigation management usually assigned to a specific person(s) or consultant (s) who do form part of the owner's day-to-day management decisions.

This distinction between the two types of farming operations was important for the research team because it was assumed that the more precise and objective irrigation scheduling methods are the more likely it to be used by the big corporate or estate enterprises, while the owner-managed enterprises tend to use the more subjective irrigation methods. Table 5.1 provides an overview of the distribution of respondents representing irrigation schemes according to the occurrence of corporate enterprises.

The percentage of corporate farming enterprises is relatively small and in 64 percent of the cases, respondents reported none at all. The survey indicates that the majority of farmers are still involved in owner-managed or family enterprises. It can be argued that although farming is increasingly seen as a business, the importance of the farm family's social fabric is too often neglected when trying to introduce change. Vanclay (2003) argues that farming is a social activity and made the following statement: "Farmers do not

Table 5. 1: Distribution of respondents according to occurrence of corporate enterprises (N=297)

% Corporate enterprise	Number of respondents (n)	% respondents
0%	190	64
0.5-10%	70	24
11-20%	6	2
21-40%	10	3
41-60%	6	2
61-100%	9	3
Missing	6	2
Total	**297**	**100**

make conscious decisions about most issues – they do what is consistent with their social situation". This is an important finding to be taken into consideration by research and extension or advisory services before farmers are introduced to new innovations and expected to change practices.

Table 5.2 illustrates the distribution of the respondents according to the types of farming operations and the implementation of irrigation scheduling methods. The findings illustrate that corporate or estate enterprises tend to make use of objective scheduling methods but this is not statistically significant. A significant negative correlation (r=-0.499; p=0.000) exists between the use of intuition as an irrigation scheduling method and the type of enterprise, meaning that corporate enterprises are in general more prepared to make use of objective irrigation scheduling with the necessary support of the irrigation extensionists and consultants. This relationship between the use of irrigation scheduling practices and the business enterprise of a specific farm provides evidence in support of Hypothesis 3, namely that the approach to problem solving and learning is determined by the obtained technology level of the farmers as well the business characteristics of a specific farm.

Table 5. 2: Distribution of respondents according to the types of farming operations and the implementation of irrigation scheduling methods (N=291)

Irrigation scheduling methods	Corporate enterprise (n=101)		One-man enterprise (n=190)		Total
	(n)	%	(n)	%	(N)
Plant measurement	3	100	0	0	3
Real ET	24	57	18	43	42
Long term ET	16	50	16	50	32
Computer models	59	60	39	40	98
Feel method	29	53	26	47	55
Soil water measurement	74	51	72	49	146
Intuition	101	35	188	65	289

This relationship is also evident from the figures reflected in Table 5.2, where only 35% of farmers involved in corporate business enterprises, rely on subjective scheduling decisions based on intuition and experience as opposed to 65% of the one-man enterprises.

5.2 INFLUENCE OF CROP SELECTION

The assumption is that objective irrigation scheduling practices become more important for commodities where water intensive and high-value crops (e.g. horticultural crops) are produced. These crops are usually very sensitive to periods of subnormal irrigation, which will directly impact on the production quality and yield. With crops like irrigated pastures the expectation is that farmers are more inclined to use fixed or semi-fixed irrigation scheduling programs. The following figures (Figure 5.1 – 5.1) provide an overview of the crops grown under irrigation as reported by respondents on the different irrigation schemes.

5.2.1 Cash crops

The most important irrigated cash crop types currently grown under irrigation based on the percentage irrigation schemes planted to each crop type are reflected in Figure 5.1

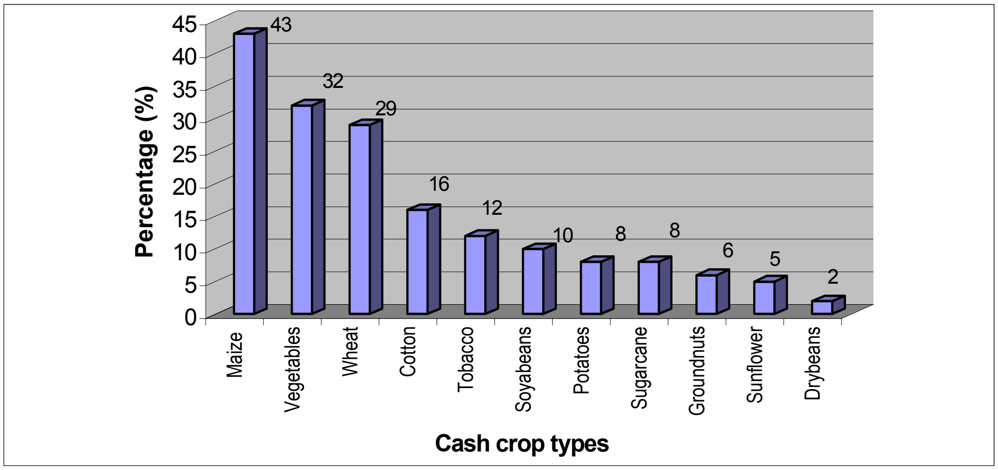


Figure 5. 1: Percentage irrigation schemes on which various cash crops are produced (N=297)

Cereals (e.g. maize, wheat),vegetables and cotton are most commonly cash crops grown under irrigation. Crops like paprika, sugar beans; barley, peas and rice are grown by less than 2% of the respondents.

5.2.2 Intensive horticultural crops

The main horticultural crops grown under irrigation based on the percentage irrigation schemes planted are indicated in Figure 5.2.

Grapes (wine and table grapes) and citrus are popular intensive horticultural crops planted under irrigation, followed by deciduous and subtropical fruit. Other intensive crop types like strawberries, almonds, olives, tea and coffee were also mentioned, but are found on less than one percent of the irrigation scheme.

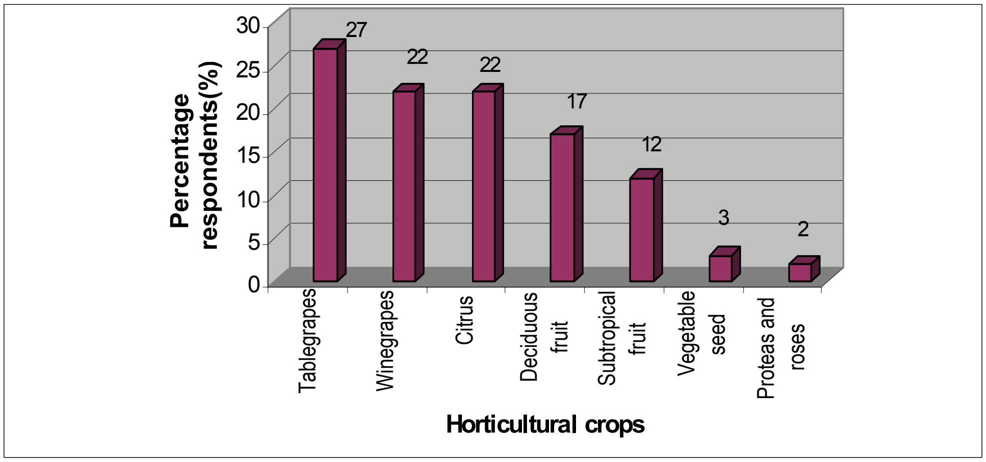


Figure 5. 2: Percentage irrigation schemes on which the different intensive horticulture crops are grown (N=297)

5.2.3 Pastures

Forty-five percent of the respondents indicate that irrigated pastures are grown on their schemes, with lucerne constituting the most important irrigated pasture (grown by 32% of the respondents). Other types of pastures produced under irrigation like ryegrass, kikuyu, and festival were also mentioned.

Table 5.3 indicates the frequency distribution of irrigation schemes according to the different crops and combination of crop types grown as well as the ratio between subjective and objective irrigation scheduling methods. Cash crops like cereals alone or in combination with intensive, high vale horticulture crop types and pastures are planted on the majority of irrigation schemes.

The differences between the various types of crops and the implementation of irrigation scheduling practices are significant (X^2=96; df=2; p=0.000), suggesting that farmers involved in the growing of relatively intensive horticultural crops are more inclined to schedule irrigation precisely with the support of objective irrigation scheduling methods. This relationship is supported by a significant positive correlation coefficient (r=0.271; p=0.001) to exist between the crop types selected by the farmer and the percentage

Table 5. 3: Frequency of irrigation schemes under different crops and combination of crops (N=297)

Crop types	Irrigation scheduling method		N	%
	Subjective scheduling methods	Objective scheduling methods		
Intensive crops[1)]	11	36	47	15
Cash crops[2)]	69	17	86	29
Pastures[3)]	5	3	8	3
Intensive + Cash crops	16	70	86	29
Intensive crops + pastures	3	18	21	7
Pastures + cash crops	21	17	38	13
Intensive + cash crops+ pastures	2	9	11	4
Total	**127**	**170**	**297**	**100**

[1)] *Intensive crops = high value crop types like horticulture,* [2)] *Cash crop types like maize, wheat, cotton, sugar cane, etc.;* [3)] *Pasture = lucerne, kikuyu, ryegrass, etc.*

objective irrigation scheduling that farmers apply. These findings provide evidence in support of Hypothesis 2, namely that more precise irrigation scheduling is perceived necessary to improve production efficiency (yield and quality) by industries like horticulture production and the growing of high-value crops. This significant relationship provides further evidence in support of Hypothesis 3, namely that the technology level of the farmer and the business characteristic of the farm (intensive,high-value *versus* cash crop commodities) determine farmers' approach to learning and problem solving through the adoption of specific irrigation scheduling methods.

Table 5.4 indicates the implementation of the different irrigation scheduling methods as reported for the different crop types and combination of crop types grown.

Table 5. 4: Percentage distribution of irrigation schemes according to the types of crops and irrigation scheduling methods used (N=297)

Irrigation scheduling method	Intensive or high value crops		Cash crops		Pastures	
	(n)	%	(n)	%	(n)	%
Plant measurement	3	2	0	0	0	0
Real ET	15	9	3	2	2	4
Long term ET	6	3	8	6	2	4
Scheduling models	33	19	13	9	3	6
Feel method	14	8	6	4	5	10
Soil water measurement	45	26	27	19	10	21
Intuition	59	33	83	60	26	55
Total	**175**	**100**	**140**	**100**	**48**	**100**

Significant positive correlations exist between the implementation of subjective irrigation scheduling and the production of cash crops like cereals, cotton, vegetables, tobacco and sugarcane (r=0.531; p=0.000) and pastures (r=0.238; p=0.032) which provide evidence in support of Hypothesis 3, namely that the business character (high value crops *versus* cash crops) influence the farmers' approach to irrigation scheduling. This finding can be attributed to the possibility that a relatively high percentage of cash crop types and the majority of pastures reported by respondents are grown under conditions where the amount of irrigation applied and the irrigation interval are determined by the irrigation method (sprinkler irrigation), and the time it takes to get around the whole farm.

With regard to the growing of vegetables and sugar cane respondents relate the low adoption of objective scheduling to the fact that these industries typically have large number of fields all at different growth stages. The number of sites that would be needed for representative monitoring and the time taken to analyse and interpret data of each field are perceived by respondents to be prohibitive, especially as irrigation is usually at a frequent interval.

The relative low adoption of precise or objective irrigation scheduling methods by cash crop farmers may also relate to the general perception of 80% of these farmers that they have a very good workable knowledge of the crop water requirements of most of the cash crops grown on the farm, and therefore operating somewhere around the optimum point of irrigation.

5.3 INFLUENCE OF ON-FARM IRRIGATION METHOD

The on-farm irrigation method is critical as it determines the amount of irrigation that can be applied to the crop and at what interval. Irrigation scheduling defines “when” to irrigate and “how much”, but does not take into account the actual performance of the irrigation systems selected by the farmer for his specific conditions.

The selection of appropriate irrigation methods and assessment of economic benefits are important aspects of on-farm irrigation management. The method selected should be capable of applying water efficiently and uniformly. The choice of on-farm irrigation methods usually depends on many factors including capital and the operation costs, water use efficiency, labour requirements, ease of management, local soil potential (irrigability) and field topography.

5.3.1 Implementation of on-farm irrigation methods

Sprinkler irrigation is often considered to be comparatively efficient for surface irrigation because it enables better control of water application. However, this control is dependent upon the quality level in irrigation system design and on the selection of equipment, but also requires that farmers develop appropriate skills and knowledge to manage their irrigation system (Stimie, 2003). Figure 5.3 indicates that the majority of irrigation farmers (53%) are using quick coupling or hand shift sprinkler irrigation systems.

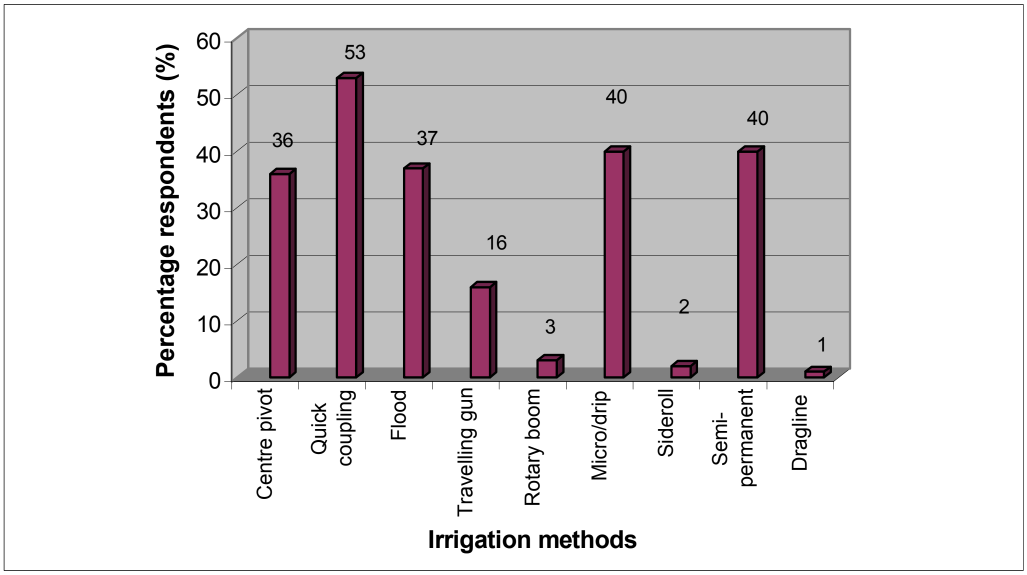


Figure 5. 3: Percentage distribution of respondents according to the implementation of different irrigation methods (N=297)

The classification of irrigation systems used in Figure 5.3 is based on a categorization developed by the ARC (1997). This figure illustrates that centre pivots, quick coupling sprinkler and micro/drip irrigation systems currently enjoy relative high acceptance by farmers and that little change took place since the Agrimarket survey (MSMA, 1999). There is however a tendency those farmers generally are prepared to use more micro/drip and mechanized irrigation systems on the farm, and are scaling down on the use of flood and sprinkler irrigation.

a) Flood or surface irrigation

Surface irrigation (predominantly border, short- and long- furrow and basin irrigation) is still a dominant method of water application to pastures and a wide range of field crops. Especially the short and long furrow irrigation methods are very popular among small- scale irrigation farmers but also often used in the Lower Orange irrigation scheme for growing of grapes (wine and table) and lucerne. The majority of farmers make use of traditional systems where the water control is carried out manually, according to the judgement of the irrigator. Many farmers (commercial and small-scale) indicated the difficulty to control "how much" water to apply.

Photo 5. 1: Short furrow irrigation implemented by the majority of small-scale irrigation farmers

b) *Mechanized irrigation systems*

- *Stationery irrigation systems* include both permanent or semi permanent systems like floppy irrigation systems. Set systems irrigate in fixed position (semi-permanent) and because there are no limitations to the duration of the set time, they can be utilized to apply small volumes of water at frequent intervals, which is usually not possible with the moveable systems because of operational constraints.

Photo 5. 2: Floppy irrigation systems (semi-permanent systems) are often used in sugarcane fields within the Inkomati water management area

- *Continuous move or mobile irrigation systems* include centre pivots, linear move, and traveling gun.

Photo 5. 3: A linear irrigation system in operation on the Riet River Irrigation Scheme (2003)

- *Portable irrigation systems* include dragline; semi-dragline, hand shift or quick coupling, rotary boom and side roll systems. These systems in general are not suitable for applying very small volumes of water because of limitations in the system's capacity.

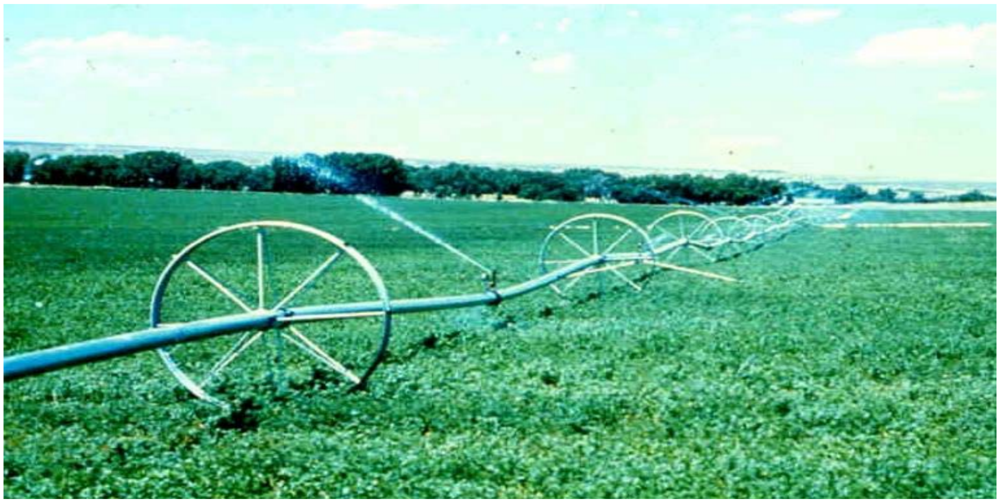


Photo 5. 4: Lucerne production under a side roll irrigation system in the Sand/Vet Irrigation Scheme

Photo 5. 5: Sprinkler, quick coupling irrigation system used for wheat production in the Riet River Irrigation Scheme

- *Micro-irrigation systems* typically apply to several systems operating at low pressure including drip, trickle, miniature distributors, bubblers and tapes. They are characterized by the localized application of irrigation water using low flow and high frequency applications, either to the surface of the ground or underground (subsurface).

Photo 5. 6: Table grape production under drip irrigation in Mpumalanga

5.3.2 Influence of on-farm irrigation methods on irrigation scheduling

There are significant differences between the on-farm irrigation scheduling methods used and the implementation of irrigation scheduling practices ($F=5.81$; $p=0.018$) as indicated in Figure 5.4.

Regarding the adoption of objective irrigation scheduling methods and the selection of on-farm irrigation methods, a clear tendency exists that farmers who use micro, drip and mobile systems on the farm are more inclined to use precise irrigation scheduling, while farmers that use portable, flood and permanent stationary systems are more inclined to use subjective irrigation scheduling practices.

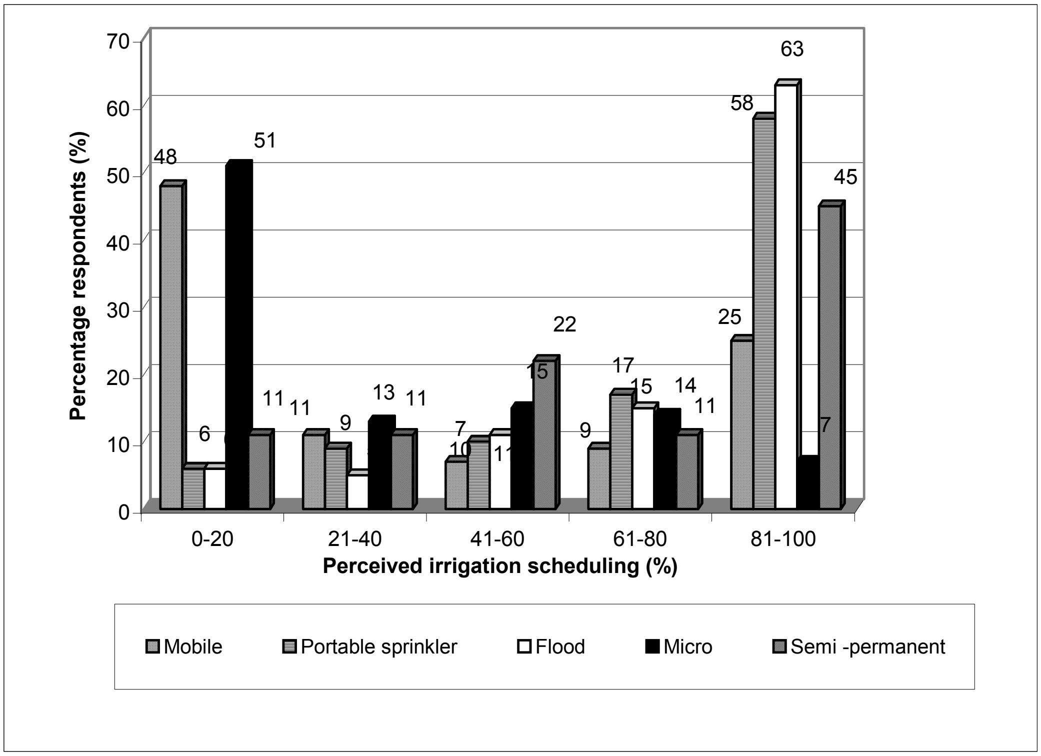


Figure 5. 4: Frequency distribution of irrigation schemes according to the use of different irrigation methods and percentage irrigation scheduling (N=297)

Table 5.5 indicates the significance of relationship between the variables as expressed by Cramer's V values and correlations (Pearson or Spearman). A significant positive relationship exists between the use of micro/drip irrigation systems and the implementation of objective scheduling as expressed in the highly signficant Cramer's V value (Cramer's V=0.540; p=0.000). Although the relationship between the use of mobile irrigation systems and the implementation of objective scheduling is significantly positive as illustrated by the Spearman correlation (r=0.290; p=0.002), the strength of association as illustrated by Cramer's V value is not statistically significant (Cramer's V =0.558, p=0.059).

Significant negative correlations exist between the use of stationery irrigation systems (Cramer's V=0.758; p=0.000), flood system (Cramer's V=0.549; p=0.000), portable irrigation systems like hand shifting (Cramer's V=0.486;

p=0.000) and the implementation of objective scheduling. This suggest that these farmers are not in a position to implement precise scheduling due to the choice of irrigation systems. These significant relationships provide evidence to support Hypothesis 1.1, namely that the implementation of irrigation scheduling practices is determined by personal and environmental factors like the choice of an irrigation system.

Table 5. 5: Relationships between on-farm irrigation methods and the implementation of objective irrigation scheduling (N=297)

Irrigation method	Cramer's V			
	Value	p	r	p
Mobile systems (centre pivot, travelling gun)	0.558	0.059	0.290	0.018
Portable system (dragline, semi-dragline, side roll, hand shift)	0.486	0.000	-0.246	0.002
Flood system (short furrow, flood basin)	0.549	0.027	-0.271	0.025
Micro system (micro, drip)	0.540	0.000	0.294	0.032
Stationery system (semi permanent, floppy)	0.758	0.000	-0.825	0.023

5.4 SUMMARY

The technology level of the farm, size of the farming operation and the type of crops produced on the farm determine the selection of scheduling methods. The use of a centre pivot and drip/micro are positively associated with the use of objective irrigation scheduling. Corporate farming enterprises and farms with high value irrigated crops are more likely to adopt and invest in precise scheduling methods.

CHAPTER 6
INFLUENCE OF EXTERNAL FACTORS ON THE IMPLEMENTATION OF ON-FARM IRRIGATION SCHEDULING

6.1 BULK WATER DELIVERY ON IRRIGATION SCHEME

Irrigation scheduling at farm level implies real time decision as to when and how long to irrigate, expressed in absolute values. This however, depends on the regular and effective supply of bulk water. Four approaches to the management of irrigation water conveyance systems are generally found:

- *"Continuous flow or on demand approach*

  In this system the scheme manager aims to maintain the supply of the system so that any user can abstract water at any time. In canal and river systems, this usually means that the scheme manager has to monitor the flow depth at strategic points, and adjust the in-flow to the system accordingly. In pipeline systems, the pressure (and sometimes the flow rate) in the conduit has to be monitored and controlled.

  According to Knoetze (2003), the scheme manager needs to be experienced and know the system and relevant farming practices on the scheme well in order to operate a scheme in this way. Especially in the case of river schemes, he needs a few seasons to understand the flow of the river, since water releases can take up to a few days to reach the point in the system where there is a shortage. This system lend itself well to the use of telemetric monitoring of critical points, since it eliminates driving to the point itself to observe the flow.

- *The "request" approach*

  The objective of this type of management system is to supply the amount of water that is requested by the users in advance. Farmers request the water they will need, specifying the flow rate at which they will abstract the water, the period of time they will be abstracting it for, and the time during the week they will be abstracting. The scheme manager then uses this information for planning the water releases into a system and how it will be adjusted to meet the constraints of the system (van Strijp, 2002).

- *Irrigation turn approach*

  This system is usually followed where a conveyance system has insufficient capacity for an “on demand” approach to be followed. In this approach, each user is allowed to abstract water at certain times within an applicable schedule (e.g. every 7 days or fortnight). The flexibility of irrigation farmers’ decision making regarding the application rate and intervals of irrigation within this system is very limited. For these farmers the advantages of on-farm storage facilities could be enormous in providing additional flexibility in terms of irrigation management, since a farmers irrigation time may come at a time when he does not need to irrigate or he may need water during a hot spell but his turn is still a few days away (Eksteen, 2002).

  Many of the small-scale irrigation schemes were designed to operate using irrigation turns. Therefore these scheme were divided into blocks along the main canal, and farmers in each block receive an irrigation turn on a specific day.

- *Water quality management approach*

  The objective with this approach is to maintain an acceptable water quality in the distribution system by monitoring the water quality and releasing additional water from the source if necessary. The quality of water is the limiting factor rather than the quantity that needs to be abstracted by the users in the distribution system.

Twenty five percent of the farmers were of the opinion that they could hardly implement precise crop-based scheduling methods due to fixed proportional bulk water delivery system, or due to problems they experience with the advance ordering of irrigation water due to the lack of canal capacity, especially during peak irrigation requirements periods in the production season. Delivering irrigation water with a high degree of flexibility and reliability depends not only on the technical means but also requires:

- o decentralization of decisions and responsibilities of the delivering system (e.g. main canal level and secondary canal levels), and

- o the institution of seasonal or yearly water allocations (Burt, 1996, Knoetze, 2003).

Irrigation scheduling based on soil water balance requires that farmers take an appropriate amount of water from the irrigation water supply system at the proper time. However where fixed turns of bulk water delivery are experienced, this approach usually results in excessive water being applied by irrigation farmers when the water is available. Water stress periods can occur during the gaps between successive water applications when these gaps are too large as in the case reported by some of the small-scale farmers. The rigidity of the "irrigation turn approach" that many of the small-scale farmers and some commercial farmers in areas of the Western Cape and Northern Cape experience, caused them not to use the system as intended, but as "on demand system".

The inappropriate design of canals where water takes a considerable time to travel the length of the canal and where insufficient canal capacity often causes shortages especially during peak periods of irrigation requirements during the growing season, were raised as some of the constraints that prevent farmers from the practising of objective irrigation scheduling methods.

Reliability, as recalled by Burt (1996) is a prerequisite for the implementation of precise irrigation scheduling. Whatever the delivering schedule applicable, either dictated by a water institution or as an agreement between neighbours, either rigid or flexible, it is imperative that water is supplied in conformity with the expectations of the user. Reliability of water was found to be sufficient in the majority of cases where interviews were held, but some farmers complained about not receiving what was due to them, especially farmers at the end of a canal delivery system. Reliability of bulk water delivery was also found to be an essential condition for the establishment of trust and confidence between water management institutions and irrigation farmers.

Figure 6.1 indicates the percentage distribution of irrigation schemes according to the percentage irrigation scheduling applied and the perception of farmers with regard to the flexibility of bulk water delivery on the irrigation scheme. Significant differences exist between the different irrigation scheduling groups with regard to the perceived flexibility of bulk water delivery on the irrigation scheme (F=6.14; p=0.014). The difference lies in the fact that with increasing reported irrigation scheduling figures there is a tendency that farmers also perceive bulk water delivery to be less flexible.

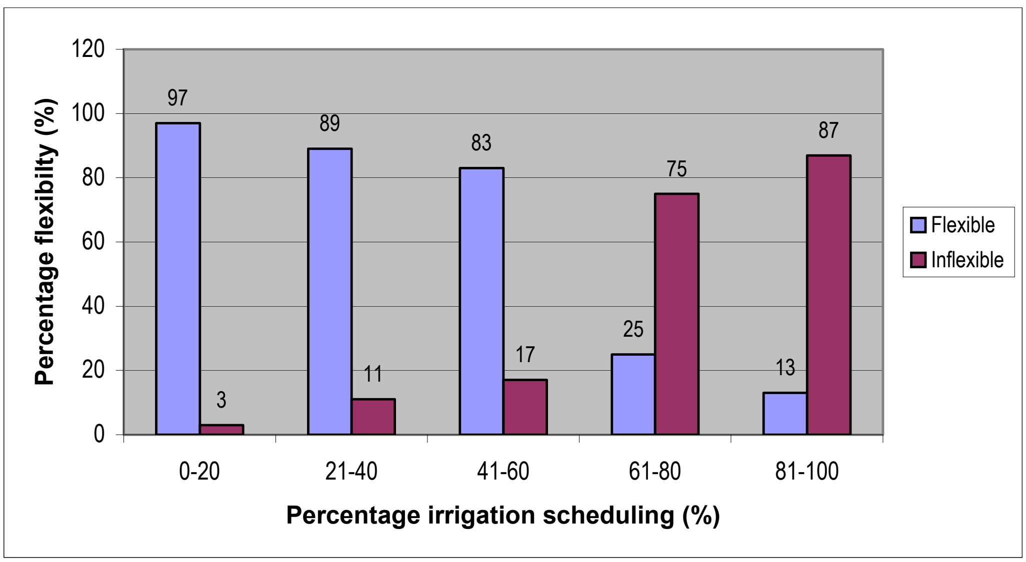


Figure 6. 1: Percentage distribution of irrigation schemes according to the percentage irrigation scheduling applied and the percentage ratio between perceived flexibility of water delivery (N=297)

The relationship between flexibility of bulk water delivery to the farm and the implementation of objective irrigation scheduling is significantly negative (r=-0.316; p=0.006) implying that increased flexibility in bulk water delivery is associated with higher reported implementation of objective irrigation scheduling. Respondents in the Northern Cape (Lower Orange and Upper Orange water management areas) indicated the lowest flexibility (25%) in terms of freedom to irrigate. The majority of respondents (62%) in this province use surface irrigation and indicated that precise irrigation scheduling is very difficult to associate with a higher reported implementation of objective irrigation scheduling. This also means that higher levels of fixed turn bulk water delivery are associated with higher levels of reported implementation of subjective irrigation scheduling. This significant relationship provides evidence in support of Hypothesis 1.1, namely that an independent environmental factor, like bulk water delivery, determines the ability of farmers to implement on-farm objective irrigation scheduling methods.

Respondents in the Northern Cape (Lower Orange and Upper Orange water management areas) indicated the lowest flexibility (25%) in terms of freedom to irrigate. The majority of respondents (62%) in this province use surface irrigation and indicated that precise irrigation scheduling is very difficult to implement due to fixed water delivery and the practicing of surface irrigation methods. The performance of these specific irrigation methods are still considered to be low, and irrigation efficiency must be evaluated in terms of uniformity of water application and the ease of scheduling and timing of irrigations (Eksteen, 2002). According to Terblanche (2003), the adoption of laser levelling shows the way to a significant improvement in accuracy of distribution uniformity. This practise also contributes to improvement of water use efficiency and production yields.

6.2 ALLOCATION OF IRRIGATION WATER

On many of the schemes, individual abstractions are not measured, even though the rate of abstraction may be specified. In most river systems, no quantitative data on the abstractions are available.

There are generally two approaches involved with paying for the use of irrigation water followed by farmers:

- Pay the full allocation of irrigation water, regardless of the actual amount of water used. Water is usually requested on a weekly basis, which is then monitored and compared with the allocation.
- Pay only for the volume of water (m^3) they are likely to use based on the areas planted under a specific crop. The allocation is then based on the specific water crop requirements in that area (See Box 6.1: Oranje Riet WUA area).

Box 6.1: Oranje Riet Water Users Association

"The Oranje Riet WUA has conducted a survey to determine the total area under irrigation as well the major crops grown within the WUA district. The area under production for each crop was determined with the use of satellite technology. This information was included in the database of the Oranje Riet WUA. The net monthly and annual irrigation requirements for the WUA were subsequently calculated. Farmers in this WUA are receiving a predetermined allocation based on the average crop water requirements as calculated on the combination of possible crops typically grown as based on "crop grow norms" for the area. This allocation however includes additional water to safeguard farmers against very hot spells or other extreme climatic conditions.

Farmers are paying a minimum flat tariff for 85% of the predetermined allocation as based on crop requirements and historical data. The rest (15%) of the allocation can either be used for additional irrigated area (double cropping) at a differentiated tariff or sold to other farmers within the scheme who may need more water than they have been allocated. This differentiated tariff structure serves as a motivation and incentive for farmers to use water more efficiently on the farm and also provide some flexibility in terms of their water management"

According to Pretorius (2003), the differentiated tariff system applied by the Department of Water Affairs and Forestry (DWAF) until 1998 encouraged farmers to use water efficiently. This system included a minimum fixed tariff for 75% of the allocation, while the rest of the allocation was based on volumetric supply against a differentiated tariff. He is of the opinion that this tariff system provides farmers with financial incentives to use water more efficiently. However, he also agrees that this did not prevent farmers at the beginning of the conveyance systems to take more than was allocated unless effective measurements were introduced for individual abstractions.

Photo 6. 1 Main irrigation canal system used for water distribution at Riet River Irrigation Scheme

Ninety four percent of the respondents indicate the licensing of specific allocation of irrigation water while the rest, mainly private irrigation farmers, make use of boreholes and weirs. The mean irrigation allocation applicable for the nine provinces is 8 336 m^3/ha/annum, with the Lower Orange River scheme receiving the highest allocation of 15 000 m^3/ha/annum because of relative higher evaporation figures. The majority of irrigation farmers (57%) received an allocation for irrigation between 6 201-11 000 m^3/ha/annum (Figure 6.2).

The general expectation that farmers with bigger allocations are more reluctant to implement precise irrigation scheduling is partially supported. Sixty one percent of the farmers with bigger allocations (>11000 m^3) perceive irrigation scheduling to imply the use of subjective irrigation scheduling methods, while 72 percent of the farmers that belong to the smaller allocations (<6201 m^3) perceive irrigation scheduling to entail objective scheduling methods.

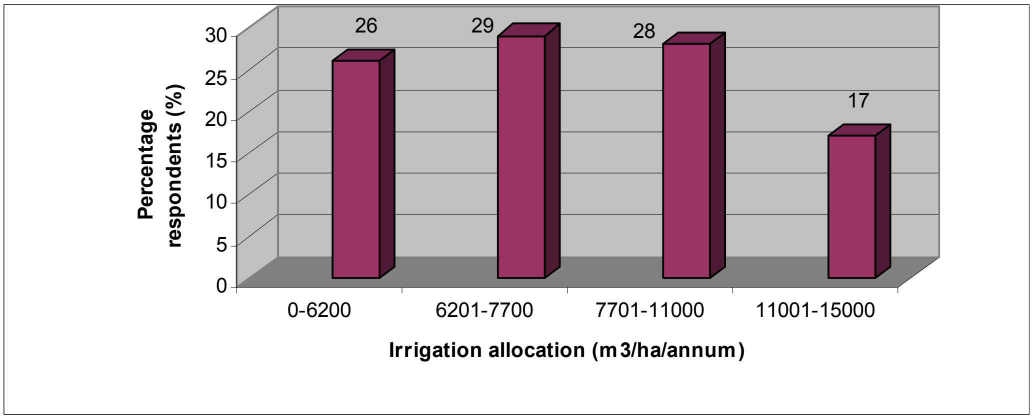


Figure 6. 2: Distribution of respondents regarding irrigation water allocation in South Africa (N=297)

Table 6.1 reveals a significant positive correlation between volume of irrigation water allocations and the use of intuition (r=0.242; p=0.004) as well as the feel method (r=0.447; p=0.045). This provides partial evidence in support for Hypothesis 1.1, namely that environmental factors like irrigation water allocation influence the implementation of irrigation scheduling methods. However, it needs to be emphasized that many of the respondents with bigger irrigation water allocations also make use of surface irrigation or receive water on fixed turns (e.g. farmers from the Lower Orange) and are therefore not in a position to apply precise irrigation scheduling methods.

Table 6. 1: Relationships between implementation of irrigation scheduling methods and irrigation water allocations as reflected in a test of association (N=297)

Irrigation scheduling methods	r	p
Real time ET	- 0.515	0.097
Long term ET	-0.144	0.448
Computer irrigation scheduling models	-0.188	0.068
Soil water content measurement	-0.168	0.066
Feel method	0. 477	0.045
Intuition	0.242	0.004

Although the majority of farmers that belong to smaller irrigation allocations perceived irrigation scheduling to entail the use of objective irrigation scheduling methods, Table 6.1 indicates that no significant correlations exist between the implementation of objective irrigation scheduling methods and the allocation of relative smaller volumes of irrigation water.

6.3 IRRIGATION TARIFFS

The National Water Act (1998, No 36) determines that any person who is registered in terms of a regulation or is holding a license to use water, must pay all imposed charges. Since 1996/97 new water tariffs are imposed on commercial irrigation farmers and on government schemes. The implementation of the new water tariff structure applies within a three-tiered structure:

- The first tier is determined by the pricing of bulk raw water supply, and relates to water supplied by DWAF.
- The second tier relates to water supplied by water boards and irrigation boards.
- The third tier deals with water supplied and managed by local authorities.

Farmers on the irrigation schemes are responsible for two different charges that are included in the current water tariff:

- *Water resource management charge*

  The water resource management charge relates to the expenditure of activities that are required to regulate, manage and maintain the water resources or catchments in a specific water management area. Initially the water resource management will continue to be the task of DWAF, however within the new act the intention is to delegate or assign significant water resource management functions to the Catchment Management

Agencies (CMAs) that are established or in the process of being established. The water resource management charge relates to all water utilized within the water management area, and is therefore charged to all water users.

- *Water resource development and use of waterworks (O&M) charge*
  This cost includes the related costs of investigation, planning, design and construction of water schemes, which constitutes the capital cost of irrigation projects. In order to recover fully the water resource development costs, the capital component of the unit cost of water is determined by a depreciation charge and a return on assets charge. This charge is only levied on the users of specific government schemes or systems, and is based on the costs associated with that particular scheme (Van der Merwe, 2004).

The water tariffs, as indicated in Table 6.2, reflect the water resource management charges levied for users of irrigation board schemes and WUAs as per province, while the tariff applicable to irrigation farmers on government irrigation schemes include the water resource development as well as the operation and maintenance (O&M) charge. According to Table 6.2, it appears that the irrigation tariffs (R/ha/annum) significantly differ (X_i^2=67.33; df=27; p=0.001). On an irrigation scheme like Pongola, for instance, the tariff that irrigation farmers are paying also recovers a portion of the capital investment of the newly built Bivane or Parisdam and amounts to approximately 16c/m^3 for irrigation water or R1 285 per (registered) irrigated hectare per annum. The dam was funded through a three-way partnership between Pongola sugarcane growers, Illovo Sugar Limited and DWAF.

The mean tariff that irrigation farmers pay for irrigation water is R397.97 per hectare per annum, with the highest tariff R3 900 per hectare per annum reported in the Western Cape. Fifty nine percent of irrigation farmers that pay the higher irrigation tariff (R1044 - 3900/ha/annum) are farming in the Western Cape. Irrigation water tariffs are a flat rate based on the sum of the individual volumetric allocations field edge, adapted for assurance of supply to represent long-term average annual use, plus average annual distribution losses on communal infrastructure (Van der Merwe, 2001). According to Table 6.2, irrigation farmers from Gauteng Province pay the lowest mean irrigation tariff, namely R109/ha/annum, while farmers from the Western Cape recorded the highest mean irrigation tariff (R622/ha/annum).

Table 6. 2: The distribution of respondents according to the irrigation tariffs reported as per province (N=297)

Province	Irrigation tariffs (R/ha/annum)								Mean tariff (R/ha/ annum)	Total number respondents	
	0-250		251-520		521-1043		1044-3900				
	(n)	%	(n)	%	(n)	%	(n)	%		(N)	%
Gauteng	5	3	0	0	0	0	0	0	109	5	2
Free State	6	4	2	3	7	13	0	0	414	15	5
KwaZulu Natal	19	13	3	4	1	2	2	12	253	25	8
Mpumalanga	19	13	12	16	3	6	0	0	241	34	12
Northern Cape	8	5	12	16	10	19	2	12	504	32	10
Eastern Cape	6	4	4	5	1	2	2	12	487	13	4
Western Cape	35	24	12	16	9	17	10	59	622	66	22
Limpopo	11	8	7	9	2	4	0	0	232	20	7
Northwest	18	12	5	7	10	19	0	0	305	33	11
Small-scale	19	13	17	23	9	17	1	6	337	46	15
No figure reported										8	3
Total	**146**	**100**	**74**	**100**	**52**	**100**	**17**	**100**		**297**	**100**

Seventy eight percent of the small-scale farmers pay less than R520/ha/annum, since they are supported through the inclusion into a concessionary period during which the full cost of water is not levied. In this survey the majority of small-scale farmers on government schemes indicated that they are only responsible for the maintenance and operation costs (electricity costs) of irrigation on the scheme.

Figure 6.3 compares the different types of irrigation schemes regarding the irrigation tariffs reported for the respective irrigation schemes. There are significant differences between type of irrigation schemes with regard to the irrigation tariffs that farmers pay (X^2=16.46, df=6; p=0.011), i.e. farmers on irrigation board schemes and WUAs are paying more than those on government irrigation schemes. Forty eight percent of irrigation farmers on government schemes and 51 perecent irrigation farmers respectively on irrigation board schemes are paying water tariffs of R250 per hectare per annum or less for their irrigation water allocation.

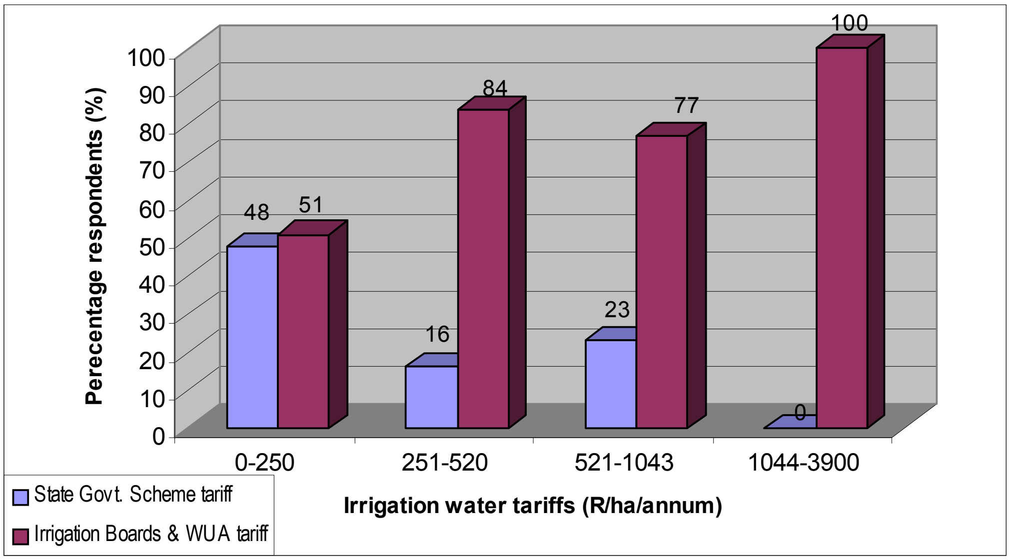


Figure 6. 3: Percentage distribution of the irrigation schemes according to the irrigation tariffs applicable (N= 297)

Caswell & Zilberman (1985 and 1990) argue that higher water tariffs would induce the adoption of water saving technologies like objective irrigation scheduling. Table 6.3 shows the correlations that were found between the implementation of irrigation scheduling methods and the applicable water tariffs for irrigation schemes.

Significant negative correlations exist between perceived implementation of intuition (r=-0.177; p=0.001) as well as the feel method (r=-0.227; p=0.002) and the applicable irrigation water tariff for irrigation farmers. Except for significant correlations that exist between objective irrigation scheduling methods like the application of real time ET methods (r=0.331; p=0.009) and the use of plant monitoring (r=1.0; p=0.014), no statistically significant correlation between the adoption of the other mentioned objective irrigation scheduling methods like soil water measurement, use of computer models or the use of long term ET figures and water tariffs exist.

Table 6. 3: Relationship between the implementation of irrigation scheduling methods and irrigation tariffs (N=297)

Irrigation scheduling methods	r	p
Plant measurement	1.0	0.014
Real time ET	0.331	0.009
Long term ET	0.203	0.141
Computer irrigation scheduling models	0.085	0.242
Soil moisture measurement	0.063	0.408
Feel method	-0.227	0.002
Intuition	-0.177	0.001

These findings provide partial evidence in support of Hypothesis1.1, namely that independent environmental factors like irrigation water tariffs influence the adoption behaviour of irrigation farmers regarding the implementation of irrigation scheduling methods. However, from this study it is clear that other factors are outweighing the water tariff factor. Some of these factors are crop diversification potential in a specific area of cultivation and the risk and flexibility involved in water delivery (i.e. the irrigation farmers guarantee of receiving his entitled water allotment). These factors have to be taken into account as well when analyzing the potential effects that a given pricing policy may have on the adoption of water saving or on incentives to engage in water use management strategies like irrigation scheduling.

Technical endowments in the different schemes have a decisive influence on the capacity that different pricing schemes have to induce in the reduction of water consumption. The relatively older irrigation schemes have a substantial margin for improving their technical conditions and therefore for attaining large water saving levels. The more modern irrigation schemes have already been endowed with more effective irrigation systems and for this reason their response to price signals by more efficient water use strategies is perhaps smaller.

6.4 SUMMARY

A negative interrelationship between bulk water delivery and the application of objective irrigation scheduling exist. The general problems experienced by some irrigation farmers confined to the relative poor state of canals due the age of many of the irrigation schemes and also the lack of canal capacity during peak production periods, hamper implementation of more precise scheduling methods.

Evidence indicates that farmers with relatively bigger irrigation water allocations and lower water tariffs tend to make more use of intuition and are more reluctant to implement precise irrigation scheduling. However, from the study it is clear that other factors are outweighing the water tariff factor like flexibility with regard to bulk water delivery on scheme level.