Technology Transfer of SAPWAT3, Verifying Correctness of Program Output and Evaluation of its Adoption Potential

Report to the
WATER RESEARCH COMMISSION

by

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EXECUTIVE SUMMARY

SAPWAT3, in its present form, is the product of WRC Project K5/1578 as well as 20 years of research related to irrigation, agricultural engineering, soil, crop, agricultural meteorology and agricultural economics funded by the Water Research Commission. Development time and the cost involved accentuate the need to disseminate knowledge of SAPWAT3 to as wide a scope of potential users as possible, as well as to provide the necessary back-up, otherwise the danger exists that SAPWAT3 will not be used to its fullest potential and development time and funding would have been wasted. The next program version will include the expansion of functionality and correction of errors that have been identified, some of which is included in this report.

The development of models that could be used as tools in the estimation of irrigation water requirements have all been faced with varying degrees of the problem of credibility. The Green Book and its update used A-pan based crop factors. Irrigation estimates went well as long as the A-pan evaporation was calibrated for the specific area. In the energy-balance and mass-transfer approaches the potential for shorter-term verification of crop coefficient became more of an option, although credibility problems were still present.

The one problem that could not be solved with the development of estimation approaches is that of correct crop coefficients, which are usually costly to determine through mainly lysimeters testing. Some crops, have been well researched while other have been less well researched. Unexpected deviations of estimated irrigation from measured requirements are found from time to time, even in well researched crops. The result is that crop irrigation requirements need to be continuously verified and the relevant crop coefficients adapted where required. Furthermore, it is acknowledged that problems are found with the fitting of the FAO four-stage crop curve to perennial tree and vine crops. The problem of the costly verifying crop coefficients used for irrigation estimate output could be solved by the inclusion of a subroutine in an irrigation estimation program that compares the daily estimated program output with actual, measured data from a field. Such a subroutine has now been included in SAPWAT3, it seems to work, but it still needs extensive field testing.

The acceptance of SAPWAT by more than 300 users in 13 countries shows that the program has qualities that make it acceptable to potential users. While a lot of speculation about the reasons for this phenomenon has been going on for quite a while, the real reasons for this widespread adoption has not been field-tested. The characteristics that make SAPWAT acceptable as an innovation, as well as the potential for adoption of SAPWAT3 have been researched.

The theory of diffusion of innovations and the acceptance thereof seeks to explain the spread of new ideas through a social system through communication over time. Members of a community go through five stages of adoption. During its communication, an idea is rarely evaluated from a scientific standpoint. Instead, subjective perceptions of the innovation influence its diffusion, a process that happens over time. Finally, social systems determine diffusion; the system's norms on diffusion, roles of opinion leaders, types of innovation decisions, as well as innovation consequences.

More recent research into the adoption of innovations has been on ways that are characteristic of an innovation influence potential acceptance. One such approach is the technology acceptance model (TAM), which seems to be particularly suitable for testing technological innovations that can make office and related work easier. It is mainly based on two factors that are theorized to be fundamental determinants of system use and are therefore predictors of adoption. These characteristics are the perceived usefulness of the innovation as well as the perceived ease of use. TAM proposes that perceived ease of use and perceived usefulness of technology are predictors of user attitude towards the use of such technology, subsequent behavioural intentions and actual usage and can therefore predict user acceptance of a technology before the users get heavily involved in it, and thus is a cost-effective tool in screening potential systems that could possibly be used.

The main objectives of this project were to verify program outputs, to demonstrate SAPWAT3 and its use to potential users and to determine the adoption potential of SAPWAT3. In this process, the characteristics of SAPWAT which led to its large scale adoption, was also researched.

For the estimation of irrigation requirements with a program such as SAPWAT3 that is not a crop growth model, but a model that imitates crop growth and development on a fairly simple basis, it is necessary that crop growth and development be described as accurately as possible. The one input that remains fairly rough and ready, is the description of crop growth and development through the four stage FAO crop growth curve and its related crop coefficients. The next version of SAPWAT3 will contain a module described in this report which will enable researchers to improve the accuracy of the FAO four stage crop growth stages and the related crop coefficients.

SAPWAT is used by a variety of professional groups, mostly used for designing and planning of irrigation systems, and to a lesser extent for planning and management of irrigation water reticulation systems. It is mostly used on a monthly basis, which is in line with the expected use of such a tool. Reasons for its popularity are mainly its ease of use, the quick results and good crop irrigation requirement output, its user-friendliness, the credibility of its results, as well as the fact that it is scientifically based.

Evaluating SAPWAT against the characteristics that make an innovation acceptable, SAPWAT scored much better than average in the fields of relative advantage, observability and compatibility and better than average on complexity and trialability. Comparing this to the TAM approach, there was a marked better than average score for usefulness and a better than average score for ease of use, which is an accurate reflection of the results of the Rogers scores.

The acceptability of SAPWAT3 was tested after about three months' use through the TAM approach. SAPWAT3 is used by most of the more experienced and higher trained people that have to do with irrigation water planning, management and use. Of these users, the designers and planners of irrigation systems are the biggest group.

Slightly more than half of the respondents are of opinion that the Water Act imposes necessary regulations to irrigation water users, even though there is no clear opinion on whether or not irrigation scheduling could be effectively applied only if farmers have full control of the water supply.

Most SAPWAT3 users are familiar with research done by the WRC and are also users of the knowledge generated. The generated knowledge is mostly used for planning and designing of systems, research and for irrigation water management.

The original SAPWAT was built as simply as possible with the aim of involving all sectors of the irrigation fraternity as well as all levels of training in its use. SAPWAT3 has more functionality and is therefore less simple to use than SAPWAT, but at the same time giving users more flexibility of application. It is designed as a planning tool, and the expected major users were found to be irrigation water use planners, irrigation water use managers and designers of irrigation systems.

The credibility of SAPWAT3 output is relatively high and all users use it for assessing water resource demand and supply in some way. WUA managers tend to concentrate on water resource assessment and demand management while consultants use SAPWAT3 more for the on-farm part of irrigation planning and management as well as for larger scale water resource demand and supply assessment. Lecturers use SAPWAT on a very wide scope of application, whereas scheduling services tend to concentrate on the on-farm water management part. Designers and planners concentrate on the on-farm irrigation requirement planning and management, and they also see the use of SAPWAT3 as leading to increased productivity.

The importance of a user manual for SAPWAT3 is high, and though the flexibility of SAPWAT3 was highly acclaimed by just about all groups, a disappointing number of user groups have indicated that SAPWAT3 is difficult to use.

SAPWAT3 users prefer back-up support by the research team with visits and e-mail support being the most important. Most respondents are satisfied with the present communication and support by the research team.

SAPWAT3 users see lack of available time as the biggest barrier to learning to use the program or, alternatively, to use the program as an analysing tool.

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All the agricultural scientists, technicians, water user association personnel and farmers who willingly shared their knowledge of and experience in crop irrigation requirements and crop characteristics.

TABLE OF CONTENTS

INTRODUCTION

1.1 Background

SAPWAT3, in its present form, is the product of Project K5/1578 as well as 20 years of research related to irrigation, agricultural engineering, soil, crop, agricultural meteorology and agricultural economics funded by the Water Research Commission. Development time and the cost involved accentuate the need to disseminate knowledge of SAPWAT3 to as wide a scope of potential users as possible, as well as to provide the necessary back-up, otherwise the danger exists that SAPWAT3 will not be used to its fullest potential and development time and funding would have been wasted. The next program version will include the expansion of functionality and correction of errors that have been identified, some of which is included in this report.

SAPWAT3 is essentially an enhanced and improved version of SAPWAT (Crosby and Crosby, 1999) that is extensively applied and was developed to establish a decision-making procedure for the estimation of crop water requirements by irrigation engineers, planners and agriculturalists. The intention was that the procedure would provide a shell or framework within which crop water requirements could be estimated; would enhance the user's understanding of the elements that influence water requirements; would be suitable for use by practitioners; would be in line with current international practice; and would incorporate both interpreted research results and the practical experience of specialists.

The development and testing of SAPWAT3 as a further development of SAPWAT was done with Water Research Commission funding. It is now generally in use and is also the accepted model to use in the calculation of irrigation requirements for registration and licensing purposes by the Department of Water affairs. SAPWAT has been developed through two consecutive Water Research Commission research projects as a further development of CROPWAT (Smith, 1992). The Water Research Commission has funded and managed the SAPWAT-SAPWAT3 development over the past 15 to 20 years. Development time and the cost involved accentuates the need to disseminate knowledge of SAPWAT3 to as wide a scope of potential users as is possible, otherwise the danger exist that SAPWAT3 will not be used to its fullest potential and development time and funding would have been wasted. The development of SAPWAT was followed by two technology transfer projects to demonstrate the application of SAPWAT on seven irrigation schemes (Pot, *et al.*, 2008; Van Heerden, *et al.*, 2001). The application of SAPWAT and program shortcomings that have emerged during these actions has highlighted the importance of continuous upgrading and further development. This has led to the development of SAPWAT3 as an upgrade of SAPWAT through Project K5/1578.

The development of models that could be used as tools in the estimation of irrigation water requirements have all been faced with varying degrees of the problem of credibility. The Green Book and its update (Green, 1985) used A-pan based crop factors. Irrigation estimates went well as long as the A-pan evaporation was calibrated for the specific area. In the energy-balance and mass-transfer approaches the potential for shorter-term verification of crop coefficient became more of an option, although credibility problems was still present (Doorenbos & Pruitt, 1977; Du Plessis & Wittwer, 1991; Tanner, 1987).
The one problem that could not be solved with the development of estimation approaches is that of correct crop coefficients, which are usually costly to determine through mainly lysimeters testing. Some crops, which include beans, cabbage, citrus, cotton, maize, onion, peas,

peppers, potatoes, sugar beet, sugar cane, sunflower and wheat, have been well researched (Doorenbos & Kassam, 1986), while other crops such as berries, canola, gourds, granadillas, mangoes, and papaws have been less well researched. Unexpected deviations of estimated irrigation from measured requirements are found from time to time, even in well researched crops. The result is that crop irrigation requirements need to be continuously verified and the relevant crop coefficients adapted where required. Furthermore, it is acknowledged that problems are found with the fitting of the FAO four-stage crop curve to perennial tree and vine crops (Allen *et al*., 1998).

The problem of the costly verifying crop coefficients used for irrigation estimate output could be solved by the inclusion of a subroutine in an irrigation estimation program that compares the daily estimated program output with actual, measured data from a field. Such a subroutine has now been included in SAPWAT3, it seems to work, but it still needs extensive field testing.

The acceptance of SAPWAT by more than 300 users in 13 countries shows that the program has qualities that make it acceptable to potential users. While a lot of speculation about the reasons for this phenomenon has been going on for quite a while, the real reasons for this widespread adoption has not been field-tested. The time has become ripe for the determining of the characteristics that makes a program like SAPWAT acceptable as an innovation, because the results could be a pointer for future development. At the same time, the potential for adoption of SAPWAT3 need to be determined to find out to what extent the more functional, and therefore more complex, program satisfies the characteristics that would enhance adoption.

The theory of diffusion of innovations and the acceptance thereof seeks to explain the spread of new ideas. In his, by now, classical study of diffusion, Rogers (1962) defined it as an innovation that spreads through a social system through communication over time. On becoming aware of an innovation, members of a community go through five stages of adoption: awareness, persuasion, decision, implementation, and adoption (or rejection). During its communication, an idea is rarely evaluated from a scientific standpoint. Instead, subjective perceptions of the innovation influence its diffusion, a process that happens over time. Finally, social systems determine diffusion; the system's norms on diffusion, roles of opinion leaders, types of innovation decisions, as well as innovation consequences (Rogers 1995).

More recent research into the adoption of innovations has focused upon the characteristics of innovations or adopters, or interpersonal factors or the influence of social or commercial stimuli (Rogers, 1995). One such approach is the technology acceptance model (TAM), which seems to be particularly suitable for testing technological innovations that can make office and related work easier. It is mainly based on two factors that are theorized to be fundamental determinants of system use and are therefore predictors of adoption (Davis, 1989; Goa, 2005). These characteristics are the perceived usefulness of the innovation as well as the perceived ease of use. TAM proposes that perceived ease of use and perceived usefulness of technology are predictors of user attitude towards the use of such technology, subsequent behavioural intentions and actual usage. TAM can serve the purpose of predicting user acceptance on a technology before the users get heavily involved in it, and thus is a cost-effective tool in screening potential systems that could possibly be used (Goa, 2005).

Both the Rogers' and TAM approaches were used to determine the reasons for the widespread acceptance of SAPWAT and to determine to what extent the TAM approach could be used as a predictor of the future adoption of SAPWAT3. The main reason for this testing was based on Davis (1989) who pointed out that compatibility, relative advantage and complexity have the most consistent significance in relationships across a broad range of innovation types. Of these, complexity, as defined by Rogers (1995), parallels perceived ease of use quite closely. The determination of reasons for adoption done on SAPWAT by using both approaches has shown that the TAM approach could be used as a predictor of acceptance of SAPWAT3. At the time of the SAPWAT3 survey most of the users have had very little experience of SAPWAT3, and even though the results show a fair chance of acceptance, some doubt might be raised because of the lack of experience by the respondents.

SAPWAT3, like SAPWAT enables a user to estimate crop irrigation requirement one at a time. The need was in the mean time identified to import crops grown under similar weather and management approaches as a group and let the program then automatically estimate irrigation requirements of all crops imported as such. This development was done for a client other than the WRC, but as the WRC is the copyright holder, all such developments need to be reported on in the next development report to the WRC. A short report on this development is included as a chapter in this report.

1.2 Objectives for the technology transfer of SAPWAT, the verifying of its output and the evaluation of its adoption potential

The objectives for this project were:

- To further verify program outputs;
- To evaluate the adoption potential of SAPWAT3 as an innovation;
- To demonstrate SAPWAT3 as a tool for estimating and analyzing crop irrigation requirements to potential users.

The execution of this project has satisfied all these objectives.

CHAPTER 2
IMPORTING CROP DATA EN MASSE

2.1 Introduction

A handicap of working with SAPWAT3 is that it can estimate irrigation water for crops one at a time, with user input for each run. Estimating irrigation requirements for a number of crops that are grown in the same weather station area, on the same soil and under the same irrigation system could become tedious. A module has been developed that will allow the user to import any number of crops simultaneously and the program will then automatically run through all the crops and estimate irrigation requirements for them. This allows the user to make use of a crops data base, such as the WARMS data base of the department of Water Affairs, as a basis for importation.

2.2 Methodology

2.2.1 Getting there

Select the irrigation requirement approach "Import all crops of an area" on the opening screen of SAPWAT3 and click the "Next" button. The screen shown in Figure 2.1 appears:

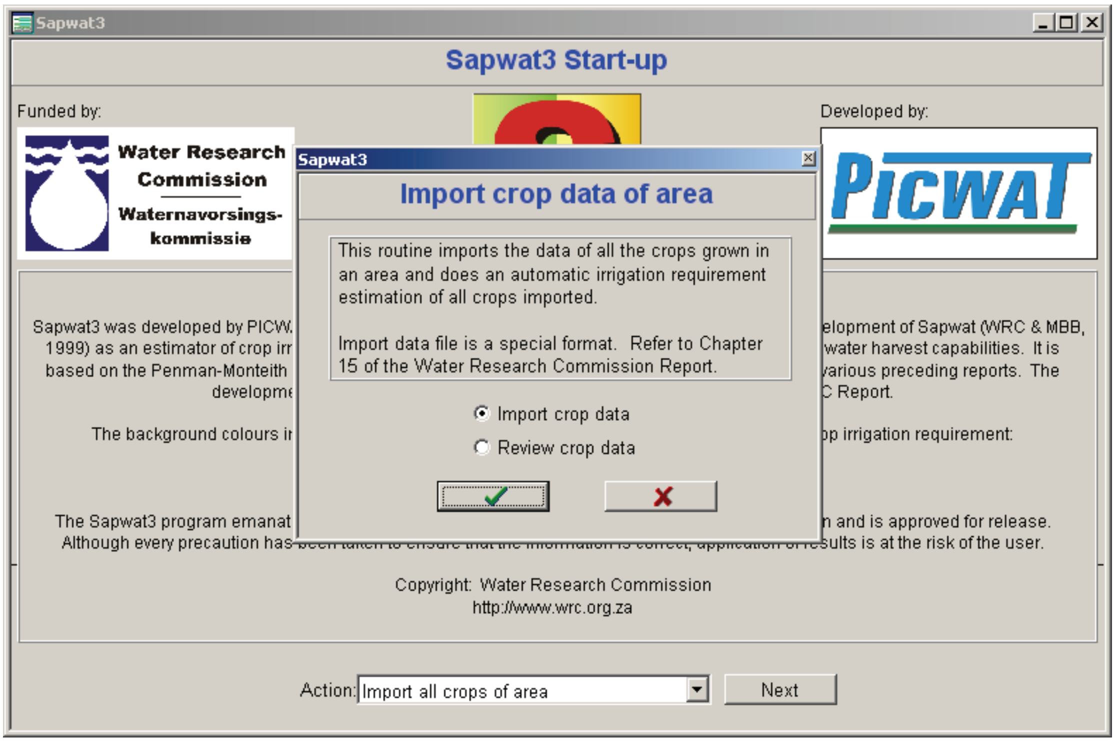

Figure 2.1 Opening screen for importing and estimating crop irrigation requirements *en masse*.

Select import crop data to start the process and click the "Next" button to go to the screen format shown in Figure 2.2:

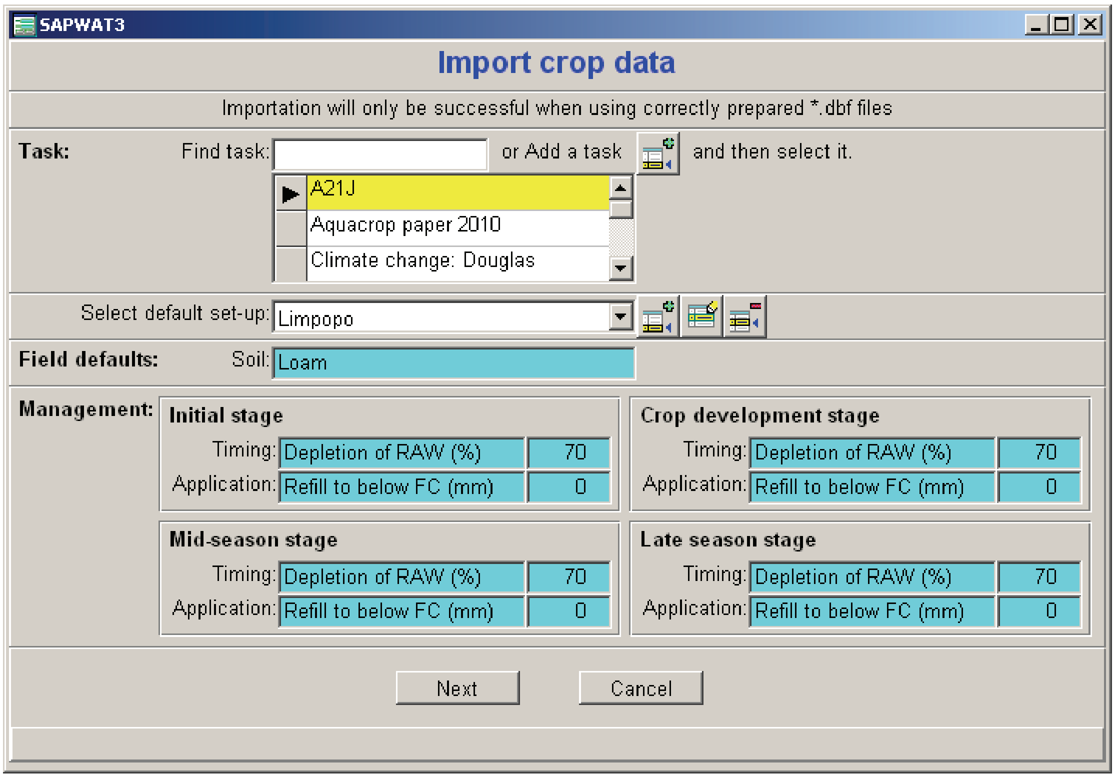

Figure 2.2 The set-up screen for default values to be used for estimating irrigation requirements of a group of crops.

Add or edit data as required. When the set-up is complete, click the "Next" button to go to the screen where the import file can be identified and marked for importation.

2.2.2 The import file

Some data preparation is required before it can be imported. Needles to say, the correctness of data in the file from which importation takes place, must be verified.

The structure of the import file is shown in Table 2.1:

Table 2.1 Data table structure for importation of crop data

Name	Type	Width	Decimal	Comments
Quat	Character	9		Based on SA quaternary system to link into the SA weather station file
S3SystemID	Numeric	11	0	See irrigation system table (Table 2.2)
S3Crop	Character	30		See crop data table (Appendix A)
S3CropID	Numeric	8	0	
S3Option	Character	50		
S3OptionID	Numeric	8	0	
Plantdate	Date	10		Format dd/mm/yy (Month and day must be the same as in Appendix A)
ActualCover	Numeric	12	0	% cover at full growth
Wettedarea	Numeric	11	0	% soil surface wetted during irrigation

The table can be constructed in any data or spread-sheet program, but must be translated into a DBF5 file for importation. Most spreadsheet and data programs have such a function.

Table 2.2 Irrigation systems in SAPWAT3 for choice of SystemID

SystemID	System	IrriSysAppl	Efficiency	DU	WettedArea
1	Centre pivot	25	80	100	100
2	Drip	25	95	100	20
3	Flood: basin	25	75	100	100
4	Flood: border	20	60	100	100
5	Flood: furrow	50	65	100	100
6	Linear	50	85	100	100
7	Micro spray	25	90	100	70
8	Micro sprinkler	75	85	100	70
9	Sprinkler: big gun	75	70	100	100
13	Sprinkler: boom	75	75	100	100
14	Sprinkler: dragline	75	75	100	100
15	Sprinkler: hop-along	75	75	100	100
16	Sprinkler: permanent	75	85	100	100
17	Sprinkler: quick-coupling	75	75	100	100
18	Sprinkler: side roll	75	75	100	100
19	Sprinkler: travelling boom	75	80	100	100
20	Sprinkler: travelling gun	75	75	100	100
21	Subsurface	75	95	100	20
22	Sprinkler: permanent (floppy)	75	85	100	100

2.2.3 After importation

SAPWAT3 goes through the normal estimation of irrigation requirement routine. If planting dates fall outside those provided for in SAPWAT3, an error message appears to this effect. By clicking on the “OK” button the program carries on and runs the next crop.

Crop irrigation requirement results can be viewed and edited through the normal editing functions in SAPWAT3.

CHAPTER 3
TESTING THE CORRECTNESS OF SAPWAT3 ESTIMATES

3.1 Introduction

Over the time that crop irrigation requirement estimates have been based on historic weather data, questions have been asked about the correctness of these estimates for future scenarios because estimation tools often need to be applied under climatic and agronomic conditions very different from those under which they were originally developed. Testing the accuracy of estimation tools under a new set of conditions is laborious, time-consuming and costly and yet credible crop water requirement data are often needed at short notice for project planning.

In the planning of crop water requirements for new irrigation schemes, for upgrading of existing schemes or for designing of irrigation systems, the credibility of irrigation requirement estimates need to be high. Wrong decisions based on incorrect data can have serious social, economic, engineering and political implications on the viability of a proposed irrigation scheme or on the upgrading of an existing scheme or even on the potential of the irrigation farmer to continue farming. One of the real problems that the irrigation planner faces when planning for future irrigation water use is that future water requirement might differ from the planned because of changes in cropping patterns due to changes in market, changes in available water supply, scale of farming, mechanisation trends, availability of seasonal labour, economic viability as well as personal preferences of future farmers. More recently expected climate change has also come into the picture as a further complication in the estimation of future irrigation requirement planning.

The perceived and experienced problems with the estimation of irrigation water requirement for planning purposes come a long way. In South Africa it started approximately during the beginning of the 20th century when various experiments to determine irrigation water requirement was done for purposes of irrigation scheme planning and construction, as well as for the management of such schemes. One such case was where the Great fish River Irrigation Board asked for the experimental determination of irrigation water requirements of lucerne for planning and management purposes. This was done on the Tarka Training Farm near Cradock in the Eastern Cape during the early 1920s, and although the experimental technique would not stand up to critical scrutiny, the then recommendation of "two irrigation of three inches per cutting" was a fair but under-estimation of the real requirements (Van Heerden & De Kock, undated). Similar underestimations of crop irrigation requirements used for the planning of older irrigation schemes, such as Vaalharts, Riet River (now Orange-Riet) and Hartbeespoort have resulted in inadequate conveyance systems that require costly upgrading to rectify this problem.

As far back as 1950, Israelson has defined irrigation as essentially being the practice of supplementing the natural precipitation for the production of crops. This definition is, with minor modifications – such as the addition of the concepts of the right amount of water at the right time – still valid today and it forms the basis of irrigation requirement planning (Tanner, 1987). The problem that faced researchers ever since those early days, have been the estimation of future irrigation water requirements for areas, especially for those areas where irrigation has not yet been practised and an experiential base for irrigation requirement estimates therefore did not exist.

In the short term the tools in general use for this purpose is usually seen as credible, provided that correct models for the conversion of the historic data into prediction results are used. Various tools and models that came into being since the middle of the previous century are described in literature and in most cases their strong and weak points are indicated. Most of these were subject to rigorous local calibrations and proved to have limited global validity. Some of these that are or have been in fairly general use are:

3.1.1 Evaporation pans

The best known of these are the American Class A-pan, and to a lesser degree, the Colorado Sunken pan. They provide a measurement of the integrated effect of the weather parameters wind, radiation, temperature and humidity on evaporation from a specific open water surface. The plant responds in a similar way to the same climatic variables, but several factors may produce significant differences in loss of water. Reflection of solar radiation from a water surface is only 5-8%, whereas it is 20-25% from most vegetative surfaces. Storage of heat within the pan can be appreciable and may cause almost equal evaporation during the night and day: most crops transpire only during the day. The differences in water loss from the pans and from crops can be caused by differences in turbulence, temperature and humidity of the air immediately above the surface. Heat transfer through the sides of the pan can occur, which may be severe for sunken pans. The colour of the pan and the use of a screen will also affect water losses. The siting of the pan environment influences the measured results, especially when the pan is placed in fallow rather than in cropped fields (Allen, et al., 1998; Doorenbos & Pruitt, 1977; Haise & Hagan, 1987).

Notwithstanding these deficiencies, with proper siting the use of pans to predict crop water requirements for periods of 10 days of longer, is still warranted. Siting includes calibrating of the pans for specific areas and situations, otherwise discrepancies of 20% or more could result (Doorenbos & Pruitt, 1977; Haise & Hagan, 1987).

3.1.2 Blaney-Criddle method

This relatively simplistic method is recommended for areas where available climatic data cover air temperature only. The equation of this method involves the calculation of the consumptive use factor from mean temperature and percentage of total annual daylight hours occurring during the period being considered. The effect of climate on crop water requirements is, however insufficiently defined by temperature and day length; crop water requirements will vary widely between climates having similar values of temperature and percentage of total annual daylight hours. Consequently the consumptive use crop coefficient will need to vary not only with the crop but also very much with climatic conditions (Doorenbos & Pruitt, 1977). The Blaney-Criddle method has been adapted to estimate a reference evapotranspiration value, which seems to give it some more stability.

Calculation of mean ET_0 should be made for periods no shorter than one month. Since for a given location climatic conditions and consequently ET_0 may vary greatly from year to year. ET_0 should preferably be calculated for each calendar month for each year of record rather than by using mean temperatures based on several years' records (Doorenbos & Pruitt, 1977).

3.1.3 Radiation method

This method is suggested for areas where available climatic data include measured air temperature and sunshine, cloudiness or radiation, but not measured wind and humidity. Knowledge of general levels of humidity and wind is required, and these are to be estimated using published weather descriptions or extrapolation from nearby areas or local sources. Relationships are given between the present radiation formula and reference crop evapotranspiration, taking into account general levels of mean humidity and daytime wind (Doorenbos & Pruitt, 1977).

This method should be more reliable than the Blaney-Criddle approach in equatorial zones, on small islands or at high latitudes even if measured sunshine and cloudiness data are not available (Doorenbos & Pruitt, 1977).

Calculation of mean daily ET_0 should be made for periods no shorter than one month. Except for equatorial zones, climatic conditions and consequently ET_0 may vary. ET_0 should preferably be calculated for each calendar month for each year of record rather than by using mean temperatures based on several years' records (Doorenbos & Pruitt, 1977).

3.1.4 Penman method

For areas where measured data on temperature, humidity, wind and sunshine duration or radiation are available, an adaptation of the Penman method is suggested: compared to the other methods discussed here, it is likely to give the most satisfactory results (Doorenbos & Pruitt, 1977).

The original Penman approach predicted evaporation losses from an open water surface. It consisted of two terms, an energy (radiation) term and an aerodynamic (wind and humidity) term. Experiments showed that the energy part of the equation gave good results in humid cool and arid cold climates. However the aerodynamic part of the equation gave erratic results. A slight modification to the aerodynamic term seems to have solved this problem and it was considered to offer the best results with minimum possible error in relation to a living grass reference crop (Allen, et al., 1998; Doorenbos & Pruitt, 1977).

3.1.5 Penman-Monteith approach

The Penman-Monteith equation requires daily mean temperature, wind speed, relative humidity, and solar radiation to predict net evapotranspiration.

Evapotranspiration contributions are very significant in a watershed's water balance, yet are often not emphasized in results because the precision of this component is often weak relative to more directly measured phenomena, e.g. rain and stream flow. In addition to weather uncertainties, the Penman-Monteith equation is sensitive to vegetation specific parameters, e.g. stomatal resistance or conductance and thus has a wider application than any of the previously mentioned methods. Gaps in knowledge of such are filled by educated assumptions, until more specific data accumulates.

In the energy-balance and mass-transfer approaches the potential for shorter-term verification of crop coefficient became more of an option, although credibility problems were still present. The problems experienced eventually led to the acceptance of the combined Penman-Monteith approach as an international standard by a consultative forum which met in Rome during May 1990. At this forum it was decided to use a defined, reference crop for ET_0 calculations in the future. This reference crop was defined as; **A hypothetical crop with an assumed height of 0.12 m, with a surface resistance of 70 s m^{-1} and albedo of 0.23,** closely resembling the evaporation from an extensive surface of green grass of uniform height, actively growing and adequately watered. In an effort to reduce the credibility problems experienced thus far, the Irrigation and Drainage Report No 56 was published (Allen, et al., 1998; Doorenbos & Pruitt, 1977).

3.2 Problem

The development of models that could be used as tools in the estimation of irrigation water requirements have all been faced with varying degrees of the problem of credibility. The Green Book and its update (Green, 1985) used A-pan based crop factors. Irrigation estimates went well as long as the A-pan evaporation was calibrated for the specific area. This calibration was not necessarily done, with the result that incorrect estimates resulted, which had a negative influence on the credibility of the estimates (Du Plessis & Wittwer, 1991, Tanner, 1987). In the energy-balance and mass-transfer approaches the potential for shorter-term verification of crop coefficient became more of an option, although credibility problems was still present (Doorenbos & Pruitt, 1977).

The one problem that could not be solved with the development of estimation approaches is that of correct crop coefficients. Some crops, which include beans, cabbage, citrus, cotton, maize, onion, peas, peppers, potatoes, sugar beet, sugar cane, sunflower and wheat, have been well researched (Doorenbos & Kassam, 1986), while other crops such as berries, canola, gourds, granadillas, mangoes, and papaws have been less well researched. Unexpected deviations of estimated irrigation from measured requirements are found from time to time, even in well researched crops. This is usually the result of crop coefficient values that are not quite correct. The result is that crop irrigation requirements need to be continuously verified and the relevant crop coefficients adapted where required. Furthermore, problems are found with the fitting of the FAO four-stage crop curve to perennial tree and vine crops, to such an extent that these crops are not included in the FAO Aquacrop model (Allen, 1998).

The problem of verifying irrigation estimate output could be solved by comparing the daily estimated output with actual, measured data from field. The availability of continuous logging probes for soil water content which has become more generally available during the past few years, has now made it possible to compare SAPWAT3 daily crop evapotranspiration estimates to real time crop evapotranspiration values within the framework of time and budget constraints. The results could be used to adjust crop coefficient values for different growing stages.

The inclusion of crops that have not been well researched in SAPWAT3 is based on the philosophy that available data should be used, and when and where newer and better data becomes available the included data be updated. This approach is followed to enable SAPWAT3 users to at least approximate irrigation requirements for most of the crops grown in South Africa. Having said that, the authors of SAPWAT have experienced that the estimation of irrigation requirements of better researched field crops grown in South Africa seem to be fairly close to actual irrigation water use.

3.3 Objectives

To increase the credibility of SAPWAT3 irrigation water requirement estimates by the further verification of program outputs.

In order to reach this main objective, the following need to be done:

- To test the correlation between the SAPWAT3 crops daily evapotranspiration with field measured daily evapotranspiration to determine the measure of similarity;

- To test the correlation between the SAPWAT3 crop cumulative evapotranspiration with field measured cumulative transpiration to determine the measure of similarity;

- To superimpose the SAPWAT3 cumulative evapotranspiration on the field measured cumulative evapotranspiration over time in order to determine similarity;

- To compare the SAPWAT3 four stage crop K_{cb} curve with K_{cb} values based on field measured evapotranspiration in order to determine whether the crop K_{cb} curve needs adjustment and what the scope of adjustment should be.

3.4 Theoretical background

Statistical testing of the mutual relationship between estimated evapotranspiration and field measured evapotranspiration data can best be done by calculating the correlation coefficient between the two sets of data. Correlation coefficient shows the degree of mutual relationship between two sets of evapotranspiration data where there is no reason to believe that one set of evapotranspiration data is the dependant variable and the other set of evapotranspiration data is the independent variable. If the pairs of data are plotted on graph paper, and if a mutual, positive relationship exists, the data would lie in an ellipse from bottom left to top right of the page. The better the relationship, the narrower the ellipse would be. A correlation coefficient of one show a perfect relationship, with the ellipse converging into a straight line, while a correlation coefficient of zero shows no relationship and the resultant ellipse would become a circle (Snedecor, 1991). In this case the common linkage factor between the SAPWAT3 estimated and field measured data is the day of growth of the crop, with planting day as day of growth one.

In order to test the correlation coefficient between field measured and SAPWAT3 estimated data, it is necessary to calculate daily crop evapotranspiration based on field measured data through the application of the water balance equation (Equation (1)) and to compare the calculated crop evapotranspiration with the SAPWAT3 estimated crop evapotranspiration for the same day.

$$ET = I + P - RO - DP + CR \pm \Delta SF \pm \Delta SW \quad (1)$$

Where:
ET : Evapotranspiration
I : Irrigation
P : Precipitation
RO : Run-off
DP : Deep percolation
CR : Capillary rise
ΔSF : Change in sub-surface flow
ΔSW : Change in soil water content

Irrigation and precipitation could be field measured. Run-off could be field measured, although it cannot be easily done under field conditions. Deep percolation, capillary rise and changes in sub-surface flow are virtually impossible to determine under field conditions. The FAO 56 approach is to treat run-off and deep percolation as a unit and to treat all excess irrigation as deep percolation (Allen, et al., 1989). The problem of capillary rise and changes in sub-surface flow could be accepted as zero, provided that the user of SAPWAT3 who tests for estimation accuracy selects a field for conduction tests that show no signs of any of these two events taking place. Such indications are water tables in profile pits or signs thereof through wetness and mottled discolouration, visible signs of salinity at soil surface, as well as changes in plant density and composition in the vicinity (Maletic & Hutchings, 1987; Grondklassifikasiewerkgroep, 1991).

A major problem when calculating crop evapotranspiration through the soil water balance equation is found where water added to the soil through irrigation or rain is enough to exceed the water holding capacity of the soil. Ideally speaking, the amount of water that is lost through run-off or deep percolation should be measured, but as the quantity thus lost is virtually impossible to determine under field conditions, it must be assumed that the quantity lost would be about equivalent to the total soil water content after the rain or irrigation event, minus the soil water storage capacity minus the theoretical crop evapotranspiration for that day (Equation 16.2).

$$(RO + DP) = \Delta SW + I + P - ET_{ce} \quad (2)$$

Where:
(RO+DP) : Run-off plus deep percolation
ΔSW : Change in soil water content
I : Irrigation
P : Precipitation
ET_{ce} : SAPWAT3 calculated evapotranspiration

Research tools for the determination of crop evapotranspiration are available, and some, like lysimeters, have been used for many years (Tanner, 1987). Scintillometers can be used to determine aerodynamic fluxes above a crop, from which evapotranspiration can be deduced. Newer still are remote sensing techniques, such as the SEBAL approach which makes use of satellite technology (Bastiaanssen, 2005). These approaches require any combination of capital expenditure and expertise, which might not be available to the average SAPWAT3 user. The lack of any other affordable and easily used approach forces SAPWAT3 to use the approach described here until something better comes up that could easily be used at field level by users who might not be experienced researches.

3.5 Program

The algorithm for the accuracy testing module is shown in Figure 3.1.

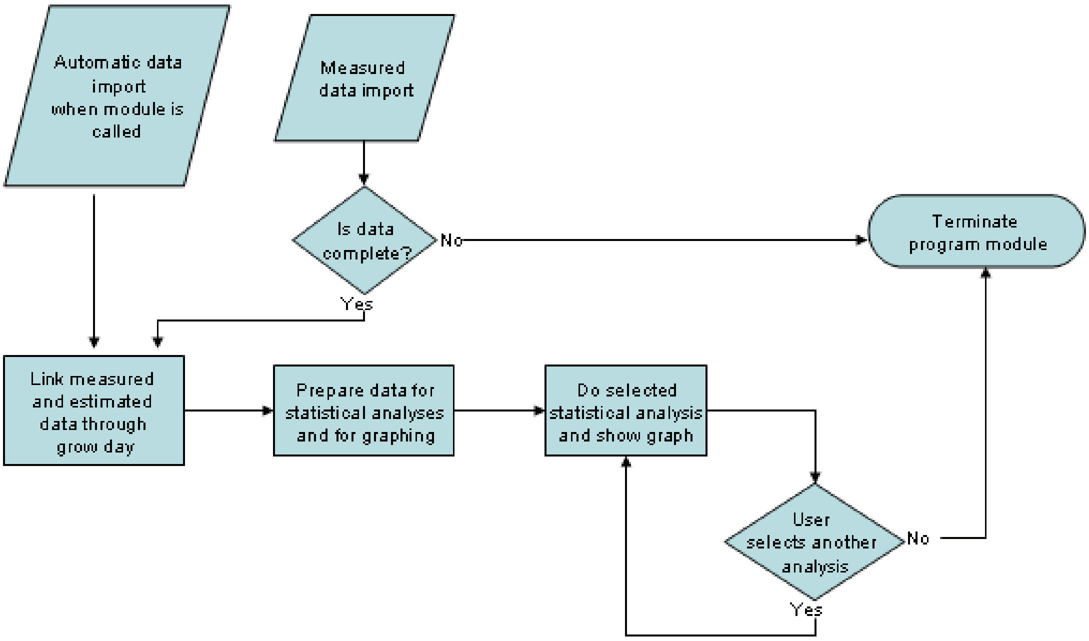

Figure 3.1 The Accuracy Testing Module algorithm.

This module is called from the crop set-up page in the irrigation requirement estimation module of SAPWAT3. On opening, the ID of the crop on which the cursor is, is passed on and that crop data is automatically imported into the module. The user is then asked to indicate the table name and directory of the field measured data that need to be imported. The field measured data table is imported and the completeness thereof is verified. Data that is incomplete cannot be used for accuracy analysis and, if found, this program module is terminated.

The program goes through the imported field measured data and determines the maximum soil water depletion found. For purposes of the program run this will be accepted as the maximum soil water content of the soil and any exceedence of that will be seen as a combination of percolation and run-off. Crop evapotranspiration calculations based on field measured data are done as follows:

- Test if previous day soil water content plus rain and/or irrigation exceeds maximum soil water content plus SAPWAT3 calculated evapotranspiration for this day, otherwise this step is ignored. On such days, evapotranspiration based on soil water balance calculations cannot be done because excess water has been added to the soil and run-off plus deep percolation can be expected. This calculation is done through the application of Equation (2) by which the combined run-off and deep percolation is determined.

- Calculate crop evapotranspiration through the application of Equation (1). Run-off plus deep percolation is assumed to be zero, unless a value for it is determined as above. Capillary rise and change in subsurface water flow is assumed to be zero.

- The change in soil water content applied in equation (1) is calculated as the difference between the previous and this day's field measured soil water content (Equation (3)).

$$\Delta SW = SW_{d-1} - SW_d \qquad (3)$$

Where: ΔSW : Change in soil water content
SW_{d-1} : Soil water content previous day
SW_d : Soil water content on day of measurement

Results of the accuracy determination are not stored.

3.6 Methodology

The required comparison can only be made with daily data of water additions to the soil, daily field measured soil water content and then to construct a daily soil water balance equation in order to determine changes in soil water content. The extraction of soil water by a crop is assumed to be the equivalent of crop evapotranspiration. This is compared to the SAPWAT3 estimated evapotranspiration of the same crop for the same day in order to verify SAPWAT3 estimated evapotranspiration.

SAPWAT3 is used to estimate irrigation requirements at farm/field level therefore verification should also be done at that level within constraints of limited budget and available time.

The methodology would be to:

- Identify a weather station relevant to the area and collect its daily temperature, humidity, wind, sunshine or radiation and rainfall data for transfer into the SAPWAT3 weather station data set. At least a year's data, covering the growing period of the crop, is required. (Refer to Chapter 4 for importation of weather data);

- Collect the relevant crop data such as crop, crop option, planting date and irrigation management that will enable the user to imitate the crop growth and development and its irrigation water management in SAPWAT3;

- Collect daily field measured data for rainfall, irrigation and soil water content on the field for which verification is to be done. Enough rain gauges should be placed on the field to ensure a reliable data of irrigation applied and/or rainfall experienced. The probes should be calibrated and enough probes placed in the field to ensure reliable data;

- Daily field measured soil water content is converted to mm water for at least crop rooting depth;

- Imitate crop growth and water management in the SAPWAT3 irrigation requirement set-up and run for the relevant year to determine daily crop evapotranspiration;

- Click on "Accuracy" button to start the accuracy calculation;

Import the field measured data as a dbf table (Table 3.1) into the Accuracy module when indicated to do so.

Table 3.1 Table structure for importing field measured data into the Accuracy module.

Column name	Type	Length	Decimals	Description
rDate	Character	10		date, format dd/mm/yyyy
SWC	Numeric	9	0	Soil water content, mm/m or mm/per rooting depth
IrriRain	Numeric	9	0	Irrigation or rain as measured at point of application

The program module compares the field measured and SAPWAT3 estimated data, does the required correlation calculations and displays four results and graphs that can be used to interpret the data.

A simulation exercise based on a theoretical field and crop set-up was done to demonstrate the working of this module.

3.7 Results and discussion

The program produces four graphs to enable the user to visually evaluate SAPWAT3 estimated against field measured data for evaluation and for potential amendments of the crop coefficient values. The program provides the user with choice of measurement frequency, from daily to 10-day periods. However, it is important that the background data must be at daily intervals. In practice it so happens that irrigation day might not be on the same day as predicted, therefore the odd situation could arise where an SAPWAT3 estimated value varies considerably from field measured because of differences in irrigation dates. Working on average values of a number of days limits this problem.

3.7.1 Correlation between daily SAPWAT3 estimated and in-field measured evapotranspiration

The result of a correlation on daily data is shown in Figure 3.2 where the tendency of data in the graph is from bottom left to top right, indicating a positive correlation. The screen also shows the frequency on which the correlation is calculated, daily in this case. It also shows a table of data on which the correlation is based; the correlation coefficient (0.8); run-off plus percolation losses (23 mm) as well as an interpretation of the significance of the resultant correlation (highly significant).

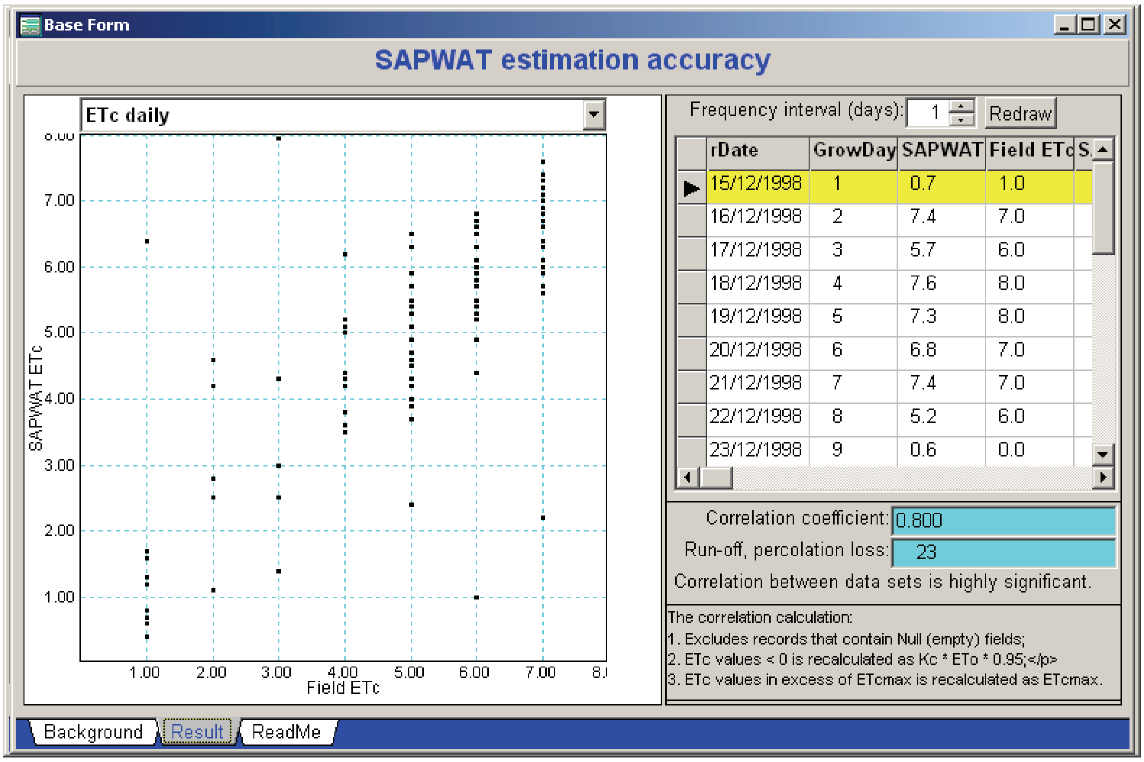

Figure 3.2 Correlation result of SAPWAT3 estimated and field measured evapotranspiration at a daily interval.

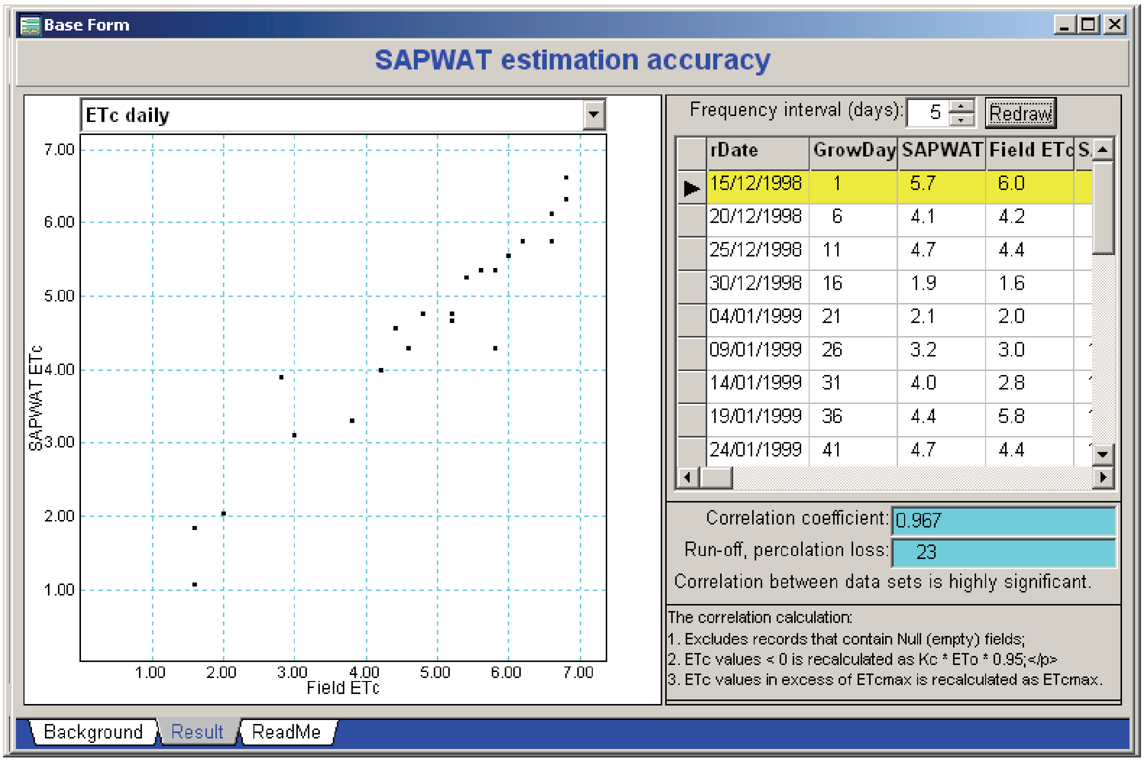

Figure 3.3 Correlation result of SAPWAT3 estimated and field measured evapotranspiration at a 5-day interval.

In Figure 3.3 the result of a correlation based on 5-day averages can be seen. It will be noticed that the correlation coefficient has now increased to 0.967. The lower correlation coefficient shown for a daily interval as can be seen in Figure 3.2 is partly the result of actual irrigation days that did not happen on the same day as the expected SAPWAT3 estimated irrigation days. These differences could result in significant differences between the SAPWAT3 generated and soil water balance calculated ET_c values, especially in the initial and development crop stages where evaporation from a wet surface not covered by foliage could be large en could lead to large differences due to soils surface evaporation. Giving the user the opportunity to work on average values at frequencies of several days could reduce this problem.

3.7.2 Correlation between cumulative estimated and measured data

Doing a correlation analysis on cumulative values of SAPWAT3 generated evapotranspiration and soil water balance calculated evapotranspiration values tend to give very high correlations, refer to Figure 3.4 where a correlation of 1.0 is indicated. A deviation of slope from the expected 1:1 could indicate Kcb values that are not correct.

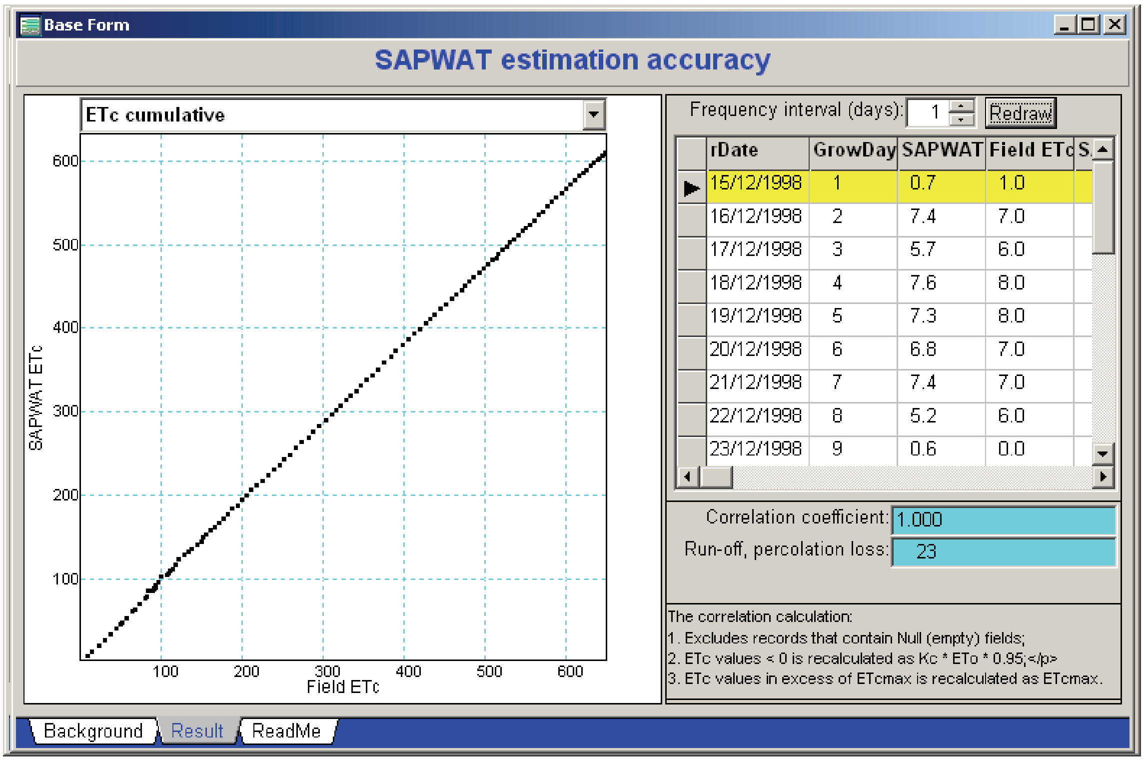

Figure 3.4 Correlation result of cumulative SAPWAT3 estimated and field measured evapotranspiration at daily interval.

3.7.3 Correlation of cumulative estimated and measured data over time

Graphing the SAPWAT3 generated and soil water balanced cumulative evapotranspiration values over time is an indicator of SAPWAT3 estimated crop coefficient deviations from that indicated by field measured data. In Figure 3.5 it can be seen that the SAPWAT3 estimated cumulative evapotranspiration tends to drop below the line based on field measured data. This is another indicator of crop coefficient values that might not be correct. In this case it could be deduced that the crop coefficient values for the latter part of the midseason stage and for the late season stage could be adjusted upwards.

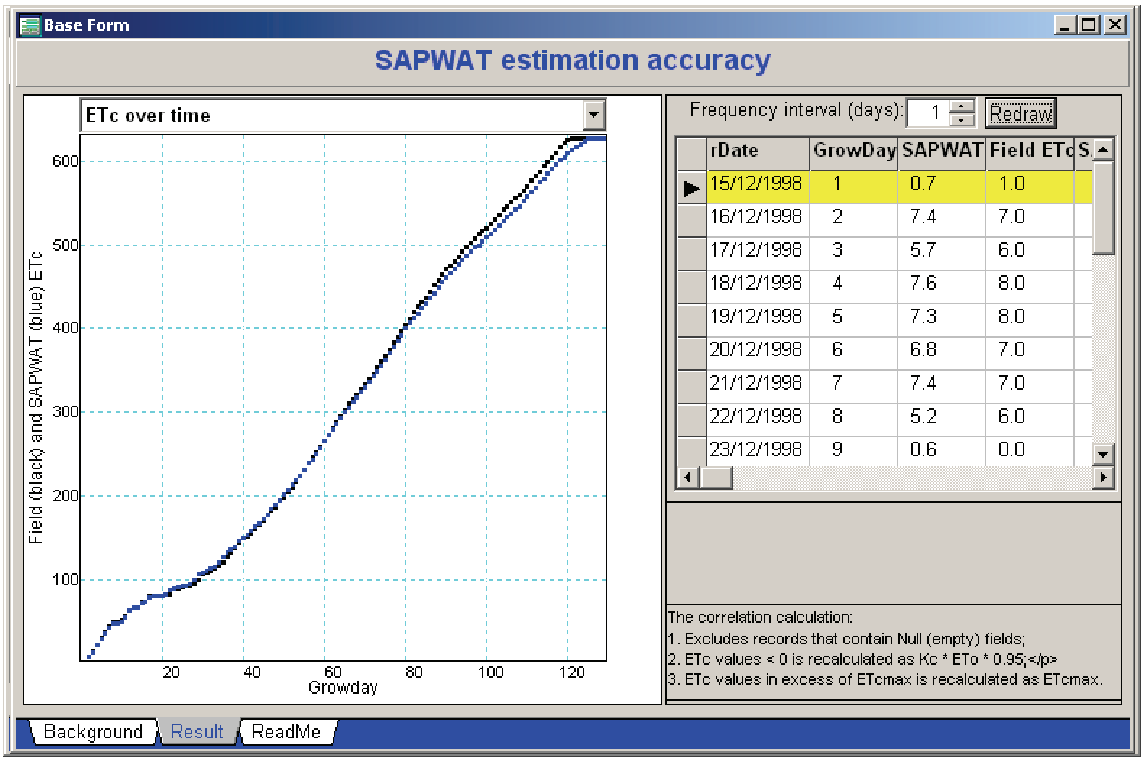

Figure 3.5 The cumulative SAPWAT3 estimated and field measured evapotranspiration over the crop growing period.

3.7.4 Comparing crop coefficients with measured data

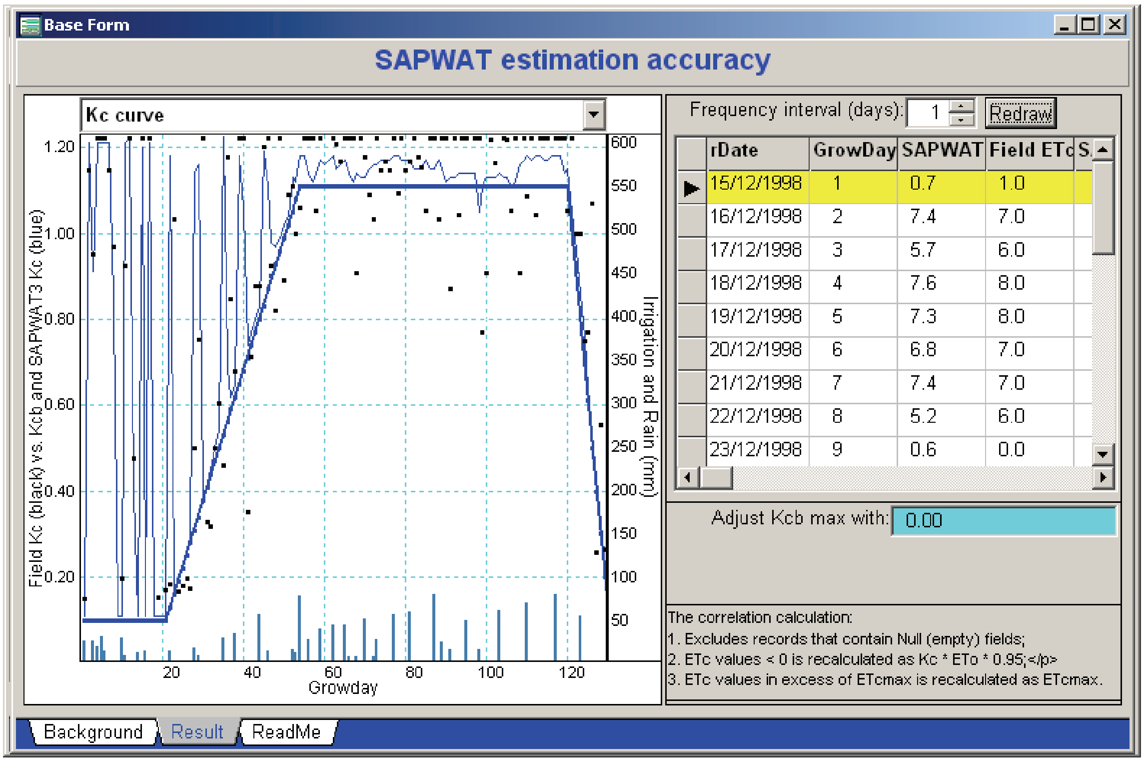

Figure 3.6 SAPWAT3 crop coefficients compared to crop coefficients based on measuerd data.

In Figure 3.6 the crop coefficient and evaporation values are compared to soil water balance calculated coefficient values. This can be a very good indicator if crop coefficient values need adjustment for both coefficient values and for the length of the growth stages. In the figure, the black dots show the crop coefficient values based on field measured data, the blue dots and thick lines show the present crop coefficient values and the oscillating thin blue line shows the crop evapotranspiration trends. The wide range of values indicated by the oscillations of the crop evapotranspiration during the initial and development stages is an indicator of the effect that soil surface evaporation has on crop evapotranspiration. Every time that and irrigation or rain event takes place, soil surface evaporation plus crop transpiration increases to more or less the maximum evapotranspiration value expected for the area. This is a natural occurrence, but the effect thereof can be reduced by management practices such as mulching which would decrease soil surface evaporation. The spread of the field measured data, the black dots, between higher and lower values, is a natural phenomenon. It is the result of daily variations in temperature, humidity, wind and radiation that occurs in any given site throughout a year.

The superimposing of field measured and SAPWAT3 estimated values gives a good indication of what the height and slope of the different parts of the crop coefficient curve should be. Through inspection of the turning points of the field measured data, the lengths of the four stages can also be adjusted. The program compares the mid-season stage crop coefficient value based on field measured data of the crop with the given crop coefficient value and recommends a change in the given mid-season crop coefficient, if so required.

CHAPTER 4
ACCEPTANCE OF SAPWAT3 AS AN IRRIGATION WATER PLANNING TOOL

4.1 Introduction

Project K5/1578, "Integrating and upgrading of SAPWAT and PLANWAT to create a powerful and user friendly irrigation planning tool" has been completed with the publication of Water Research Commission Report TT 391/08 in 2008. SAPWAT3, which is the product of this project, was a further development of the SAPWAT program, which was in its turn developed and tested with Water Research Commission funding and has been in general use since the publication of the first full program in 1999 (Crosby & Crosby, 1999). Some of the background information included as data in the program is based on more than 20 years of Water Research Commission research projects related to irrigation, soils, crop production and agricultural economics. Development time and the cost involved accentuate the need to disseminate knowledge of SAPWAT3 to as wide a scope of potential users as possible and that SAPWAT3 be accepted by potential users as a planning tool for irrigation water requirements.

SAPWAT3 extends the functionality provided by SAPWAT and other similar programs, such as CROPWAT (Smith, 1992), through the addition of facilities to sum irrigation requirements backwards so that, while planning for specific crop irrigation requirements, these requirements are summed to also provide irrigation requirements for the field, farm, WUA and CMA. Further added functionality includes crop enterprise budgets parallel to irrigation requirement estimates, as well as small scale water harvesting. This extended functionality does make the initial set-up for irrigation requirement estimation somewhat more intimidating and could make the program somewhat more complicated to use.

4.2 Motivation

It has been observed that SAPWAT has become the accepted methodology for estimating crop irrigation requirements. This observation is supported by the fact that it has at least been tested by more than 300 potential users in 13 countries and is extensively applied as a planning tool in South Africa (Van Heerden, *et al*., 2008). However, the level of and reasons for the acceptance of SAPWAT has never been tested scientifically. SAPWAT3 eliminates some of the shortcomings of SAPWAT, e.g. the non-storage of estimates done, the lack of its potential to print results, the lack of the facility to add the estimated irrigation requirements of crops to the level of a farm or bigger area. The influence of this wider applicability and more functionality on program acceptance needs to be assessed.

A further shortcoming of SAPWAT is that the calculation of the Penman-Monteith reference evapotranspiration is based only on long term average climatic data. SAPWAT's estimation of risk is based on the same approach as that of CROPWAT, which is to estimate risk by using rainfall variation only (Smith, 1992). The problem is that this approach does not necessarily predict a year of maximum or minimum irrigation requirements. This shortcoming is alleviated by the inclusion of a quaternary weather database, (Schulze and Maharaj, 2006) with fifty years of daily weather data for each of South Africa's quaternary drainage regions, which allows for the estimation of successive years of irrigation requirement. This enables SAPWAT3 to do sequential year-on-year irrigation requirement estimates which is used to determine irrigation requirements at different levels of non-exceedence so that risk also becomes an element of output. To what extent this inclusion could enhance or retard the acceptance of SAPWAT3 needs to be evaluated as well.

Reasons for the acceptance of SAPWAT could also influence the acceptance of SAPWAT3, therefore it would be advisable to test the acceptance of both programs and compare the results.

4.3 Objectives

To demonstrate SAPWAT3 as a tool for estimating and analyzing crop irrigation requirements to potential users and to evaluate the adoption potential of SAPWAT3 as an innovation. This overall objective could be expanded:

- To do technology transfer of SAPWAT3 through demonstrating its application to mainly existing SAPWAT users;
- To test the reasons for the general acceptance of SAPWAT by its users;
- To compare the Rogers (1995) and TAM methodologies of testing acceptability on SAPWAT with the aim of using only the TAM methodology for the future testing of the acceptance of SAPWAT3;
- To, after a time to allow the users of SAPWAT3 to gain experience in its use, evaluate its acceptance by users.

4.4 Literature overview

The theory of diffusion of innovations and the acceptance thereof seeks to explain the spread of new ideas. In his, by now, classical study of diffusion, Rogers (1962) defined it as an innovation that spreads through a social system through communication over time. On becoming aware of an innovation, members of a community go through five stages of adoption: awareness, persuasion, decision, implementation, and adoption (or rejection). During its communication, an idea is rarely evaluated from a scientific standpoint. Instead, subjective perceptions of the innovation influence its diffusion, a process that happens over time. Finally, social systems determine diffusion; the system's norms on diffusion, roles of opinion leaders, types of innovation decisions, as well as innovation consequences.

4.4.1 The adoption process

Diffusion of an innovation occurs through a five-step process: awareness, interest, evaluation, trial, and adoption. An individual might reject an innovation at any time during or after the adoption process (Rogers, 1962). In later editions of his book "Diffusion of Innovations" Rogers (1995) changes the terminology of the five stages to: knowledge, persuasion, decision, implementation, and confirmation. However the descriptions of the categories have remained similar throughout the editions:

Knowledge: The individual is first exposed to an innovation but lacks information about it. During this stage the individual has not been inspired to find more information about the innovation.

Persuasion: The individual is interested in the innovation and actively seeks information or detail about it.

Decision: The individual takes the concept of the innovation and weighs the advantages and/or disadvantages of using it and decides whether to adopt or reject the innovation. Due to the individualistic nature of this stage Rogers (1995) notes that it is the most difficult stage to acquire empirical evidence.

Implementation: The individual employs the innovation to a varying degree depending on the situation. During this stage the individual determines the usefulness of the innovation and may search for further information about it.

Confirmation: The individual finalizes his decision to continue using the innovation and may use it to its fullest potential. Or the user might finally abandon the adoption of the innovation.

4.4.2 Rates of adoption

The rate of adoption is defined as the relative speed with which members of a social system adopt an innovation. It is usually measured by the time required for a certain percentage of the members of a social system to adopt an innovation (Rogers, 1995). The rates of adoption for innovations are determined by an individual's adopter category. In general individuals who first adopt an innovation require a shorter adoption period than late adopters, such a person moves quicker through the adoption process.

Within the rate of adoption there is a point at which adoption of an innovation reaches critical mass. This is a point in time within the adoption curve where enough individuals have adopted an innovation so that continued adoption of the innovation become self-sustaining. In describing how an innovation reaches critical mass, Rogers (1995) outlines several strategies in order to help an innovation reach this stage. These strategies are: have an innovation adopted by a highly respected individual within a social network, creating an instinctive desire for a specific innovation; inject an innovation into a group of individuals who would readily use it and provide positive reactions and benefits for early adopters of an innovation.

4.4.3 Characteristics of innovations

Rogers (1995) defines several characteristics of innovations that influence an individual's decision to adopt or reject it.

Relative advantage: The innovation is perceived to be an improvement over the previous generation. An innovation that is perceived to have a high relative advantage is more likely to be adopted than one with a low perceived relative advantage.

Compatibility: The level of compatibility that an innovation has with an individual's life and work for it to be assimilated by the individuals environment. The more compatible, the better the chance of its adoption.

Complexity: Is a significant factor in the adoption of an innovation by an individual. If the innovation is perceived as being too difficult or complex for easy use, it will probably not be adopted.

Trialability: This determines how easily an innovation may be experimented with during the adoption process. If a user has a hard time using and trying an innovation this individual will be less likely to adopt it.

Observability is the extent that an innovation is visible to others. An innovation that is more visible will drive communication among the individual's peers and personal networks and will in turn create more positive or negative reactions.

More recent research into the adoption of innovations has focused upon the characteristics of innovations or adopters, or interpersonal factors or the influence of social or commercial stimuli (Rogers, 1995). One such approach is the technology acceptance model (TAM), which seems to be particularly suitable for testing technological innovations that can make office and related work easier. It is mainly based on two factors that are theorized to be fundamental determinants of system use and are therefore predictors of adoption (Davis, 1989; Goa, 2005):

Perceived usefulness: The degree to which a person believes that using a particular system would enhance his or her job performance.

Perceived ease of use: The degree to which a person believes that using a particular system would be free from effort.

TAM proposes that perceived ease of use and perceived usefulness of technology are predictors of user attitude towards the use of such technology, subsequent behavioural intentions and actual usage. TAM can serve the purpose of predicting user acceptance on a technology before the users get heavily involved in it, and thus is a cost-effective tool in screening potential systems that could possibly be used (Goa, 2005).

Davis (1989) points out that compatibility, relative advantage and complexity have the most consistent significance in relationships across a broad range of innovation types. Of these, complexity, as defined by Rogers (1995), parallels perceived ease of use quite closely.

On analyzing existing research data Davis (1998) concluded that questionnaires on usefulness should cover three areas: (i) job effectiveness, (ii) productivity and time saving, as well as (iii) the importance of the system (innovation) to one's job. Similarly, questionnaires on ease of use should cover the following areas: physical effort, mental effort, and how easy the new system is to learn. He found that six well-defined questions that cover the full spectrum of areas seem to be enough for each of the factors.

Davis (1998) and Goa (2005) further found strong evidence of an "ease of use → usefulness → usage" chain of causality. The causal influence of ease of use on usefulness makes sense conceptually. All else being equal, the easier a system is to interact with, the less effort needed to operate it, and the more effort one can allocate to other activities, contributing to overall job performance. According to Davis (1998), there is increasing evidence that the effective functioning of a system depends on its usability. However, he further argued that perceived usefulness should be significant, because no amount of ease of use can compensate for a system that does not perform a useful function.

4.5 Methodology

The testing of the acceptance of SAPWAT took place simultaneously with the technology transfer of SAPWAT3. Existing SAPWAT users were identified by taking their names from the SAPWAT registration list. However, it was found that at some stage the function that added new subscribers to the list, had developed a malfunction, and therefore people who have downloaded SAPWAT from the web over the last number of years had not been added. With the list as a starting point, discussions with the chairpersons of the SABI (Suid-Afrikaanse Besproeiingsinstituut / South African Irrigation Institute) branches on whom in their areas could possibly be SAPWAT users, the list was expanded 226. This list was used to invite SAPWAT users to meetings in different parts of the country. During the contacting of SAPWAT users to invite them to attend the meetings, it transpired that a large number of them had left the industry, had gone abroad, or lived too far away too attend the meetings. The result was that 72 SAPWAT users attended the meetings. Non-SAPWAT users in the irrigation industry have also heard of these meetings, and it turned out that 39 of them have attended the meetings, so that the total contacts were 111. Attendance is shown in Table 4.1.

Table 4.1 Attendance of SAPWAT3 demonstrations at different venues in South Africa

Date	Area	SAPWAT users	Attendance
24/08/2009	Western Cape province: Stellenbosch	9	12
3/09/2009	Free State province: Bloemfontein	4	5
9/09/2009	Free State province: Orange-Riet WUA (Jacobsdal)	3	4
16/09/2009	North Cape province (including North-west province portion of Vaalharts): Vaalharts WUA (Jan Kempdorp)	6	7
7/10/2009	Kwazulu-Natal province: Durban	9	15
8/10/2009	Kwazulu-Natal province: Pietermaritzburg	5	7
20/10/2009	Gauteng province: Pretoria	7	13
21/10/2009	Limpopo province: Polokwane	7	14
17/11/2009	Eastern Cape province: Nanaga	10	15
24/11/2009	Mpumalanga province: MBB (Nelspruit)	2	4
25/11/2009	Mpumalanga province: Nelspruit	10	15
Totals		72	111

A breakdown of attendees is as follows:

White male	70%
Black male	17%
Black female	11%
White female	2%

During the meetings, the attendees were asked to fill out the SAPWAT questionnaire, after which a demonstration was given of the working of SAPWAT3. Copies of the report, which contains a program disk, were handed to each of the attendees. They were asked to use SAPWAT3 as much as possible, because a follow-up survey would be done to determine the acceptability of SAPWAT3.

Testing of the acceptability of SAPWAT included both the Rogers (1995) and the TAM approaches so that the acceptability results of these two approaches could be compared. This approach was followed because of the wide acceptance of SAPWAT as a tool for estimating irrigation water requirements, its apparent ease of use and the accepted credibility of its results. If such an apparent correlation is found to exist between the Rogers (1995) approach and the TAM, the acceptability of SAPWAT3 will be analyzed using only the TAM approach as the next step (Davis, 1989; Gao, 2005).

4.6 Results and Discussion

4.6.1 Acceptance of SAPWAT

The survey that was done to determine to what extent SAPWAT is used in the industry, shows that SAPWAT is used for a wide variety of purposes, although its use as a planner of irrigation water requirement is by far the most important with a 25% application, as shown in Figure 4.1. Next in importance is the design and planning of systems at farm and field level, with an occurrence of 16%, followed by water use registration and licensing at 10.5%. This is to be expected, as this is what SAPWAT has been designed for. A surprising indication is scheduling services at 3%, because SAPWAT was built as a planning and not scheduling tool. Comments of users indicate that the use of SAPWAT by scheduling services is as a planning tool for advising farmers on irrigation management.

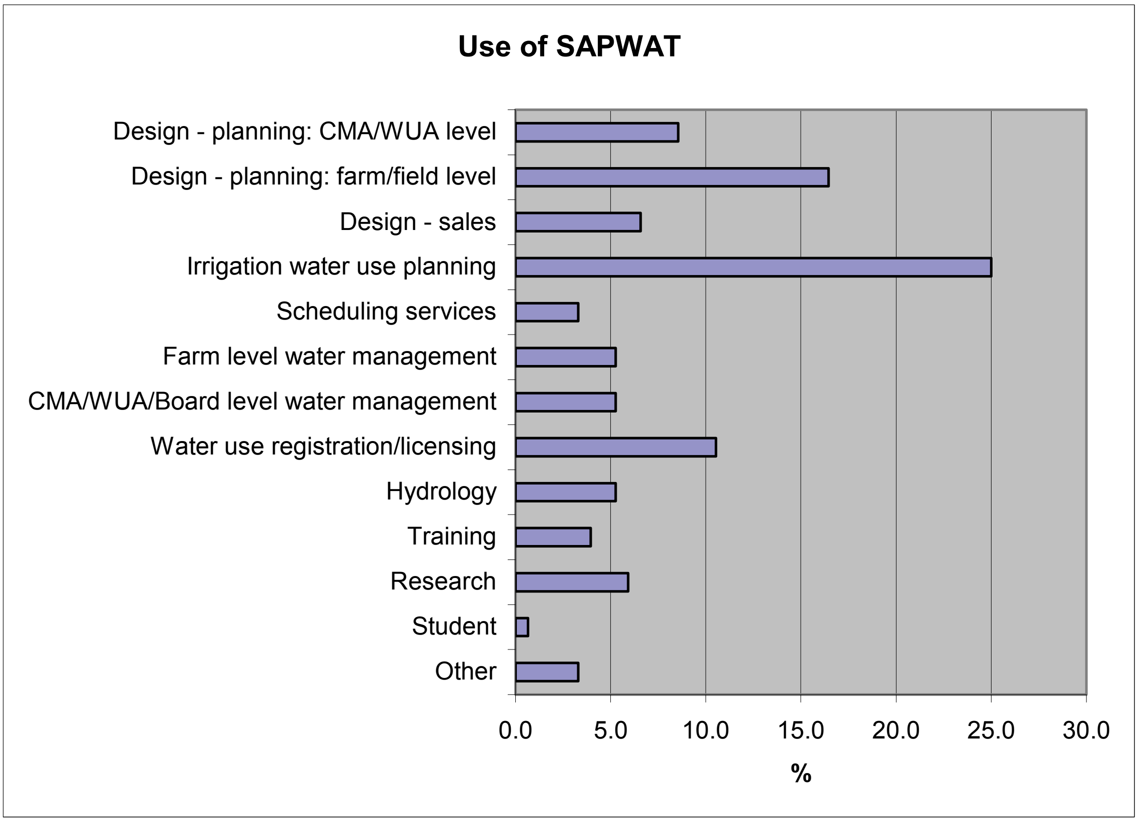

Figure 4.1 Use of SAPWAT by different sectors of the irrigation industry.

The frequency at which SAPWAT is used show that by far the most usage is on a monthly basis, with yearly and weekly following. Experience has shown that SAPWAT, as a planning tool, is usually used less than more frequently, as can be expected the use of a planning tool should be.

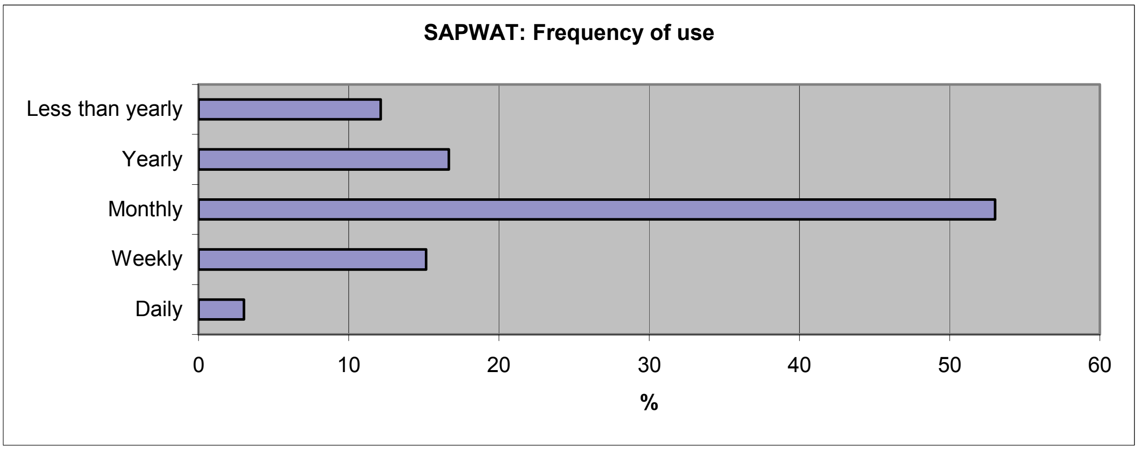

Figure 4.2 Frequency of SAPWAT usage

4.6.1.1 The Rogers (1995) approach

Fewer people could be tested during this survey than planned for. Most of those that were not involved are single users in places far removed from places where the meetings were held. Time and budgetary constraints prevented including them in the survey.

The results obtained are people's perceived worth of the characteristics tested and do not necessarily reflect objective reality. Perceptions are assumed to be meaningful variables in their own right, which function as behavioural determinants and are not regarded as substitute measures of objective phenomena.

Values to the right of the neutral column in Figure 4.3 show the average strength of agreement while values to the left of the neutral column show disagreement of respondents to the generalised statement in the first column. Distance from the neutral column (yellow) indicates strength of agreement or disagreement. The relatively strong positive values of relative advantage and of compatibility (green) indicate that using SAPWAT is perceived as advantageous in relation to time and effort and that the compatibility level is an indication of the degree that SAPWAT is compatible with work done by users. Complexity, trialability and observability are also perceived as being positive (Green) for SAPWAT, even though to a lesser extent than relative advantage and compatibility. The positive perception of the Rogers (1995) five characteristics indicates that SAPWAT is seen as a positive contributor to ease of work in the office of the user. This enhanced the acceptability of SAPWAT and resulted in its adoption on a relatively big scale in the irrigation industry.

Characteristic	Disagree fully	Disagree partially	Disagree slightly	Neutral	Agree slightly	Agree partially	Agree fully
Relative advantage (I can save time/effort by using SAP-WAT (Q5-Q8))							
Observability (SAPWAT can be explained easily and is easily understood if explained (Q42-Q46))							
Compatibility (SAPWAT is compatible with my work, values and norms (Q12-Q23))							
Complexity (SAPWAT is easy to use (Q24-Q39))							
Trialability (Can the application of SAPWAT be evaluated by partial usage (Q40-Q41))							

Figure 4.3 User's perceptions of the characteristics that influence the adoption of SAPWAT3 (Yellow = neutral; Green = response value)

4.6.1.2 The Technology Acceptance Model

The survey also provided for testing the Technology Acceptance Model as described by Davis (1989) and Gao (2005); the following picture emerges:

Characteristic	Disagree fully	Disagree partially	Disagree slightly	Neutral	Agree slightly	Agree partially	Agree fully
Usefulness ("Using SAP-WAT will improve my work performance" (Q5-Q23))							
Ease of use ("SAPWAT can be use with a minimum of effort" (Q24-Q39))							

Figure 4.4 Perceived Usefulness and Ease of Use of SAPWAT by its users (Yellow = neutral; Green = response value)

This approach tests two perceptions of an innovation by potential users. These two perceptions play a major role in the adoption. Adoption will be enhanced if the perceptions of both are positive or will be retarded if both are perceived in a negative light. If one is positive and the other negative, adoption will be shifted to faster or slower, depending upon the relative weight of the two perceptions. The perception of the usefulness of SAPWAT is strong positive and ease of use is positive, which is reflected in both the speed and the scope to which SAPWAT has been adopted by the irrigation fraternity.

4.6.1.3 The Rogers versus the TAM approach

The results obtained with the application of both the Rogers (1995) and TAM approaches indicate that for an innovation like SAPWAT3 the TAM approach should be a good enough indicator of acceptance and therefore all indications of acceptance of SAPWAT3 will be done with the TAM approach.

4.6.1.4 Perceptions of SAPWAT by respondents

The questionnaire included open-ended questions in which the respondents were asked to list strong points, weak points, functions that should be included as well as functions that seem superfluous. The following are comments from respondents – some translation was done to group comments with similar meaning – organised on a basis of frequency of occurrence and alphabetically within each frequency group:

Advantages/Strong points

Easy to use (12)
Get quick results (7)
Good data output (crop irrigation requirements) (9)
User friendly (5)
Accurate / Credible (4)
Scientific based (3)
Short and to the point (3)
Can be used to determine system capacity / area requirement (2)
Covers most areas and crops (2)
Can also be used for evaluation
Descriptive
Easy to transfer data to reports
Eliminates water metering at each field
Makes a complex situation manageable
Provides one platform between designers
Results can be debated and supported
Well packaged

Disadvantages/Weak points

Need a good knowledge of area, crops and soils to get applicable results (7)
Can be manipulated (5)
Cannot store results (4)
Gaps in weather station distribution (4)
Some needed crops/crop options not included (4)
Cannot print results (2)
Only SA weather stations included (2)
Cannot be used for scheduling
Difficult to get a copy of the software
Difficult to get weather station data
Difficult to select climate area
Does not provide for fallow fields
Does not require understanding to get an answer
Ignores runoff
Lack of help functions in the program
Limited applicability
No A-pan evaporation data for all weather stations
No communication to Microsoft software
Only monthly values
Over-simplification of time to drain excess irrigation water and/or rain
Program instability
Results vs. practice not always in agreement
Seemed to overestimate mango irrigation requirements
Too many variables, consultants usually do not have the time to make complex analyses
Tree crops not sorted out yet
Weak GIS

Functions that need to be included

Include more soils (3)
Be able to print results (2)
Include weather stations from outside SA (2)
Need to interface with GIS, ACAD, etc. (2)
Save results (2)
Need to interface with MS Office programs (2)
Access to automatic weather stations
Be able to manipulate soil types

Dam balances
Drip irrigation data for trees
Expand the crop file to include more pasture crops
Give all surrounding stations when a station name is typed
Imaginary farms that could be used for student training
Importing of crop and weather data
Multiple crops on a field
Need individual rain events for complete planning
Need to cover all of SA with weather data
Notepad for sketching scenarios
Reconciliation with existing WARMS data
Salinisation management
Water source and reliability of water resource as additional functions
"Om koffie te maak terwyl ons werk!"

Functions not necessary
None

4.6.2 Acceptance of SAPWAT3

The questionnaire to test the acceptance of SAPWAT3 was adapted from the SAPWAT questionnaire so that the same questionnaire could also be used to test the acceptance and use of other irrigation related models funded by the Water Research Commission. The request for such a study was made after the SAPWAT questionnaire was distributed but before the SAPWAT3 questionnaire was distributed. The result of this is that the presentations of SAPWAT3 results differ from the presentation of the SAPWAT results, although the tendencies of acceptance and use observed remained similar.

4.6.2.1 Profile of SAPWAT3 users in terms of occupation, training and experience

Thirty-four of the 72 identified SAPWAT users responded on the questionnaire regarding SAPWAT3 and its use. These respondents are characterized in terms of occupation grouping, years of experience and qualifications. The results are shown in Table 4.2 which shows that the biggest occupation-group is the people who design and plan irrigation systems. This tendency is expected, as the original SAPWAT was specifically designed with this group in mind. There seem to be an overall tendency that SAPWAT3 is used by better trained and more experienced people. In a way this seems to be out of line with the idea behind SAPWAT3's development, as is it was originally thought that SAPWAT3 would make irrigation requirement planning so much easier that the less experienced and lesser trained people could become its main users.

It can also be seen in Table 4.2 that, over and above the designers and planners of irrigation systems, who are the main users, SAPWAT3 is used by a wide variety of occupation groups: water managers; consultants; lectures / trainers; farmers; as well as scheduling services.

On a question on previous use of tools and models similar to SAPWAT3, 79% of respondents indicated that they have had previous experience in the use of such tools and models.

4.6.2.2 Attitude of SAPWAT3 users to efficient irrigation water use and related research

The attitude of respondents regarding efficiency of irrigation water requirement planning and its use, as well as research done by the Water Research Commission and the application of such research knowledge, has been evaluated.

Table 4.3 shows the response to the statement “The National Water Act imposes necessary regulations to irrigation water users to apply efficient irrigation water management strategies”. Fifty-three percent of all respondents agreed or agreed strongly with the statement, while 26% were neutral and 6% disagreed or disagreed strongly. Fifteen percent did not indicate a level of agreement. There is a tendency of more agreement from the system designer/planner group with 62% agreeing or agreeing strongly, a result that could possibly be influenced by the close contact this group usually have with individual farmers for whom they design for and/or advise on irrigation systems.

Table 4.2 Profile of SAPWAT users

Group	Experience	2: Grade 12 (%)	3: Certificate (%)	4: Diploma (%)	5: B.Agric. / B.Tech. (%)	6: B.Sc. (%)	7: Honours (%)	8: Masters (%)	9: PhD. (%)	Total (%)
Agricultural economist	1: < 6 years (%)						3		3	6
Agricultural economist Total							3		3	6
CMA/WUA management	2: 6-10 years (%)				3					3
	3: 11-15 years (%)	3								3
	4: 16-20 years (%)	3								3
CMA/WUA management Total		6			3					9
Consultant	1: < 6 years (%)							3		3
	2: 6-10 years (%)						3			3
	3: 11-15 years (%)						3			3
	Not indicated (%)							3		3
Consultant Total							6	6		12
Farmer	2: 6-10 years (%)		3							3
	3: 11-15 years (%)				3					3
Farmer Total			3		3					6
Lecturer/trainer	2: 6-10 years (%)			3				3		6
	3: 11-15 years (%)								3	3
	5: > 20 years (%)								6	6
Lecturer/trainer Total				3				3	9	15
Scheduling service	3: 11-15 years (%)					3				3
	5: > 20 years (%)			3						3
Scheduling service Total				3		3				6
System designer/planner	2: 6-10 years (%)						3			3
	3: 11-15 years (%)			3						3
	4: 16-20 years (%)	3		6				6		15
	5: > 20 years (%)					9	9	3		21
System designer/planner Total		3		9		9	13	9		43
Water Act administrator	5: > 20 years (%)					3				3
Water Act administrator Total						3				3
Not indicated	Not indicated (%)									
Not indicated Total										
Total		9	3	15	6	15	22	18	12	100

Table 4.3 Response to statement "The National Water Act imposes necessary regulations to irrigation water users to apply efficient irrigation water management strategies” (1 = disagree strongly; 5 = agree strongly).

Group	Not indicated	Disagree		Neutral	Agree		Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
System designer/planner (%)	6	3		6	6	18	38
Lecturer/trainer (%)	3			6		6	15
Consultant (%)	3			3	3	3	12
CMA/WUA management (%)	3			3		3	9
Not indicated (%)				3	3		6
Agricultural economist (%)				6			6
Farmer (%)			3		3		6
Scheduling service (%)					6		6
Water Act administrator (%)					3		3
Total (%)	15	3	3	26	24	29	100

In this case there is a clear trend that groups that is involved in irrigation water management, is of the opinion that the National Water Act does impose the necessary management strategies for efficient irrigation water use.

The response to the statement "Irrigation scheduling methods and tools are developed for use by irrigation advisors and researchers" is shown in Table 4.4.

Table 4.4 Response to the statement "Irrigation scheduling methods and tools are developed for use by irrigation advisors and researchers" (1 = disagree strongly; 5 = agree strongly).

Group	Not indicated	Disagree	Neutral	Agree		Total (%)
	0 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
System designer/planner (%)	3	3	9	9	15	38
Lecturer/trainer (%)		3	3	3	6	15
Consultant (%)	3			3	6	12
CMA/WUA management (%)	3		3	3		9
Not indicated (%)				3	3	6
Agricultural economist (%)		3	3			6
Farmer (%)			3	3		6
Scheduling service (%)			3		3	6
Water Act administrator (%)					3	3
Total (%)	9	9	24	24	35	100

In Table 4.4 it can be seen that 59% of respondents agreed or agreed strongly, while 24% remained neutral. There are no real deviations between groups to this general trend. This indicated an agreement with the perception that tools like SAPWAT3 is for the use of specialists, instead of for use by all members of the irrigation industry. This question might not have been phrased clearly enough.

Table 4.5 shows the response to the statement “The refinement in irrigation management offered with the implementation of irrigation scheduling computer models is not cost effective” where 29% of the respondents were neutral and 50% disagreed or disagreed strongly. The general perception amongst irrigation specialists that scheduling is cost-effective and the result of this negative response to the statement that scheduling is not cost-effective bears this out.

Table 4.5 Response to the statement "The refinement in irrigation management offered with the implementation of irrigation scheduling computer models is not cost effective" (1 = disagree strongly; 5 = agree strongly).

Group	Not indicated	Disagree		Neutral	Agree	Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	
System designer/planner (%)	3	9	18	6	3	38
Lecturer/trainer (%)	3	3	3	6		15
Consultant (%)	3	3	3	3		12
CMA/WUA management (%)	3		3	3		9
Not indicated (%)			6			6
Agricultural economist (%)				3	3	6
Farmer (%)				6		6
Scheduling service (%)			3		3	6
Water Act administrator (%)				3		3
Total (%)	12	15	35	29	9	100

The response to the statement “Variability (rainfall and weather) is too complex to be accommodated in the irrigation scheduling tools and programs available” is shown in Table 4.6. This statement elicited a negative response with only 9% of respondents not agreeing with the statement. Therefore the respondents did not see the variability of weather as an inhibiting factor for the use of such models and programs.

Table 4.6 Response to the statement “Variability (rainfall and weather) is too complex to be accommodated in the irrigation scheduling tools and programs available” (1 = disagree strongly; 5 = agree strongly).

Group	Not indicated	Disagree		Neutral	Agree	Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	
System designer/planner (%)	3	9	15	9	3	38
Lecturer/trainer (%)		6	6		3	15
Consultant (%)	3		6		3	12
CMA/WUA management (%)	3	3		3		9
Not indicated (%)			6			6
Agricultural economist (%)			6			6
Farmer (%)			6			6
Scheduling service (%)		3	3			6
Water Act administrator (%)		3				3
Total (%)	9	24	47	12	9	100

On the statement “Irrigation scheduling could only be effectively applied once farmers have full control of the water supply”, the response was fairly evenly spread over the spectrum of disagreement to agreement, therefore there seems to be no clear-cut standpoint amongst the respondents on this issue (Table 4.7.

Table 4.7 Response to the statement "Irrigation scheduling could only be effectively applied once farmers have full control of the water supply" (1 = disagree strongly; 5 = agree strongly.

Group	Not indicated	Disagree		Neutral		Agree	Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
System designer/planner (%)	3	9	9	6	9	3	38
Lecturer/trainer (%)		3	3	3		6	15
Consultant (%)	3			3	6		12
CMA/WUA management (%)	3	3		3			9
Not indicated (%)					3	3	6
Agricultural economist (%)			6				6
Farmer (%)				6			6
Scheduling service (%)		3			3		6
Water Act administrator (%)					3		3
Total (%)	9	18	18	7	24	12	100

On the question whether the respondents are familiar with the research done by the Water Research Commission and whether they are regular users of the research knowledge generated, the response was:

Familiar with the research: 85%

Regularly user of the research knowledge generated: 76%

The respondent's use of this research knowledge is shown in Table 4.8. Planning and design as well as research and irrigation management are the most important applications of Water Research Commission generated research knowledge. Water Research Commission generated research knowledge is applied over a wide spectrum of the irrigation industry.

Table 4.8 The purpose for which WRC generated research knowledge is applied.

Application	%
Planning and design	50
Research	47
Irrigation management	41
Training	24
Water use administration	15
Policy designing and implementation	9
Other (scheduling)	3

4.6.2.3 Characterizing the SAPWAT3 users

SAPWAT3 is used by most of the more experienced and higher trained people that have to do with irrigation water planning, management and use. Of these users, the designers and planners of irrigation systems are the biggest, a tendency that can be expected as the original SAPWAT was designed with this group in mind. Most of the SAPWAT3 users are furthermore people who had previously used other models or programs similar to SAPWAT3.

Slightly more than half of the respondents are of opinion that the Water Act imposes necessary regulations to irrigation water users, even though there is no clear opinion on whether or not irrigation scheduling could be effectively applied only if farmers have full control of the water supply.

Most agree that methods and tools such as SAPWAT3 are developed for use by irrigation advisors and researchers and half of them think that it is cost-effective to implement irrigation scheduling computer models. Most are of opinion that variability in rainfall and weather is not too complex to be accommodated in the irrigation scheduling tools and programs.

Most SAPWAT3 users are familiar with research done by the WRC and are also users of the knowledge generated. The generated knowledge is mostly used for planning and designing of systems, research and for irrigation water management.

4.6.3 SAPWAT3 and its uses

SAPWAT3 is used by the respondents to fulfil various functions, as can be seen in Table 4.9. Respondents use SAPWAT3 for more than one function, therefore the table values add up to more than 100%. Most respondents use it for the function of designing and planning at field level, with the functions of water licensing and registration; design and planning at CMA and WUA level; irrigation water management at CMA and WUA level also being important with application of more than 30% each.

Table 4.9 Purpose for which SAPWAT3 is used.

Function	%
Design and planning at field level	74
Water use licensing or registration	41
Design and planning at CMA and WUA level	35
Irrigation water management at CMA and WUA levels	32
Training	26
Scheduling service	24
Research	24
Hydrology planning	21
Planning for irrigation water policy	21
Administration of the Water Act	12
Other	3

Reasons why SAPWAT3 is used for these functions are given as:

Easy to work with (12)
To estimate crop water requirements (10)
Basic concepts and use are introduced during training (8)
Gives me information (4)
For the management of irrigation water (2)
Irrigation scheduling (2)
Prescribed by the Dept of Water Affairs (2)
Excellent source for obtaining reliable and credible data for Africa.
I preferred the simplicity of the old SAPWAT
I would use where greater accuracy is needed on sugar cane irrigation estimation – for scheme design
Installation is quick, easy and simple to use although nutrient guidelines may be lacking
Interaction between demand and supply
It provides answers on many different scenarios that can be created
Many parameters to describe runoff conditions
National and international data base
SAPWAT3 allows great accessibility to all relevant variables. A lot of information is poorly understood.
Scientifically based
Scientific justification for publications
Support available
Targeting small-scale irrigators
The many options it offers with respect to various parameters
To make sure that there is enough water for the relevant crops planted. Very important in financing
To compare different irrigation strategies
To determine moisture content of the soil
To determine water balance

Upgrading of previous version of SAPWAT
Used SAPWAT to predict the peak and off-peak water requirement to plan dry weeks
Use for hydrological studies
Used as a planning and management tool to refine and support the Green Book
Used as a scheduling tool in conjunction with soil water probes. Now use continuous logging probes
Used for the calculation of salt balance in profiles for research purposes
Valuable tool in supporting water management by farmers as well as planning new irrigation schemes
Very good soil information, e.g. soil water holding capacity
Well-designed and well-developed model
You can plan a water balance for a proposed project

SAPWAT3 is used as a decision-making support tool in the fields depicted in Table 4.10 where it can be seen that SAPWAT3 is used mainly for the designing of irrigation systems as well as for evaluating and designing irrigation strategies. Estimation of catchment water balances is the area in which it is the least used.

Table 4.10 Decision making support functions that SAPWAT3 is used for.

Decision making support	%
Designing of irrigation systems	53
Planning and designing of irrigation water management	47
Confirmation of appropriateness of current irrigation strategy	41
Trouble shooting of irrigation water management	38
Enlightenment of certain aspects of irrigation water management	32
Problem solving of irrigation management problems	29
Policy planning and implementation	26
Estimation of catchment water balances	18
Other	3

The respondents indicated that SAPWAT3 is mainly used at the following levels:

Field or farm level	85%
Scheme level	44%
Catchment level	18%
National level	12%

This usage shows that SAPWAT3 is presently used mostly at farm and scheme level and less so at catchment and national level. It does have the ability to handle estimation at higher level, but as most of its users operate at farm and scheme level the above usage supports the indications of its use at the lower levels.

First awareness of SAPWAT3 is shown in Table 4.11. The most important channels of awareness are contact with researcher, research reports, training sessions, on advice of researcher or specialist or at conferences and symposia.

Table 4.11 Response to indicate how first time awareness happened

Became aware	%
Contact with researcher or specialist on your request	50
Research reports	38
Training session on specific research knowledge	32
Advice of researcher or specialist	32
Conference or symposium	26
Introduction through peer	15
Introduction through advisor or specialist	6
Other	3
Scientific articles	1
Popular articles	1
Contact via web site	0

On being asked to indicate frequency of use and how important their use of SAPWAT3 is in terms of their decision-making, the response is indicated in Table 4.12.

Table 4.12 Frequency of use and decision-making importance of SAPWAT3 (1 = not important; 5 = very important).

Frequency of use	Not indicated	Not important	Neutral	Important		Total (%)
	0 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Sporadically			19	14	6	39
Monthly			12	12	9	33
Weekly		3		9	1	13
Yearly				12		12
Not indicated	3					3
Total (%)	3	3	31	47	16	100

SAPWAT3 is used more sporadically than at specific intervals, although the importance of decision-making tends to be important or very important for 63% of cases.

4.6.4 Perceived usefulness and ease of use

Figure 4.5 shows the summarised results of questions on usefulness and ease of use of SAPWAT3. In both cases SAPWAT3 was found to be adjudged as being in the middle between acceptance and non-acceptance. One of the reasons for this neutral positioning of users could be that their experience in the use of SAPWAT3 is limited because of the newness of the program (published August 2009) when the survey was done (November 2009).

Characteristic	Disagree fully	Disagree partially	Neutral		Agree partially	Agree fully
Usefulness ("Using SAPWAT3 will improve my work performance")						
Ease of use ("SAPWAT3 can be used with a minimum of effort")						

Figure 4.5 Perceived Usefulness and Ease of Use of SAPWAT3 by its users (Yellow = neutral; Green = response on same level)

Table 4.13 shows a compilation of reasons why SAPWAT3 users found it useful. A good data base, taking guesswork out of decision-making, good management of irrigation water and efficient water use are the top contenders, with 18% or more mentioning amongst the respondents. Some comments were not complimentary. These are shown in Table 4.14, and although these are real problems experienced by some users, the total percentage occurrences of these are low.

Table 4.13 A compilation of reasons given by respondents as to the usefulness of SAPWAT3

Reason	%
Good climate and crops data base	21
It is a tool which takes the guesswork out of decision making	18
To know exactly how to manage the irrigation supply	18
Ease of use and applicability / good data base / support	18
Efficient use of water	18
To estimate crop water use	15
Fast set-up, climate, crop and soil data are available	15
Identify best irrigation strategies	6
It's a lengthy process but useful	6
To improve the knowledge of the water requirement of the area and system	6
It provides a good basis for the rest of project planning and design	6
Data available for small water catchment planning	6
Tool for farmer training: the farmer can understand the effect of irrigation strategies	3
Tool for student training	3
A planning tool for water restriction scenarios	3
Enables standardisation across a catchment	3
Reliable climate information	3
Work through the program with the farmer increases confidence in you	3
Models helps in accomplishing research objectives	3
SAPWAT3 improves your irrigation management skills	3
SAPWAT3 can show trends if used well	3
Quicker research decisions	3
To improve the knowledge of the water requirement of the area and system	3
Test different strategies	3
When client is uncertain, you will be able to assist in 100% of cases	3
Easy to use and support is available	3
Take the guesswork out of water management	3
Test different strategies	3
Research outputs are increased	3

Table 4.14 A compilation of reasons given by respondents for not finding SAPWAT3 useful

Reason	%
Weather station difficult to append	6
Both BEWAB and SAPWAT are easier to use	3
It was a click away with the previous version; it is now a long way before getting the final answer	3
Not necessary to add all data asked for in some cases	3
Not very clear what to use as inputs, will become clear after some use	3
The system is wrong in some instances about what crop data	3
I have found the input data difficult to manipulate and thereby adapt to my situation	3

Table 4.15 To what extent does SAPWAT3 help you with the planning of irrigation water use? (1 = no improvement; 5 = Great improvement).

Group	Not indicated	No improvement	Neutral	Improvement		Total (%)
	0 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
			6			6
Agricultural economist			3	3		6
CMA/WUA management		3	3	3		9
Consultant	3			6	3	12
Farmer		3	3			6
Lecturer/trainer	6			9		15
Scheduling service			3		3	6
System designer/planner	3		9	12	15	38
Water Act administrator			3			3
Total (%)	12	6	29	32	21	100

Response to the question "To what extent does the method or tool help you with the planning of irrigation water use?" the system designers / planners showed the biggest degree of positive reaction, farmers tended to be somewhat negative, CMA/WUA management was neutral and the other groups showed a slight to more positive reaction. The overall response was improvement to great improvement.

Table 4.16 shows the extent to which the respondents see that SAPWAT3 help them with the evaluation of irrigation water use. The overall trend is that SAPWAT3 users see that it improves their ability to evaluate irrigation water use, with the system designers / planners showing the strongest trend and farmers showing the opposite trend, that is they do not see SAPWAT3 as an aid to evaluate irrigation water use.

Table 4.16 To what extent does SAPWAT3 help you with the evaluation of irrigation water use (1 = no improvement; 5 = great improvement).

Group	Not indicated	No improvement		Neutral	Improvement		Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated				6			6
Agricultural economist				3	3		6
CMA/WUA management			3	3	3		9
Consultant			3		6	3	12
Farmer	3	3					6
Lecturer/trainer	3				12		15
Scheduling service				3		3	6
System designer/planner	3		3	12	12	9	38
Water Act administrator					3		3
Total (%)	9	3	12	24	38	15	100

Table 4.17 To what extent does SAPWAT3 help you with the planning of system design (1 = no improvement; 5 = Great improvement).

Group	Not indicated	No improvement	Neutral	Improvement		Total (%)
	0 (%)	1 (%)	3 (%)	4 (%)	5 (%)_	
Not indicated			6			6
Agricultural economist		3		3		6
CMA/WUA management	3	3		3		9
Consultant	3	3		3	3	12
Farmer	3	3				6
Lecturer/trainer	6		3	6		15
Scheduling service			3		3	6
System designer/planner			3	15	21	38
Water Act administrator	3					3
Total (%)	18	12	15	29	26	100

The extent to which SAPWAT3 can help with the planning and system design and the relationship between the professional groups comes out clearly in Table 4.17. A high positive relationship comes out between designers and planners, while the managers of water do not use this function and therefore a negative relationship is shown in these cases.

Table 4.18 To what extent does SAPWAT3 help you with the evaluation of system design?

Group	No improvement		Neutral	Improvement		Total (%)
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated		2	3			5
Agricultural economist			3	5		8
CMA/WUA management	1		3			4
Consultant	1	2				3
Farmer	1					1
Lecturer/trainer				15		15
Scheduling service			3		6	9
System designer/planner		2	15	15	23	55
Water Act administrator						
Total (%)	3	6	27	35	29	100

Table 4.18 shows that SAPWAT3 helps 64% of all users in the evaluation of system design. In the case of system designers / planners, this percentage is increased to 69%, while it is low for CMA/WUA managers and consultants whose job is mainly the distribution and management of irrigation water between users.

Table 4.19 To what extent does SAPWAT3 help you with water resource assessment of catchments?

Group	No improvement		Neutral	Improvement		Total (%)
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated		3	5			8
Agricultural economist				12		12
CMA/WUA management	2					2
Consultant			5		8	13
Farmer	2					2
Lecturer/trainer			5	6		11
Scheduling service	2		5			7
System designer/planner	2	8	9	6	15	40
Water Act administrator			5			5
Total (%)	8	11	34	24	23	100

Forty-seven percent (47%) of respondents indicated that SAPWAT3 can help them with water resource assessment of catchment. The stronger positive groups are agricultural economists, consultants and system designers / planners, people who are usually more interested in looking at a bigger water balance picture than the other groups.

Table 4.20 To what extent does SAPWAT3 help you with water resource assessment for irrigation water demand and supply?

Group	No improvement		Neutral	Improvement		Total (%)
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated			6			6
Agricultural economist				8		8
CMA/WUA management	1			8		9
Consultant			3		10	13
Farmer			3			3
Lecturer/trainer			3	8		11
Scheduling service			3		5	8
System designer/planner		2	8	15	14	39
Water Act administrator			3			3
Total	1	2	29	39	29	100

Table 4.20 shows that there is a general tendency that SAPWAT3 helps all groups in the assessment of irrigation water demand and supply with 68% of respondents reporting improvement or great improvement through the use of SAPWAT3.

Table 4.21 The extent to which the use of SAPWAT3 lead to better-informed decision-making in irrigation management.

Group	No improvement	Neutral	Improvement		Total (%)
	1 (%)	3 (%)	4 (%)	5 (%)	
Not indicated		5			5
Agricultural economist		3	4		7
CMA/WUA management	1	3		4	8
Consultant	1	3	4		8
Farmer		3	4		7
Lecturer/trainer			11	4	15
Scheduling service		3		4	7
System designer/planner		5	20	18	43
Water Act administrator					
Total (%)	2	25	43	30	100

Table 4.21 shows a clear tendency towards better informed water management decision making by users of SAPWAT3, with 73% indicating an improvement or great improvement.

On better control over the implementation of an irrigation management strategy, Table 4.22 shows that there is a small positive perception, but overall the perception on this aspect is neutral.

Table 4.22 The extent to which the use of SAPWAT3 helps to have better control over the implementation of an irrigation management strategy.

Group	No improvement		Neutral	Improvement		Total (%)
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated		3	4			7
Agricultural economist			4	5		9
CMA/WUA management			7			7
Consultant	1		4			5
Farmer		3				3
Lecturer/trainer	1		4	5	7	17
Scheduling service			4		7	11
System designer/planner	1	5	17	5	13	41
Water Act administrator						
Total (%)	3	11	44	15	27	100

Most of the reasons (50%) given for response in Table 4.22 refer to estimated crop irrigation requirements, but there are also negative indications, such as that BEWAB or SAPWAT are preferred over SAPWAT3 because they are easier to use (3%).

Table 4.23 The extent to which the use of SAPWAT3 helps to accomplish quicker decisions regarding irrigation management.

Group	No improvement		Neutral	Improvement		Total (%)
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated			7			7
Agricultural economist		2		4		7
CMA/WUA management	1					1
Consultant			3	4		8
Farmer			3			3
Lecturer/trainer			3	9	6	18
Scheduling service					6	6
System designer/planner	1		7	31	11	51
Water Act administrator						
Total (%)	2	2	24	49	22	100

Seventy-one percent (71%) of respondents are of opinion that using SAPWAT3 does lead to quicker decision-making regarding irrigation management (Table 4.23). More than half of the respondents (55%) gave no reason for this, while 18% indicated a combination of ease of use, a good data base and support as main reasons. Six percent (6%) indicated it as being a lengthy but useful process Table 4.13.

Table 4.24 The extent to which the use of SAPWAT3 helps to make easier decisions regarding implementation of irrigation management strategies

Group	No Improvement		Neutral	Improvement		Total (%)
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated		3	4			7
Agricultural economist			9			9
CMA/WUA management	1					1
Consultant	1		4			5
Farmer			3			3
Lecturer/trainer			9	6	7	22
Scheduling service					7	7
System designer/planner	1	3	9	12	21	46
Water Act administrator						
Total (%)	3	6	38	18	35	100

Table 4.24 shows that a majority of the users of SAPWAT3 found that using it has aided them in making easier decisions regarding the implementation of irrigation management strategies.

A true-false response on the question of whether SAPWAT3 is useful as a tool for management of irrigation water, the Water Act Administrators gave it a unanimous negative (0:100). In other cases the response varied from neutral (50:50) to slightly better with the highest positive at 75:25.

Table 4.25 The extent to which the output of SAPWAT3 help to increase productivity.

Group	Not indicated	No improvement		Neutral	Improvement		Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated				6			6
Agricultural economist			3	3			6
CMA/WUA management	3	3			3		9
Consultant	6	3			3		12
Farmer		3		3			6
Lecturer/trainer	6			3	3	3	15
Scheduling service	3					3	6
System designer/planner	3		3	8	12	11	37
Water Act administrator				3			3
Total (%)	21	9	6	26	21	17	100

Unfortunately 21% of respondents did not respond to this question; however 37% indicated that the output of SAPWAT3 increased their productivity for reasons shown in Table 4.13. Apart from the 58% who did not give a reason 12% indicated that set-up time is quick and that it provides a good basis for further project planning. The 18% indication of efficient water use is due to a possible misunderstanding, the question referred to the respondent's productivity. This question was not phrased clear enough.

Table 4.26 The degree to which the input data included in SAPWAT3 allow for its use.

Group	Not indicated	No improvement		Neutral	Improvement		Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated	3			3			6
Agricultural economist			3	3			6
CMA/WUA management	6	3					9
Consultant	6		3			3	12
Farmer	6						6
Lecturer/trainer	6			3	3	3	15
Scheduling service	3					3	6
System designer/planner	3		3	11	11	9	37
Water Act administrator				3			3
Total (%)	33	3	9	23	14	18	100

SAPWAT3 includes data for use in the program. Of the respondents, 32% indicated that it improves its use, compared to only 12% who indicated no improvement. Thirty-three percent (33%) of respondents did not respond to this question (Table 4.26).

Table 4.27 Availability of input data for effective operation of SAPWAT3.

Group	Not indicated	Not available		Neutral	Freely available		Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated			3	3			6
Agricultural economist				3	3		6
CMA/WUA management		3	3			3	9
Consultant	6		3			3	12
Farmer			3	3			6
Lecturer/trainer	3	3		3		6	15
Scheduling service			3			3	6
System designer/planner	3			14	17	3	37
Water Act administrator				3			3
Total (%)	12	6	15	29	20	18	100

Table 4.27 shows that 12% of respondents were of no opinion, 29% had a neutral opinion, 38% were positive, against 21% who had a negative attitude on this aspect.

Table 4.28 The credibility of SAPWAT3 output.

Group	Not indicated	Low credibility		Neutral	High credibility		Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated				6			6
Agricultural economist			3		3		6
CMA/WUA management		3		3		3	9
Consultant	6			3	3		12
Farmer				3	3		6
Lecturer/trainer	3				12		15
Scheduling service				3		3	6
System designer/planner	3			12	24		38
Water Act administrator				3			3
Total (%)	12	3	3	33	44	6	10

The credibility of SAPWAT3 output is shown in Table 4.28. Fifty percent (50%) of respondents see the credibility as high, 6 percent as low and 33% were of no opinion. Twelve percent (12%) did not respond.

Table 4.29 The need for input information not provided by SAPWAT3

Group	Need for additional information		Total (%)
	False (%)	True (%)	
Not indicated	0	100	100
Agricultural economist	100	0	100
CMA/WUA management	100	0	100
Consultant	50	50	100
Farmer	50	50	100
Lecturer/trainer	100	0	100
Scheduling service	100	0	100
System designer/planner	69	31	100
Water Act administrator	0	100	100
Grand Total	71	29	100

Table 4.29 shows that 71% of respondents are of opinion that there is no need for information not provided for by SAPWAT3.

Table 4.30 Main reasons for additional input information required

Main reason for additional input data	**%**
Not indicated	82
More weather stations	6
More crop factors	3
Need knowledge and experience	3
More localised rainfall data	3
Most people do not know the soil profile moisture	3

Table 4.31 Importance of additional input information.

Group	Not important		Neutral	Important		Total (%)
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated	3		8			11
Agricultural economist				11		11
CMA/WUA management						
Consultant			16			16
Farmer		5				5
Lecturer/trainer						
Scheduling service	3					3
System designer/planner	3	11	7	11	14	46
Water Act administrator			8			8
Total (%)	9	16	39	22	14	100

Table 4.31 shows that in general no real importance or non-importance is given to additional information required.

Table 4.32 Barriers to information availability

Barrier	**%**
Not indicated	85
Access to input tables	3
Can be generated	3
Fairly available	3
Method of data input	3
Water users use of tools and soil moisture knowledge	3
Grand Total	100

On the question of the barriers to availability of additional input information, 85% did not respond, possibly indicating that no barriers exist (Table 4.32). On the availability of additional information, 42% indicated that it is freely available, 41% remained neutral and 17% indicated that it is not available, as shown in Table 4.33.

Table 4.33 Availability of additional input information.

Group	Not available	Neutral	Freely available		Total (%)
	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated	4				4
Agricultural economist			9		9
CMA/WUA management				11	11
Consultant		14		11	25
Farmer		7			7
Lecturer/trainer					
Scheduling service				11	11
System designer/planner	9	20			29
Water Act administrator	4				4
Total (%)	17	41	9	33	100

4.6.4.1 Characterising usefulness

Initially SAPWAT and now SAPWAT3 were designed and built with the designers and planners of irrigation systems and water use in mind as potential main users. The original SAPWAT was built as simply as possible with the aim of involving all sectors of the irrigation fraternity as well as all levels of training in its use. SAPWAT3 has more functionality and is therefore less simple to use than SAPWAT, but this was not aimed at reducing the spectrum or scope of usage, it was rather aimed at giving users more flexibility of application. The survey on SAPWAT3 use was designed to find out what SAPWAT3 was used for as well as by whom. The results are depicted in Table 4.34 where overall usage is shown.

SAPWAT3 is designed as a planning tool, and the expected major users should be irrigation water use planners, irrigation water use managers as well as designers of irrigation systems. Table 4.34 reflects this expectation; SAPWAT3 is used more by system designers and planners, scheduling services as well as agricultural economists than for any other group. On the negative side, farmers and administrators of the Water Act use SAPWAT3 much less than average.

Most of the agricultural economists, who were involved in the survey, are linked to the commercial banks' agricultural financing sector and their role in determining the viability of loan applications out of the irrigation sector could play a role in the high level of SAPWAT3 use by them. The surprising sector is the scheduling industry, which normally uses real-time data, the only reason why they have come out as such big users, is the possibility that SAPWAT3 irrigation requirement planning is used as a preliminary to their real-time scheduling service.

Experience has been that farmers who use SAPWAT3, use it once every number of years when they replan their cropping pattern to determine how much irrigation water they would require. Once the new cropping pattern is in place SAPWAT3 is not used again until the next replanning. This could explain the low level of SAPWAT3 use by farmers.

Table 4.34 Table showing the relative importance of SAPWAT3 use by users and their application of the program (Max value per cell = 5).

	Agricultural economist	WUA manager	Consultant	Farmer	Lecturer	Scheduling service	Designer planner	Administrator	Average
Planning irrigation water use	3.50	3.00	3.25	2.50	2.40	4.00	3.95	3.00	3.20
Evaluate irrigation water use	3.50	3.00	4.00	0.50	3.20	4.00	3.55	4.00	3.22
Planning of system design	1.50	1.67	2.50	0.50	2.60	4.00	4.58	0.00	2.17
Evaluate system design	3.63	2.50	1.67	1.00	4.00	4.33	4.07	0.00	2.65
Water resource assessment of catchments	4.00	1.00	4.23	1.00	3.55	2.43	3.60	3.00	2.85
Water resource assessment: demand & supply	4.00	3.67	4.54	3.00	3.73	4.25	4.05	3.00	3.78
Better informed decision-making in irrigation management	3.57	3.75	3.25	3.57	4.27	1.22	2.74	0.00	2.80
Better control over implementation of irrigation strategy	3.56	3.00	2.60	2.00	4.00	4.27	3.59	0.00	2.88
Quicker decisions regarding irrigation management	2.86	1.00	3.13	3.00	4.17	5.00	3.94	0.00	3.01
Easier decisions on implementation of irrigation strategies	3.00	1.00	2.60	3.00	3.91	5.00	4.07	0.00	2.82
Increase productivity	2.50	1.67	1.25	2.00	2.40	2.50	3.59	3.00	2.36
Input data included to allow SAPWAT3 use	2.50	0.33	1.25	0.00	2.40	2.50	3.46	3.00	1.93
Availability of input data for effective use	3.50	2.67	1.75	2.50	2.80	3.50	3.38	3.00	2.89
Credibility of SAPWAT3 output	3.00	3.00	1.75	3.50	3.20	4.00	3.47	3.00	3.12
Importance of additional input information	4.00	0.00	3.00	2.00	0.00	1.00	3.48	3.00	2.06
Availability of input information	4.00	5.00	3.88	3.00	0.00	5.00	2.69	2.00	3.20
Average	3.29	2.27	2.79	2.07	2.91	3.63	3.64	1.88	2.81

The low level of use by Water Act administrators is disappointing seen in the light that the Department of Water Affairs has decided that the validity of irrigation water application for registration and licensing should be evaluated against SAPWAT output. However, what has been experienced is that regional offices of the Department of Water Affairs have used runs of SAPWAT to determine guideline irrigation requirement values, which are then used to compare irrigation requirement applications against, instead of doing new irrigation requirement planning runs on SAPWAT3 for each application.

The credibility of SAPWAT3 output is relatively high, where all groups except consultants, indicated an above average credibility.

Over all sectors that use SAPWAT3, its use for assessing water resource demand and supply has come out as the most important application. The agricultural economists tend to be more interested in irrigation water use planning and management, including the design and evaluation of irrigation systems.

WUA managers tend to concentrate on water resource assessment and demand management, but are generally below average about using SAPWAT3 for on-farm irrigation management strategies. They do not see the use of SAPWAT3 as a tool that could increase productivity. The consultants use SAPWAT3 more for the on-farm part of irrigation planning and management as well as for larger scale water resource demand and supply assessment.

The best use of SAPWAT3 by farmers is to be able to make better informed decisions about irrigation water management. Lecturers use SAPWAT well on a very wide scope of application, where-as scheduling services tend to concentrate on the on-farm water management part. Designers and planners concentrate on the on-farm irrigation requirement planning and management, and they also see the use of SAPWAT3 as leading to increased productivity. Water Act administrators use SAPWAT3 below average for just about any application possible.

4.6.5 Perceived ease of use

Table 4.35 Ease of use of SAPWAT3

Group	Not indicated	Not easy to use	Neutral		Easy to use	Total (%)
	0 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated		3		3		6
Agricultural economist			6			6
CMA/WUA management			6		3	9
Consultant	6	3		3		12
Farmer	3		3			6
Lecturer/trainer			6	9		15
Scheduling service			3	3		6
System designer/planner	6	6	12	15		38
Water Act administrator	3					3
Total (%)	18	12	35	32	3	10

Thirty-five percent (35%) found it easy to very easy to use SAPWAT3, while 35% gave no indication either way, and 12% found it difficult to use and 18% did not give an opinion.

Table 4.36 Ease of understanding the research report

Group	Not indicated	Did not understand	Neutral	Did understand		Total (%)
	0 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated		3		3		6
Agricultural economist			6			6
CMA/WUA management			6		3	9
Consultant	6	3		3		12
Farmer	3		3			6
Lecturer/trainer			6	9		15
Scheduling service			3	3		6
System designer/planner	6	6	12	15		38
Water Act administrator	3					3
Total (%)	18	12	35	32	3	100

In Table 4.36 it can be seen that 35% understood the research report, 35% did not express and opinion, while 12% had difficulty in understanding the research report; some consultants and system designers seemed to have experienced a problem in this regard. Eighteen percent (18%) did not respond to this question.

Table 4.37 The ease to understand and follow the user manual

Group	Not indicated	No easy to understand and follow		Neutral	Easy to understand and follow		Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated				6			6
Agricultural economist			3	3			6
CMA/WUA management				6		3	9
Consultant	6				3	3	12
Farmer			3	3			6
Lecturer/trainer	3	3	3	3	3		15
Scheduling service	3		3				6
System designer/planner	6			21	12		38
Water Act administrator				3			3
Total (%)	18	3	12	44	18	6	100

The ease with which respondents could understand and follow the user manual, is depicted in Table 4.37, where it can be seen that 24% could follow and understand it easily, 44% were neutral in their opinion and 12% experienced it as difficult. Eighteen percent (18%) did not respond to this question.

Table 4.38 The importance of a user manual for SAPWAT3

Group	Not indicated	Low		Neutral	High		Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated				3	3		6
Agricultural economist				3	3		6
CMA/WUA management				3		6	9
Consultant	3					9	12
Farmer					3	3	6
Lecturer/trainer	3					12	15
Scheduling service			3		3		6
System designer/planner	3	3	3		9	21	38
Water Act administrator					3		3
Total (%)	9	3	6	9	24	50	100

Most of the respondents (74%) indicated that SAPWAT3 should have a user manual.

Table 4.39 Ease to learn to use SAPWAT3

Group	Not indicated	No easy to learn		Neutral	Easy to learn		Total (%)
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated			3		3		6
Agricultural economist				6			6
CMA/WUA management			3	6			9
Consultant	3		3	3	3		12
Farmer			6				6
Lecturer/trainer			3		3	9	15
Scheduling service		3				3	6
System designer/planner	3		6	12	18		38
Water Act administrator				3			3
Total (%)	6	3	24	29	26	12	100

Table 4.39 shows that 38% found it easy to learn SAPWAT, whilst 27% found it difficult. The number of respondents that found it difficult to learn is too high and should be lowered.

Table 4.40 Extent to which the use of SAPWAT3 increases knowledge and skills of irrigation management.

Group	Not indicated	Neutral	Increased knowledge and skills		Total (%)
	0 (%)	3 (%)	4 (%)	5 (%)	
Not indicated		6			6
Agricultural economist		6			6
CMA/WUA management		6	3		9
Consultant	6		6		12
Farmer		3	3		6
Lecturer/trainer	3	6	3	3	15
Scheduling service		3		3	6
System designer/planner	3	12	18	6	38
Water Act administrator		3			3
Total (%)	12	44	32	12	100

It can be seen in Table 4.40 that 44% are of opinion that the use of SAPWAT3 have increased their knowledge and skills of irrigation management and 44% indicated no change.

Table 4.41 The flexibility of SAPWAT3

Group	Not flexible	Neutral	Flexible		Total (%)
	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated		6			6
Agricultural economist		3	4		7
CMA/WUA management		6	4		10
Consultant	2		4		6
Farmer	2		4		6
Lecturer/trainer	2	6	4		12
Scheduling service				5	5
System designer/planner	4	6	20	15	45
Water Act administrator		3			3
Total (%)	10	30	40	20	100

Table 4.41 shows that 60% of respondents regarded SAPWAT3 as flexible while only 10% regarded it as not flexible.

Table 4.42 The use of SAPWAT3 saves time.

Group	Not indicated	Does not save time	Neutral	Saves time	
	0 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Not indicated			6		
Agricultural economist			3	3	
CMA/WUA management		3	3	3	
Consultant	6			6	
Farmer			6		
Lecturer/trainer	3	3		6	3
Scheduling service	3				3
System designer/planner	6	3	12	15	3
Water Act administrator			3		
Grand Total	18	9	32	32	9

Table 4.42 shows that the use of SAPWAT3 saves time for 41% of respondents, while 9% said that using it does not save time.

4.6.5.1 Characterising ease of use of SAPWAT3

In the design of SAPWAT3 the same approach was used as in SAPWAT, which is to make the program as easy to work with as is possible. However, the added functionality of SAPWAT3 does complicate matters somewhat. The perception on ease of use was tested per questionnaire. This included, amongst others, questions on the ease of use, ease of understanding the research report, easy to learn, flexibility.

The results can be seen in Table 4.43. Even though the importance of a user manual (the SAPWAT3 report is also a user manual) is regarded as high, and though the flexibility of SAPWAT3 was highly acclaimed by just about all groups, a disappointing number of user groups have actually indicated that SAPWAT3 is difficult to use and that the research report itself, which doubles as a user manual was not that easy to read and understand. WUA managers and designers and planners gave SAPWATA3 the highest points for ease of use, while administrators, consultants and farmers found SAPWAT3 fairly difficult to use. Agricultural economists, WUA managers, lecturers, scheduling services, designers and planners and administrators indicated that SAPWAT3 is easy to learn, does enhance skills and knowledge of irrigation management, is flexible and saves time. Agricultural economists, WUA managers, lecturers and scheduling services tended to judge SAPWAT3 as easy to learn and that the research report is easy to understand.

Table 4.43 The ease of use of SAPWAT3 as perceived by different user groups (Max value per cell = 5)

	Agricultural economist	WUA manager	Consultant	Farmer	Lecturer	Scheduling service	Designer planner	Administrator	Average
Ease of use of SAPWAT3	3.00	3.67	1.25	1.50	3.60	3.50	2.84	0.00	2.42
Ease of understanding the research report	3.00	3.67	1.50	1.50	3.60	3.50	2.84	0.00	2.45
The ease to understand and follow the user manual	2.50	3.67	2.25	2.50	2.00	1.00	2.92	3.00	2.48
The importance of a user manual	3.50	4.33	3.75	4.50	4.00	3.00	3.95	4.00	3.88
Ease to learn SAPWAT3	3.00	2.67	2.25	2.00	4.20	3.00	3.16	3.00	2.91
Extent to which skill and knowledge of irrigation management is increased	3.00	3.33	2.00	3.50	3.00	4.00	3.63	3.00	3.18
Flexibility of SAPWAT	3.57	3.40	3.33	3.33	3.17	5.00	4.02	3.00	3.60
The use of SAPWAT3 saves time	3.50	3.00	2.00	3.00	2.60	2.50	3.00	3.00	2.83
Average	3.13	3.47	2.29	2.73	3.27	3.19	3.30	2.38	2.97

4.6.6 SAPWAT3 support

Customer satisfaction was also tested and the results can be seen in the following tables.

Table 4.44 Type of assistance favoured

Type of user assistance favoured	Respondents (%)
Back-up support by research team	38
Web-linked support system	35
E-mail / SMS messages	35
Appropriate support of extensionists and advisors	18
Back-up support by dealer	15
Other	0

The respondents indicated that their first choice of support should be back-up by the research team, as seen in Table 4.44. Following this, are web-linked and e-mail/ SMS support systems. Lower levels of choice are support of extensionists and advisors, followed by support by dealer.

Table 4.45 Favoured electronic support system

Type of electronic support	Respondents (%)
Web-site / e-mail	97
SMS messages	3

On a choice between web-site / e-mail vs. SMS, Table 4.45 shows that web-site and e-mail support is the choice of 97% of the respondents.

Table 4.46 Compilation of reasons for choice of electronic support system

Reason	Total (%)
Not indicated	41
E-mail is more manageable and can be saved	38
Easy access to computer and internet	6
DWA personnel are not agricultural technicians, are engineers and exposure is limited	3
Belief that a web-based system which runs along the similar lines to Queensland DPI irrigation	3
Not always within signal range	3
Personal interaction is always the best	3
SMS is too short	3
Total (%)	100

The major reason for the choice in electronic support system, as can be seen in Table 4.46, is that e-mail is more manageable and that responses can be saved, and there is easy access to computers and internet. All other reasons and comments were each mentioned by 3% of respondents, and although valid for the relevant respondents, are at a level of “taking note of”.

Table 4.47 Importance to meet the research team.

Group	(%)
Not indicated	50
Scheduling service	100
System designer/planner	69
CMA/WUA management	67
Agricultural economist	50
Farmer	50
Consultant	25
Lecturer/trainer	20
Water Act administrator	0
Average (%)	53

Table 4.47 shows that on average 53% of respondents are of opinion that it is important to meet the research team. Amongst the occupational groups, scheduling services, system designers and planners, as well as CMA/WUA managers are more than 50% in favour of meeting the research team. The Water Act administrators give the lowest level of importance to meeting the research team.

Table 4.48 Satisfaction with communication and support by the research team (1 = very dissatisfied; 5 = very satisfied).

Group	Dissatisfied	Neutral	Satisfied		Total (%)
	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated	2	3			5
Agricultural economist		3	4		7
CMA/WUA management	2			5	7
Consultant		6	4		9
Farmer		3	4		7
Lecturer/trainer		3	4	5	11
Scheduling service		3		5	7
System designer/planner		17	4	23	44
Water Act administrator			4		4
Total	4	36	22	37	100

Fifty-nine percent (59%) of respondents are satisfied with the communication and support by the research team. Four percent (4%) indicated that they are dissatisfied.

Table 4.49 Satisfaction with communication and support by extension staff or irrigation advisors team (1 = very dissatisfied; 5 = very satisfied).

Group	Dissatisfied		Neutral	Satisfied		Total (%)
	1	2	3	4	5	
Not indicated		4	5			9
Agricultural economist			5	7		12
CMA/WUA management		4	5			9
Consultant		4	5	7		16
Farmer			5			5
Lecturer/trainer	2				9	11
Scheduling service					9	9
System designer/planner	4	11	16			3
Water Act administrator						
Total	5	21	42	14	18	100

Table 4.49 shows that satisfaction with communication and support from extension staff and irrigation advisors range from not satisfied to satisfied.

Table 4.50 Satisfaction with back-up support by dealer (1 = very dissatisfied; 5 = very satisfied).

Group	Dissatisfied		Neutral		Satisfied	Total (%)
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Not indicated		3	5			8
Agricultural economist			1			1
CMA/WUA management		3			8	12
Consultant			5			5
Farmer			5			5
Lecturer/trainer	2			14		15
Scheduling service					8	8
System designer/planner		7	15	7		29
Water Act administrator				7		7
Total	2	14	41	27	17	100

Table 4.50 shows that 44% of the respondents are satisfied and 16% are dissatisfied with back-up and support by the dealer. An interesting result, as the Water Research Commission is the distributor of the report and program, which is one of its products. The technical support is the responsibility of the developer.

Table 4.51 Major hindrances that influence the use of the SAPWAT3 research and decision-making.

Hindrance	True (%)
Lack of available time	32
Inadequate knowledge of soil-plant-atmosphere continuum	26
Poor water administration and communication to farmers	24
Other	18
Lack of computer skills and knowledge	12
Lack of skills and knowledge to interact with electronic mail system	9

Table 4.51 shows that lack of available time is the biggest hindrance to learning to use SAPWAT3 for research and decision-making, although only 32% of respondents indicated it.

Table 4.52 Other hindrances mentioned

Hindrance	%
Not indicated	82
Software not very user-friendly and too much stuff for my requirement. Bring back the old SAP-WAT please	6
Bugs in earlier version of software	3
Decision-making implementation by farmers	3
Software is too complex	3
Too little "road-shows"	3

Under “Other” in Table 4.51, some other hindrances were identified by the respondents. These are shown in Table 4.52, all are of low frequency and should not negatively influence the use of SAPWAT3 amongst the potential users.

4.6.6.1 Characterising SAPWAT3 support

Analysing the responses of SAPWAT3 users as depicted in Table 4.44 to Table 4.52, the following characteristics come to the surface.

SAPWAT3 users prefer back-up support by the research team (38%). Following this, are web-linked (35%) and e-mail/ SMS (35%) support systems. They definitely prefer e-mail above SMS, because website / e-mail systems are more manageable, responses can be saved, and there is easy access to computers and internet.

The occupational groups differ in their feeling towards meeting members of the research team. Scheduling services, system designers and planners, as well as CMA/WUA managers are more in favour, whilst Water Act administrators are the least in favour of meeting members of the research team. Fifty-nine percent (59%) of respondents are satisfied with the present communication and support by the research team while 4% are dissatisfied.

Further analyses of SAPWAT3 user responses show that their satisfaction level with support and communication from extension staff and specialists vary from complete dissatisfaction to complete satisfaction. Their perception on this aspect is probably related to the knowledge and experience of the extension staff they meet in the course of working on their tasks. An interesting finding is that 34% of the respondents are satisfied and 16% are dissatisfied with back-up and support by the dealer. This question might have been misread in relation to SAPWAT3, as the "dealer" in this case is the Water Research Commission, which distributes the SAPWAT3 report and program as one of its products.

SAPWAT3 users see lack of available time as the biggest barrier to learning to use the program or, alternatively, to use the program as an analysing tool.

CHAPTER 5
CONCLUSION

This project adds to the value of SAPWAT3 and is also an indicator that as long as a usable computer program is available, there remains a need to support its users and to continuously adapt or upgrade the program as requested by the users or as specific needs therefore are identified. In the case of SAPWAT3, upgrading and/or adaptation can be done, as long as it remains compatible with the original aim of giving the user a planning tool for use when estimating irrigation water use.

The main objectives of this project were to verify program outputs, to demonstrate SAPWAT3 and its use to potential users and to determine the adoption potential of SAPWAT3. In this process, the characteristics of SAPWAT which led to its large scale adoption, was also researched.

A request from outside to upgrade SAPWAT3 to be able to manage the importation of large numbers of data and to do an irrigation water estimate for each of the crops in the group imported without user intervention has also been concluded. The WRC, as copyright holder, needs to be informed of all changes made to SAPWAT3, and the inclusion of a description of that module in this report is the result. This module is included in the new version of SAPWAT3 that will appear shortly.

For the estimation of irrigation requirements with a program such as SAPWAT3 that is not a crop growth model, but a model that imitates crop growth and development on a fairly simple basis, it is necessary that crop growth and development be described as accurately as possible. The one input that remains fairly rough and ready, is the description of crop growth and development through the four stage FAO crop growth curve and its related crop coefficients. The determination of accurate crop coefficients usually entails the use of lysimeters for repetitive runs, a process that takes time and is usually costly. Developments in the use of scintillometers for deducing evapotranspiration by measurement of aerodynamic fluxes above a crop, or the use of remote sensing techniques, such as the SEBAL approach, could reduce the cost of such determinations. The result of the high cost of as well as the time required to accurately measure water use, is that crops with a high economic value or crops that are a major component of the production pattern of a country are the crops that are usually researched in this way, while other crops are usually ignored. The introduction of measurement probes with which the soil water content can be measured fairly easily and at relatively low cost over the last number of years have changed this situation. It is now possible to determine, at relatively low cost, crop water extraction out of the soil profile on a daily, or even shorter, period and by accurate record keeping of water added to the soil and water extraction through evapotranspiration, daily crop water use can be determined. The next version of SAPWAT3 will contain the module described in this report which will enable researchers to improve the accuracy of the FAO four stage crop growth periods and the related crop coefficients.

SAPWAT is used by a variety of professional groups, mostly used for designing and planning of irrigation systems, and to a lesser extent for planning and management of irrigation water reticulation systems. It is mostly used on a monthly basis, which is in line with the expected use of such a tool. New planning does not necessarily happen every day. Reasons for its popularity are mainly its ease of use, the quick results and good crop irrigation requirement output, its user-friendliness, the credibility of its results, as well as the fact that it is scientifically based.

Evaluating SAPWAT against the characteristics that make an innovation acceptable, SAPWAT scored much better than average in the fields of relative advantage, observability and compatibility and better than average on complexity and trialability. Comparing this to the TAM approach, there was a marked better than average score for usefulness and a better than average score for ease of use, which is an accurate reflection of the results of the Rogers scores. This implied that the TAM-approach could be used for predicting the acceptability of SAPWAT3, although lack of experience or relatively little use could reduce the value of such a test.

The acceptability of SAPWAT3 was tested after about three months use. Interesting results were found, although the average TAM-score at that stage was average in overall acceptability.

SAPWAT3 is used by most of the more experienced and higher trained people that have to do with irrigation water planning, management and use. Of these users, the designers and planners of irrigation systems are the biggest group. Most of the SAPWAT3 users are furthermore people who have had previously experience with similar models.

Slightly more than half of the respondents are of opinion that the Water Act imposes necessary regulations to irrigation water users, even though there is no clear opinion on whether or not irrigation scheduling could be effectively applied only if farmers have full control of the water supply.

Most agree that methods and tools such as SAPWAT3 are developed for use by irrigation advisors and researchers. Most are also of opinion that variability in rainfall and weather is not too complex to be accommodated in the irrigation scheduling tools and programs.

Most SAPWAT3 users are familiar with research done by the WRC and are also users of the knowledge generated. The generated knowledge is mostly used for planning and designing of systems, research and for irrigation water management.

Initially SAPWAT and now SAPWAT3 were designed and built with the designers and planners of irrigation systems and water use in mind as potential main users. The original SAPWAT was built as simply as possible with the aim of involving all sectors of the irrigation fraternity as well as all levels of training in its use. SAPWAT3 has more functionality and is therefore less simple to use than SAPWAT, but this was not aimed at reducing the spectrum or scope of usage, it was rather aimed at giving users more flexibility of application.

SAPWAT3 is designed as a planning tool, and the expected major users should be irrigation water use planners, irrigation water use managers as well as designers of irrigation systems. This found to be so, with system designers and planners, scheduling services as well as agricultural economists being the major users, although farmers and administrators of the Water Act were found to use SAPWAT3 less than expected.

Experience have been that farmers who use SAPWAT3, use it once every number of years when they replan their cropping pattern to determine how much irrigation water they would require. Once the new cropping pattern is in place SAPWAT3 is not used again until the next replanning. This could explain the low level of SAPWAT3 use by farmers.

The low level of use by Water Act administrators is disappointing seen in the light that the Department of Water Affairs has decided that the validity of irrigation water application for registration and licensing should be evaluated against SAPWAT output. However, what has been experienced is that regional offices of the Department of Water Affairs have used runs of SAPWAT to determine guideline irrigation requirement values, which are then used to compare irrigation requirement applications against, instead of doing new irrigation requirement planning runs on SAPWAT3 for each application.

The credibility of SAPWAT3 output is relatively high, where all groups except consultants, indicated an above average credibility.

Over all sectors that use SAPWAT3, its use for assessing water resource demand and supply has come out as the most important application. The agricultural economists tend to be more interested in irrigation water use planning and management, including the design and evaluation of irrigation systems.

WUA managers tend to concentrate on water resource assessment and demand management, but are generally below average about using SAPWAT3 for on-farm irrigation management strategies. They do not see the use of SAPWAT3 as a tool that could increase productivity. The consultants use SAPWAT3 more for the on-farm part of irrigation planning and management as well as for larger scale water resource demand and supply assessment.

The best use of SAPWAT3 by farmers is to be able to make better informed decisions about irrigation water management. Lecturers use SAPWAT well on a very wide scope of application, where-as scheduling services tend to concentrate on the on-farm water management part. Designers and planners concentrate on the on-farm irrigation requirement planning and management, and they also see the use of SAPWAT3 as leading to increased productivity. Water Act administrators use SAPWAT3 below average for just about any application possible.

In the design of SAPWAT3 the same approach was used as in SAPWAT, which is to make the program as easy to work with as is possible. However, the added functionality of SAPWAT3 does complicate matters somewhat. The perception on ease of use was tested per questionnaire. This included, amongst others, questions on the ease of use, ease of understanding the research report, easy to learn, flexibility.

The importance of a user manual (the SAPWAT3 report is also a user manual) is regarded as high, and though the flexibility of SAPWAT3 was highly acclaimed by just about all groups, a disappointing number of user groups have actually indicated that SAPWAT3 is difficult to use and that the research report itself, which doubles as a user manual was not that easy to read and understand. WUA managers and designers and planners gave SAPWAT3 the highest points for ease of use, while administrators, consultants and farmers found SAPWAT3 fairly difficult to use. Agricultural economists, WUA managers, lecturers, scheduling services, designers and planners and administrators indicated that SAPWAT3 is easy to learn, does enhance skills and knowledge of irrigation management, is flexible and saves time. Agricultural economists, WUA managers, lecturers and scheduling services tended to judge SAPWAT3 as easy to learn and that the research report is easy to understand.

SAPWAT3 users prefer back-up support by the research team. Following this, are web-linked and e-mail / SMS support systems. They definitely prefer e-mail above SMS, because website / e-mail systems are more manageable, responses can be saved, and there is easy access to computers and internet.

The occupational groups differ in their feeling towards meeting members of the research team. Scheduling services, system designers and planners, as well as CMA/WUA managers are more in favour, whilst Water Act administrators are the least in favour of meeting members of the research team. Fifty-nine percent of respondents are satisfied with the present communication and support by the research team.

Further analyses of SAPWAT3 user responses show that their satisfaction level with support and communication from extension staff and specialists vary from complete dissatisfaction to complete satisfaction. Their perception on this aspect is probably related to the knowledge and experience of the extension staff they meet in the course of working on their tasks.

SAPWAT3 users see lack of available time as the biggest barrier to learning to use the program or, alternatively, to use the program as an analysing tool.

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APPENDIX A
LIST OF CROPS, CROP-OPTIONS AND PLANTING DATES

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
73	Almonds	212	Standard, bare ground, frost	1	9
73	Almonds	359	High latitudes, bare ground, heavy frost	1	9
73	Almonds	360	Low latitudes, bare ground, light frost	1	9
74	Apples	215	Bud break: Late winter	15	8
74	Apples	216	Bud break: Early spring	1	9
74	Apples	361	Low latitudes, bare ground, light frost	1	9
74	Apples	363	High latitudes, bare ground, heavy frost	1	9
74	Apples	383	Bud break: Mid spring	21	9
75	Apricot	218	Bud break: Late winter	15	8
75	Apricot	220	Bud break: Early spring	1	9
75	Apricot	364	Low latitudes, bare ground, light frost	15	8
56	Artichokes	125	Globe	15	5
56	Artichokes	126	Jerusalem	15	8
56	Artichokes	126	Jerusalem	15	9
56	Artichokes	126	Jerusalem	15	10
72	Asparagus	211	Warm winter	15	8
72	Asparagus	365	Mediterranean	1	11
1	Avocado	33	Estimate cover	1	7
109	A_Grass_Reference	374	Reference crop	1	1
2	Babala	338	Standard	15	10
2	Babala	338	Standard	15	11
2	Babala	338	Standard	15	12
3	Bananas	68	First year	1	9
3	Bananas	69	Ratoon	1	8
77	Barley	283	Spring types	15	5
77	Barley	283	Spring types	5	6

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
77	Barley	283	Spring types	15	6
77	Barley	283	Spring types	25	6
77	Barley	283	Spring types	5	7
77	Barley	283	Spring types	15	7
5	Beans	109	Dry, long growers	15	1
5	Beans	109	Dry, long growers	15	11
5	Beans	109	Dry, long growers	15	12
5	Beans	110	Dry, medium growers	15	1
5	Beans	110	Dry, medium growers	15	12
5	Beans	110	Dry, medium growers	15	8
5	Beans	111	Dry, short growers	15	1
5	Beans	111	Dry, short growers	15	12
5	Beans	112	Green	15	1
5	Beans	112	Green	15	2
5	Beans	112	Green	15	3
5	Beans	112	Green	15	4
5	Beans	112	Green	15	5
5	Beans	112	Green	15	6
5	Beans	112	Green	15	7
5	Beans	112	Green	15	8
5	Beans	112	Green	15	9
5	Beans	112	Green	15	10
5	Beans	112	Green	15	11
5	Beans	112	Green	15	12
5	Beans	298	Runner	15	1
5	Beans	298	Runner	15	2
5	Beans	298	Runner	15	3
5	Beans	298	Runner	15	4
5	Beans	298	Runner	15	5
5	Beans	298	Runner	15	6

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
5	Beans	298	Runner	15	7
5	Beans	298	Runner	15	8
5	Beans	298	Runner	15	9
5	Beans	298	Runner	15	10
5	Beans	298	Runner	15	11
5	Beans	298	Runner	15	12
6	Beetroot	144	Standard	15	1
6	Beetroot	144	Standard	15	7
6	Beetroot	144	Standard	15	8
6	Beetroot	144	Standard	15	9
6	Beetroot	144	Standard	15	10
6	Beetroot	144	Standard	15	11
6	Beetroot	144	Standard	15	12
6	Beetroot	144	Standard	15	2
6	Beetroot	144	Standard	15	3
6	Beetroot	144	Standard	15	4
6	Beetroot	144	Standard	15	5
6	Beetroot	144	Standard	15	6
78	Berries	223	Standard	1	5
7	Brinjals	199	Standard	15	1
7	Brinjals	199	Standard	15	9
7	Brinjals	199	Standard	15	10
7	Brinjals	199	Standard	15	11
7	Brinjals	199	Standard	15	12
8	Broccoli	225	Early varieties	15	3
8	Broccoli	225	Early varieties	15	4
8	Broccoli	225	Early varieties	15	5
8	Broccoli	225	Early varieties	15	9
8	Broccoli	225	Early varieties	15	10
8	Broccoli	225	Early varieties	15	1

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
8	Broccoli	225	Early varieties	15	2
8	Broccoli	225	Early varieties	15	6
8	Broccoli	225	Early varieties	15	7
8	Broccoli	225	Early varieties	15	8
8	Broccoli	233	Main crop	15	3
8	Broccoli	233	Main crop	15	4
8	Broccoli	233	Main crop	15	5
8	Broccoli	233	Main crop	15	9
8	Broccoli	233	Main crop	15	10
8	Broccoli	233	Main crop	15	11
8	Broccoli	233	Main crop	15	1
8	Broccoli	233	Main crop	15	2
8	Broccoli	233	Main crop	15	12
8	Broccoli	233	Main crop	15	6
8	Broccoli	233	Main crop	15	7
8	Broccoli	233	Main crop	15	8
79	Brussels sprouts	224	Standard	15	2
79	Brussels sprouts	224	Standard	15	3
79	Brussels sprouts	224	Standard	15	4
79	Brussels sprouts	224	Standard	15	5
79	Brussels sprouts	224	Standard	15	6
79	Brussels sprouts	224	Standard	15	7
79	Brussels sprouts	224	Standard	15	8
79	Brussels sprouts	224	Standard	15	9
79	Brussels sprouts	224	Standard	15	10
10	Butternut squash	34	Standard	15	3
10	Butternut squash	34	Standard	15	4
10	Butternut squash	34	Standard	15	5
10	Butternut squash	34	Standard	15	9
10	Butternut squash	34	Standard	15	10

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
10	Butternut squash	34	Standard	15	11
10	Butternut squash	34	Standard	15	1
10	Butternut squash	34	Standard	15	2
10	Butternut squash	34	Standard	15	12
10	Butternut squash	34	Standard	15	6
10	Butternut squash	34	Standard	15	7
10	Butternut squash	34	Standard	15	8
9	Cabbage	247	Early varieties	15	3
9	Cabbage	247	Early varieties	15	4
9	Cabbage	247	Early varieties	15	5
9	Cabbage	247	Early varieties	15	9
9	Cabbage	247	Early varieties	15	10
9	Cabbage	247	Early varieties	15	11
9	Cabbage	247	Early varieties	15	1
9	Cabbage	247	Early varieties	15	2
9	Cabbage	247	Early varieties	15	12
9	Cabbage	247	Early varieties	15	6
9	Cabbage	247	Early varieties	15	7
9	Cabbage	247	Early varieties	15	8
9	Cabbage	251	Main crop	15	3
9	Cabbage	251	Main crop	15	4
9	Cabbage	251	Main crop	15	5
9	Cabbage	251	Main crop	15	9
9	Cabbage	251	Main crop	15	10
9	Cabbage	251	Main crop	15	11
9	Cabbage	251	Main crop	15	1
9	Cabbage	251	Main crop	15	2
9	Cabbage	251	Main crop	15	12
9	Cabbage	251	Main crop	15	6
9	Cabbage	251	Main crop	15	7

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
9	Cabbage	251	Main crop	15	8
11	Canola	38	Standard	15	6
11	Canola	38	Standard	15	7
11	Canola	38	Standard	15	8
12	Carrots	39	Standard	15	3
12	Carrots	39	Standard	15	4
12	Carrots	39	Standard	15	5
12	Carrots	39	Standard	15	9
12	Carrots	39	Standard	15	10
12	Carrots	39	Standard	15	11
12	Carrots	39	Standard	15	1
12	Carrots	39	Standard	15	2
12	Carrots	39	Standard	15	12
12	Carrots	39	Standard	15	6
12	Carrots	39	Standard	15	7
12	Carrots	39	Standard	15	8
110	Cassava	375	Standard	1	7
13	Cauliflower	43	Early varieties	15	3
13	Cauliflower	43	Early varieties	15	4
13	Cauliflower	43	Early varieties	15	5
13	Cauliflower	43	Early varieties	15	9
13	Cauliflower	43	Early varieties	15	10
13	Cauliflower	43	Early varieties	15	11
13	Cauliflower	43	Early varieties	15	1
13	Cauliflower	43	Early varieties	15	2
13	Cauliflower	43	Early varieties	15	12
13	Cauliflower	43	Early varieties	15	6
13	Cauliflower	43	Early varieties	15	7
13	Cauliflower	43	Early varieties	15	8
13	Cauliflower	47	Main crop	15	3

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
13	Cauliflower	47	Main crop	15	4
13	Cauliflower	47	Main crop	15	5
13	Cauliflower	47	Main crop	15	9
13	Cauliflower	47	Main crop	15	10
13	Cauliflower	47	Main crop	15	11
13	Cauliflower	47	Main crop	15	1
13	Cauliflower	47	Main crop	15	2
13	Cauliflower	47	Main crop	15	12
13	Cauliflower	47	Main crop	15	6
13	Cauliflower	47	Main crop	15	7
13	Cauliflower	47	Main crop	15	8
80	Celery	237	Standard	15	2
80	Celery	237	Standard	15	3
80	Celery	237	Standard	15	4
80	Celery	237	Standard	15	5
80	Celery	237	Standard	15	8
80	Celery	237	Standard	15	9
82	Cherries	240	High latitudes, bare ground, heavy frost	1	9
82	Cherries	366	Low latitudes, bare ground, light frost	1	9
14	Chicory	322	Standard	15	3
14	Chicory	322	Standard	15	4
14	Chicory	322	Standard	15	9
14	Chicory	322	Standard	15	10
14	Chicory	322	Standard	15	11
15	Chillies	299	Standard	15	3
15	Chillies	299	Standard	15	4
15	Chillies	299	Standard	15	5
15	Chillies	299	Standard	15	6
15	Chillies	299	Standard	15	7
15	Chillies	299	Standard	15	8

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
15	Chillies	299	Standard	15	9
15	Chillies	299	Standard	15	10
15	Chillies	299	Standard	15	11
15	Chillies	299	Standard	15	1
15	Chillies	299	Standard	15	2
15	Chillies	299	Standard	15	12
16	Citrus	53	No ground cover	1	6
16	Citrus	54	Active ground cover or weeds	1	6
17	Coffee	56	Standard	1	4
83	Coriander	241	Standard	15	7
83	Coriander	241	Standard	15	8
83	Coriander	241	Standard	15	9
83	Coriander	241	Standard	15	10
18	Cotton	328	Short growers	15	9
18	Cotton	328	Short growers	15	10
18	Cotton	328	Short growers	15	11
18	Cotton	329	Medium growers	15	9
18	Cotton	329	Medium growers	15	10
18	Cotton	329	Medium growers	15	11
18	Cotton	330	Long growers	15	9
18	Cotton	330	Long growers	15	10
19	Cow peas	331	Standard	15	10
19	Cow peas	331	Standard	15	11
19	Cow peas	331	Standard	15	12
20	Cucumber	58	Standard	15	1
20	Cucumber	58	Standard	15	2
20	Cucumber	58	Standard	15	3
20	Cucumber	58	Standard	15	4
20	Cucumber	58	Standard	15	5
20	Cucumber	58	Standard	15	6

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
20	Cucumber	58	Standard	15	7
20	Cucumber	58	Standard	15	8
20	Cucumber	58	Standard	15	9
20	Cucumber	58	Standard	15	10
20	Cucumber	58	Standard	15	11
20	Cucumber	58	Standard	15	12
21	Cucurbits	59	Medium growers	15	3
21	Cucurbits	59	Medium growers	15	4
21	Cucurbits	59	Medium growers	15	5
21	Cucurbits	59	Medium growers	15	9
21	Cucurbits	59	Medium growers	15	10
21	Cucurbits	59	Medium growers	15	11
21	Cucurbits	59	Medium growers	15	1
21	Cucurbits	59	Medium growers	15	2
21	Cucurbits	59	Medium growers	15	12
21	Cucurbits	59	Medium growers	15	7
21	Cucurbits	59	Medium growers	15	8
21	Cucurbits	355	Short growers	15	1
21	Cucurbits	355	Short growers	15	2
21	Cucurbits	355	Short growers	15	3
21	Cucurbits	355	Short growers	15	4
21	Cucurbits	355	Short growers	15	5
21	Cucurbits	355	Short growers	15	6
21	Cucurbits	355	Short growers	15	7
21	Cucurbits	355	Short growers	15	8
21	Cucurbits	355	Short growers	15	9
21	Cucurbits	355	Short growers	15	10
21	Cucurbits	355	Short growers	15	11
21	Cucurbits	355	Short growers	15	12
22	Cut flowers	63	Standard	1	6

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
84	Date palm	242	Standard	1	6
111	Fig	376	Standard	1	10
23	Forage	64	Short variety	15	10
23	Forage	64	Short variety	15	11
23	Forage	64	Short variety	15	12
24	Garlic	303	Seeded	15	2
24	Garlic	303	Seeded	15	3
24	Garlic	303	Seeded	15	4
24	Garlic	304	Short day: X-Short: Autumn transplant	15	5
24	Garlic	305	Transplant spring	15	8
112	Ginger	377	Standard	1	8
25	Gourds	306	Standard	15	9
25	Gourds	306	Standard	15	10
25	Gourds	306	Standard	15	11
25	Gourds	306	Standard	15	1
25	Gourds	306	Standard	15	2
25	Gourds	306	Standard	15	12
69	Grapes	193	Table; Bud break: Late winter	15	8
69	Grapes	194	Table; Bud break: Mid spring	21	9
69	Grapes	195	Table; Bud break: Early spring	1	9
69	Grapes	196	Wine; Bud break: Late winter	1	9
69	Grapes	197	Wine; Bud break: Mid spring	21	9
69	Grapes	198	Wine; Bud break: Early spring	1	9
27	Grenadella	66	Standard	1	6
28	Groundnuts	67	Standard	15	9
28	Groundnuts	67	Standard	15	10
28	Groundnuts	67	Standard	15	11
28	Groundnuts	67	Standard	15	12
86	Guava	244	Standard	1	5
107	Herbs	353	Perennial shrubs	1	6

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
29	Hubbard squash	308	Standard	15	3
29	Hubbard squash	308	Standard	15	9
29	Hubbard squash	308	Standard	15	10
29	Hubbard squash	308	Standard	15	11
29	Hubbard squash	308	Standard	15	1
29	Hubbard squash	308	Standard	15	2
29	Hubbard squash	308	Standard	15	12
29	Hubbard squash	308	Standard	15	7
29	Hubbard squash	308	Standard	15	8
113	Kiwifruit	378	Standard	15	10
114	Lavender	379	Standard	1	7
30	Leeks	312	Standard	15	9
30	Leeks	312	Standard	15	10
30	Leeks	312	Standard	15	11
31	Lentils	70	Arid region	15	4
31	Lentils	70	Arid region	15	5
31	Lentils	367	Cooler areas	15	10
32	Lettuce	71	Standard	15	7
32	Lettuce	71	Standard	15	8
32	Lettuce	71	Standard	15	9
32	Lettuce	71	Standard	15	10
32	Lettuce	71	Standard	15	11
32	Lettuce	71	Standard	15	12
32	Lettuce	71	Standard	15	1
32	Lettuce	71	Standard	15	2
32	Lettuce	71	Standard	15	3
32	Lettuce	71	Standard	15	4
32	Lettuce	71	Standard	15	5
32	Lettuce	71	Standard	15	6
33	Litchi	73	Standard	1	5

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
76	Lucerne	221	Non-dormant	1	6
76	Lucerne	222	Semi-dormant	1	6
76	Lucerne	332	Seed production	1	6
34	Macadamia	74	Standard	15	5
35	Maize	75	Long growers	15	8
35	Maize	75	Long growers	15	9
35	Maize	75	Long growers	15	10
35	Maize	75	Long growers	15	11
35	Maize	75	Long growers	15	1
35	Maize	75	Long growers	15	12
35	Maize	75	Long growers	15	12
35	Maize	77	Medium growers	15	8
35	Maize	77	Medium growers	15	9
35	Maize	77	Medium growers	15	10
35	Maize	77	Medium growers	15	11
35	Maize	77	Medium growers	15	1
35	Maize	77	Medium growers	15	2
35	Maize	77	Medium growers	15	12
35	Maize	79	Short growers	15	8
35	Maize	79	Short growers	15	9
35	Maize	79	Short growers	15	10
35	Maize	79	Short growers	15	11
35	Maize	79	Short growers	15	1
35	Maize	79	Short growers	15	2
35	Maize	79	Short growers	15	12
35	Maize	326	Ultra-short growers	15	8
35	Maize	326	Ultra-short growers	15	9
35	Maize	326	Ultra-short growers	15	10
35	Maize	326	Ultra-short growers	15	11
35	Maize	326	Ultra-short growers	15	1

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
35	Maize	326	Ultra-short growers	15	2
35	Maize	326	Ultra-short growers	15	12
35	Maize	388	Short growers H/H	15	12
35	Maize	389	Short growers M/H	15	12
35	Maize	390	Short growers H/M	15	12
35	Maize	391	Short growers M/L	15	12
36	Mango	81	Standard	1	5
37	Mealies (Corn-on-the-cob)	82	Standard	15	1
37	Mealies (Corn-on-the-cob)	82	Standard	15	2
37	Mealies (Corn-on-the-cob)	82	Standard	15	3
37	Mealies (Corn-on-the-cob)	82	Standard	15	4
37	Mealies (Corn-on-the-cob)	82	Standard	15	5
37	Mealies (Corn-on-the-cob)	82	Standard	15	8
37	Mealies (Corn-on-the-cob)	82	Standard	15	9
37	Mealies (Corn-on-the-cob)	82	Standard	15	10
37	Mealies (Corn-on-the-cob)	82	Standard	15	11
37	Mealies (Corn-on-the-cob)	82	Standard	15	12
58	Melon	130	Early varieties	15	3
58	Melon	130	Early varieties	15	4
58	Melon	130	Early varieties	15	9
58	Melon	130	Early varieties	15	10
58	Melon	130	Early varieties	15	11
58	Melon	130	Early varieties	15	1
58	Melon	130	Early varieties	15	2
58	Melon	130	Early varieties	15	12
58	Melon	130	Early varieties	15	7
58	Melon	130	Early varieties	15	8
58	Melon	134	Main crop	15	7
58	Melon	134	Main crop	15	8
58	Melon	134	Main crop	15	9

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
58	Melon	134	Main crop	15	10
58	Melon	134	Main crop	15	11
58	Melon	134	Main crop	15	1
58	Melon	134	Main crop	15	2
58	Melon	134	Main crop	15	12
58	Melon	134	Main crop	15	7
58	Melon	134	Main crop	15	8
38	Nectarine	83	Bud break: Late winter	15	8
38	Nectarine	84	Bud break: Mid spring	21	9
38	Nectarine	85	Bud break: Early spring	1	9
39	Oats	289	Spring types	15	5
39	Oats	289	Spring types	25	5
39	Oats	289	Spring types	5	6
39	Oats	289	Spring types	15	6
39	Oats	289	Spring types	25	6
87	Olive	245	Standard	1	9
40	Onion	86	Onion. Medium long day. Cold winter	15	5
40	Onion	88	Green onion. Short day	15	5
40	Onion	368	Onion. Short day	15	5
40	Onion	369	Onion. Long day	15	8
40	Onion	370	Onion. Seed	15	4
40	Onion	371	Medium day	15	5
89	Papaya	246	Standard	1	5
42	Paprika	92	Standard	15	3
42	Paprika	92	Standard	15	4
42	Paprika	92	Standard	15	5
42	Paprika	92	Standard	15	9
42	Paprika	92	Standard	15	10
42	Paprika	92	Standard	15	11
42	Paprika	92	Standard	15	1

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
42	Paprika	92	Standard	15	2
42	Paprika	92	Standard	15	12
42	Paprika	92	Standard	15	6
42	Paprika	92	Standard	15	7
42	Paprika	92	Standard	15	8
43	Parsley	96	Standard	15	9
43	Parsley	96	Standard	15	10
104	Pastures: perennial	243	Fescue	1	6
104	Pastures: perennial	347	Kikuyu	1	7
104	Pastures: perennial	348	Kikuyu-Ryegrass mix	1	7
44	Pastures: seasonal	256	Ryegrass	15	3
44	Pastures: seasonal	270	Winter cereals	15	3
44	Pastures: seasonal	270	Winter cereals	15	5
44	Pastures: seasonal	270	Winter cereals	15	7
44	Pastures: seasonal	335	Sorghum x Sudangrass	15	10
44	Pastures: seasonal	335	Sorghum x Sudangrass	15	11
47	Peaches	101	Bud break: Mid spring	21	9
47	Peaches	103	Bud break: Early spring	1	9
47	Peaches	104	Bud break: Late winter	15	8
48	Pears	105	Bud break: Mid spring	21	9
48	Pears	106	Bud break: Early spring	1	9
48	Pears	107	Bud break: Late winter	15	8
49	Peas	108	Standard	15	3
49	Peas	108	Standard	15	4
50	Pecan	114	Standard	1	9
26	Peppers	316	Standard	15	3
26	Peppers	316	Standard	15	4
26	Peppers	316	Standard	15	5
26	Peppers	316	Standard	15	9
26	Peppers	316	Standard	15	10

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
26	Peppers	316	Standard	15	11
26	Peppers	316	Standard	15	1
26	Peppers	316	Standard	15	2
26	Peppers	316	Standard	15	12
26	Peppers	316	Standard	15	6
26	Peppers	316	Standard	15	7
26	Peppers	316	Standard	15	8
116	Pineapple	381	Standard	1	6
90	Pistachio	255	Standard	1	9
117	Pomegranate	382	Esrly and late cultivars	1	10
52	Potatoes	266	Medium variety	15	3
52	Potatoes	266	Medium variety	15	4
52	Potatoes	266	Medium variety	15	5
52	Potatoes	266	Medium variety	15	6
52	Potatoes	266	Medium variety	15	8
52	Potatoes	266	Medium variety	15	9
52	Potatoes	266	Medium variety	15	10
52	Potatoes	266	Medium variety	15	2
52	Potatoes	266	Medium variety	15	7
52	Potatoes	266	Medium variety	15	1
52	Potatoes	266	Medium variety	15	11
52	Potatoes	266	Medium variety	15	12
52	Potatoes	349	Short variety	15	1
52	Potatoes	349	Short variety	15	2
52	Potatoes	349	Short variety	15	11
52	Potatoes	349	Short variety	15	3
52	Potatoes	349	Short variety	15	4
52	Potatoes	349	Short variety	15	5
52	Potatoes	349	Short variety	15	6
52	Potatoes	349	Short variety	15	8

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
52	Potatoes	349	Short variety	15	9
52	Potatoes	349	Short variety	15	10
52	Potatoes	349	Short variety	15	12
51	Prunes	115	Bud break: Late winter	15	8
51	Prunes	116	Bud break: Mid Spring	21	9
51	Prunes	117	Bud break: Early spring	1	9
53	Pumpkin	119	Standard	15	3
53	Pumpkin	119	Standard	15	9
53	Pumpkin	119	Standard	15	10
53	Pumpkin	119	Standard	15	11
53	Pumpkin	119	Standard	15	1
53	Pumpkin	119	Standard	15	2
53	Pumpkin	119	Standard	15	12
53	Pumpkin	119	Standard	15	7
53	Pumpkin	119	Standard	15	8
115	Quince	380	Standard	1	10
54	Radishes	123	Standard	15	1
54	Radishes	123	Standard	15	2
54	Radishes	123	Standard	15	3
54	Radishes	123	Standard	15	4
54	Radishes	123	Standard	15	8
54	Radishes	123	Standard	15	9
54	Radishes	123	Standard	15	10
54	Radishes	123	Standard	15	11
54	Radishes	123	Standard	15	12
103	Rice	344	Non-paddy, short growing varieties	15	3
103	Rice	344	Non-paddy, short growing varieties	15	4
103	Rice	345	Non-paddy, long growing varieties	15	3
103	Rice	345	Non-paddy, long growing varieties	15	4
103	Rice	387	Paddy (Lowland)	1	5

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
97	Rye	261	Spring types	5	7
97	Rye	261	Spring types	15	7
97	Rye	261	Spring types	25	7
97	Rye	261	Spring types	5	8
97	Rye	261	Spring types	25	5
97	Rye	261	Spring types	5	6
97	Rye	261	Spring types	15	6
97	Rye	261	Spring types	25	6
55	Saltbush	124	Atriplex	1	6
93	Sorghum	336	Silage	15	10
93	Sorghum	336	Silage	15	11
93	Sorghum	337	Grain	15	10
93	Sorghum	337	Grain	15	11
57	Soybeans	127	Long	15	9
57	Soybeans	127	Long	15	10
57	Soybeans	127	Long	15	11
57	Soybeans	128	Medium	15	10
57	Soybeans	128	Medium	15	11
57	Soybeans	128	Medium	15	12
57	Soybeans	129	Short	15	11
57	Soybeans	129	Short	15	12
59	Spinach	143	Standard	15	1
59	Spinach	143	Standard	15	2
59	Spinach	143	Standard	15	3
59	Spinach	143	Standard	15	4
59	Spinach	143	Standard	15	5
59	Spinach	143	Standard	15	6
59	Spinach	143	Standard	15	7
59	Spinach	143	Standard	15	8
59	Spinach	143	Standard	15	9

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
59	Spinach	143	Standard	15	10
59	Spinach	143	Standard	15	11
59	Spinach	143	Standard	15	12
41	Spineless cactus	91	Spineless cactus	1	5
60	Squash	146	Baby	15	3
60	Squash	146	Baby	15	4
60	Squash	146	Baby	15	5
60	Squash	146	Baby	15	9
60	Squash	146	Baby	15	10
60	Squash	146	Baby	15	11
60	Squash	146	Baby	15	1
60	Squash	146	Baby	15	2
60	Squash	146	Baby	15	12
60	Squash	146	Baby	15	6
60	Squash	146	Baby	15	7
60	Squash	146	Baby	15	8
60	Squash	150	Bush & vine	15	1
60	Squash	150	Bush & vine	15	2
60	Squash	150	Bush & vine	15	3
60	Squash	150	Bush & vine	15	4
60	Squash	150	Bush & vine	15	5
60	Squash	150	Bush & vine	15	6
60	Squash	150	Bush & vine	15	7
60	Squash	150	Bush & vine	15	8
60	Squash	150	Bush & vine	15	9
60	Squash	150	Bush & vine	15	10
60	Squash	150	Bush & vine	15	11
60	Squash	150	Bush & vine	15	12
94	Strawberry	258	Standard	15	3
94	Strawberry	258	Standard	15	4

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
62	Sugar-beet	160	Standard	15	8
62	Sugar-beet	160	Standard	15	9
62	Sugar-beet	160	Standard	15	10
61	Sugarcane	340	Start date	15	5
61	Sugarcane	340	Start date	15	7
61	Sugarcane	340	Start date	15	10
61	Sugarcane	340	Start date	15	12
63	Sunflower	161	Standard	15	1
63	Sunflower	161	Standard	15	10
63	Sunflower	161	Standard	15	11
63	Sunflower	161	Standard	15	12
46	Sweet potato	100	Standard	15	1
46	Sweet potato	100	Standard	15	2
46	Sweet potato	100	Standard	15	3
46	Sweet potato	100	Standard	15	4
46	Sweet potato	100	Standard	15	5
46	Sweet potato	100	Standard	15	9
46	Sweet potato	100	Standard	15	10
46	Sweet potato	100	Standard	15	11
46	Sweet potato	100	Standard	15	12
64	Sweetcorn	162	Early varieties	15	11
64	Sweetcorn	162	Early varieties	15	9
64	Sweetcorn	162	Early varieties	15	10
64	Sweetcorn	162	Early varieties	15	1
64	Sweetcorn	162	Early varieties	15	2
64	Sweetcorn	162	Early varieties	15	12
64	Sweetcorn	162	Early varieties	15	6
64	Sweetcorn	162	Early varieties	15	7
64	Sweetcorn	162	Early varieties	15	8
64	Sweetcorn	166	Main crop	15	3

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
64	Sweetcorn	166	Main crop	15	4
64	Sweetcorn	166	Main crop	15	5
64	Sweetcorn	166	Main crop	15	9
64	Sweetcorn	166	Main crop	15	10
64	Sweetcorn	166	Main crop	15	11
64	Sweetcorn	166	Main crop	15	1
64	Sweetcorn	166	Main crop	15	2
64	Sweetcorn	166	Main crop	15	12
64	Sweetcorn	166	Main crop	15	6
64	Sweetcorn	166	Main crop	15	7
64	Sweetcorn	166	Main crop	15	8
95	Swiss chard	259	Standard	15	2
95	Swiss chard	259	Standard	15	3
95	Swiss chard	259	Standard	15	4
95	Swiss chard	259	Standard	15	5
65	Tea	170	Standard	1	1
66	Tobacco	171	Standard	15	1
66	Tobacco	171	Standard	15	2
66	Tobacco	171	Standard	15	8
66	Tobacco	171	Standard	15	9
66	Tobacco	171	Standard	15	10
66	Tobacco	171	Standard	15	11
66	Tobacco	171	Standard	15	12
67	Tomatoes	172	Canning	15	3
67	Tomatoes	172	Canning	15	4
67	Tomatoes	172	Canning	15	5
67	Tomatoes	172	Canning	15	9
67	Tomatoes	172	Canning	15	10
67	Tomatoes	172	Canning	15	11
67	Tomatoes	172	Canning	15	1

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
67	Tomatoes	172	Canning	15	2
67	Tomatoes	172	Canning	15	12
67	Tomatoes	172	Canning	15	6
67	Tomatoes	172	Canning	15	7
67	Tomatoes	172	Canning	15	8
67	Tomatoes	185	Table	15	3
67	Tomatoes	185	Table	15	4
67	Tomatoes	185	Table	15	5
67	Tomatoes	185	Table	15	6
67	Tomatoes	185	Table	15	7
67	Tomatoes	185	Table	15	8
67	Tomatoes	185	Table	15	1
67	Tomatoes	185	Table	15	2
67	Tomatoes	185	Table	15	9
67	Tomatoes	185	Table	15	10
67	Tomatoes	185	Table	15	11
67	Tomatoes	185	Table	15	12
96	Turnips	260	Standard	15	2
96	Turnips	260	Standard	15	3
96	Turnips	260	Standard	15	4
96	Turnips	260	Standard	15	5
108	Vegetables	372	Summer mix	15	10
108	Vegetables	373	Winter mix	15	3
70	Walnuts	200	Standard	1	10
71	Watermelon	201	Early varieties	15	3
71	Watermelon	201	Early varieties	15	9
71	Watermelon	201	Early varieties	15	10
71	Watermelon	201	Early varieties	15	11
71	Watermelon	201	Early varieties	15	1
71	Watermelon	201	Early varieties	15	2

CropID	Crop	CropOptionID	Cropoption	Plantday	Plantmonth
71	Watermelon	201	Early varieties	15	12
71	Watermelon	201	Early varieties	15	7
71	Watermelon	201	Early varieties	15	8
71	Watermelon	206	Main crop	15	3
71	Watermelon	206	Main crop	15	9
71	Watermelon	206	Main crop	15	10
71	Watermelon	206	Main crop	15	11
71	Watermelon	206	Main crop	15	1
71	Watermelon	206	Main crop	15	2
71	Watermelon	206	Main crop	15	12
71	Watermelon	206	Main crop	15	7
71	Watermelon	206	Main crop	15	8
4	Wheat	274	Spring types	10	2
4	Wheat	274	Spring types	25	5
4	Wheat	274	Spring types	5	6
4	Wheat	274	Spring types	15	6
4	Wheat	274	Spring types	25	6
4	Wheat	274	Spring types	5	7
4	Wheat	274	Spring types	15	7
4	Wheat	274	Spring types	25	7
4	Wheat	274	Spring types	5	8