Water Research Commission

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THE UPGRADING AND UPDATING OF THE SAPWAT PROGRAM AND WEB SITE IN 2003/04

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Acknowledgements

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1 INTRODUCTION

The purpose of this project is:

The improvement of the SAPWAT database, operational and support systems to facilitate improved performance and interaction with other irrigation management and planning programmes and users as well as extending the scope and versatility of the program

With the following specific objectives:

- Linkage to and support of other irrigation management and planning programmes by improving programme file output
- Linkage to and support for irrigation water planning users and advisors, including DWAF
- Editing/Refining crop factors
- Upgrading of SAPWAT software
- Upgrading of the website, maintenance of a user register and the inclusion of additional manuals and "how to do it" user support material
- Provide electronic and telephonic support to users on an ongoing basis

The SAPWAT programme, which was developed and tested with WRC-funding (Crosby & Crosby, 1999; Van Heerden, Crosby & Crosby, 2001) is now generally in use and is also the accepted model for use in the calculation of irrigation requirements for registration and licensing purposes by the Department of Water Affairs and Forestry. However, with the use of the programme some software limitations have come to light, which might hamper interaction with some programmes, such as WAS (Benadé et al., 2002, Benadé, Annandale & van Zijl, 1997) and the open-ended planning model under development by the University of the Free State. These programmes are all part of a family of programmes used in the planning and management of irrigation water. A good interaction through data transfer between these programmes would increase the value of the investment by the WRC.

Crop data files also need to be updated. Since the launch of SAPWAT, new research on water use of some crops included in the database, indicate the need for the updating of the current values.

It is also necessary to keep track of users of SAPWAT for purposes of maintenance and updating of their versions of the programme. Such a register was started, but it needs serious updating and maintenance.

It has become evident that irrigation strategies and management can significantly influence routine crop irrigation requirement estimates. Some rearranging of the on-screen presentation of outputs is desirable.

A need for mainly telephonic and e-mail support has surfaced. Requests for assistance are received regularly.

2 UPGRADING OF THE PROGRAMME SOFTWARE

One of the first tasks undertaken under the contract was to discuss the application of SAP-WAT with users in order to establish the need for improvements and modifications.

One of the conclusions reached was that it is now desirable to provide users with two versions of Sapwat. The first **Sapwat-Admin** is suitable for use by planners and where consistent estimates of crop irrigation requirements are required for administrative purposes. The second is **Sapwat-Management** intended for use by irrigation farmers, agricultural consultants, scheme managers, and designers and, in a supportive role, agricultural researchers. The intention is to make Sapwat-Admin freely available on the WRC web site. Sapwat-Management will be available on a CD on request. Both versions utilise the same basic Sapwat engine and databases. They are both available with the recently introduced internationally classified five climatic regions for South Africa as proposed in this report (Section 3-revision of crop factors). It is assumed, however, that this is an interim arrangement and that finally the five-region version will become standard.

2.1 SAPWAT (IRRIGATION PLANNING AND MANAGEMENT)

Major improvements to the current programme are the simplification of screens and buttons and the elimination of niggling discrepancies. In addition usage and potential usage has lead to the development of a rearrangement in the sequences followed in the programme. The present version follows the precedent set by CROPWAT (Smith, 1992) and advocated by Martin Smith in personal communications that the first estimates of irrigation requirements should be based on crop evapotranspiration and empirical relationships for effective rainfall and efficiency. Initially no account is taken of soils or profile water balances. Experience has shown that the current approach is valid for planning and administrative estimates although over-estimates can be expected where rain is a significant factor.

The SAPWAT role in facilitating irrigation strategies at farm level and interaction between farmer and irrigation designer and equipment supplier as well as scheduling consultant is more valuable than was originally anticipated. The designer must cater for those extreme conditions when drought strikes, farmer customers expect to be able to "keep up". Designers have tended to leave it to the farmer to manage the system when more commonly the conditions are not extreme. Similarly scheduling consultants have the duty of monitoring the profile water situation using established instrumentation and computer routines and may not be able to devote time to "what-iffing". SAPWAT tends to facilitate discussion on ways and means and alternatives by creating a "computer game" situation. One of the more important aspects that benefits from these sessions is the management of rain, soil profile and equipment.

One of the main objectives during the programming updating phase was the consolidation and simplification and that now becomes possible as a result of several years operation and experience. The screens and the accompanying note that follow are intended to illustrate and explain the changes that have been incorporated.

The weather station map now incorporates a window that shows the names of stations selected, as can be seen in Figure 2.1. Shown in Figure 2.2 is the reference evaporation screen, which has been enhanced in that the longitude and latitude of each station is shown.

Figure 2.1 Revised weather station map with selected stations identified by name.

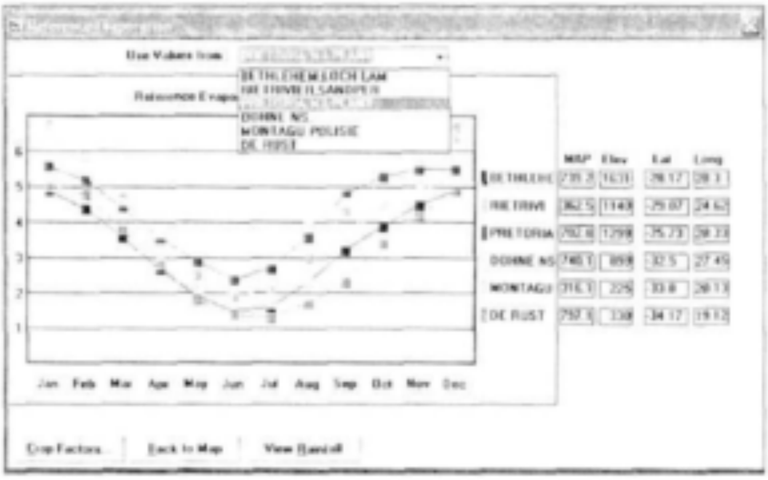


Figure 2.2 Revised reference evapotranspiration screen with site latitude and longitude added

The possibility of undertaking minor modifications to enable Sapwat to be applied anywhere in the world has been investigated. The solution being implemented is to make provision for substituting for the South African weather data files with a Climwat file. These files include latitude and longitude so the stations will be represented on a screen in correct relative positions. Software has been developed to convert the format of the Climwat files to the Sapwat format. As the climatic zones are now in accordance with an accepted international classification this means that users will be able to set up specific "other country" versions of Sapwat. The crop files would require editing to provide for local varieties, planting dates and cultivars.

The Sapwat weather stations are more than adequate for defining reference evapotranspiration (ETo) and crop characteristics applicable over a reasonably large area provided the Sapwat station is representative. This can be assured by taking MAP and altitude into account in addition to geographic location. Rainfall, however, can be more problematic and provision is now being made to provide for this. If the user wishes to use mean annual rainfall either from available records or from SW90 he will have the option of substituting the Sapwat value by entering the mean annual rainfall and the latitude and longitude of the site. This will access the appropriate Quaternary catchment and the related applicable monthly mean rainfall distribution.

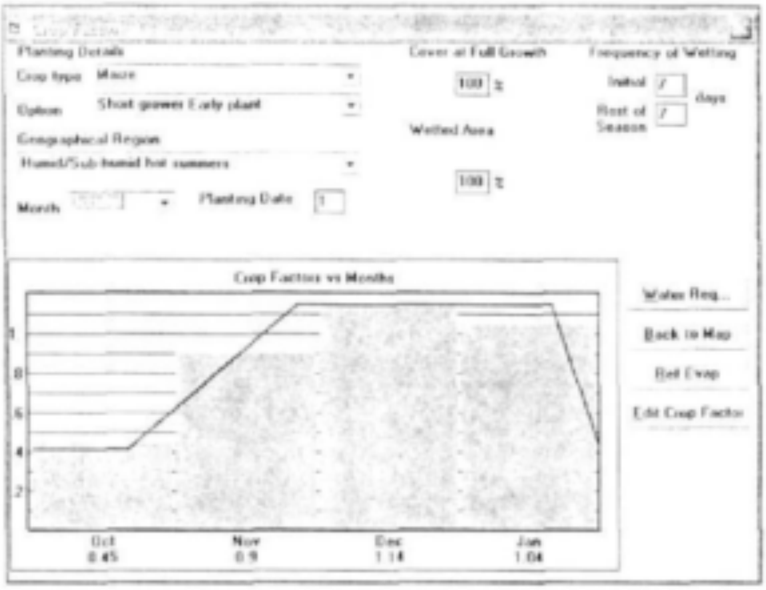


Figure 2.3 Revised crop factor screen.

The crop factor graph (Figure 2.3) remains largely unaltered in format but can now be called up at any time during the simulation process and updates automatically to reflect the impact of any changed input values such as irrigation frequencies, canopy cover and wetted area.

The irrigation requirement screen (Figure 2.4) has been reorganised so that inputs and results follow logically as one looks at the detail of the screen. An "Export data" button is included for exporting data to PLANWAT for further manipulation and for inclusion in reports on irrigation water use registration and licensing through spreadsheets or through database programmes. Figure 2.5 shows the export screen, while Figure 2.6 shows the result of Excel spreadsheet manipulation and graphing.

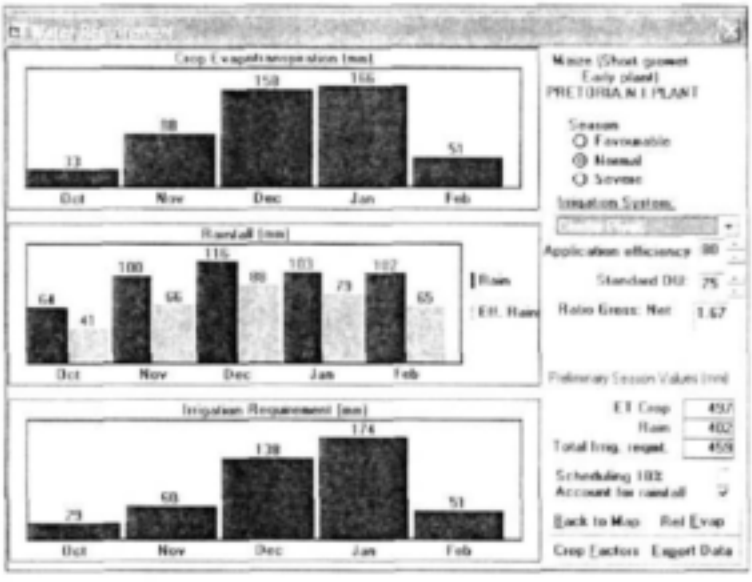


Figure 2.4 Revised irrigation requirement screen

Figure 2.5 Outputs file in a comma-delimited format permits direct export to PLANWAT or to any data-base or spreadsheet.

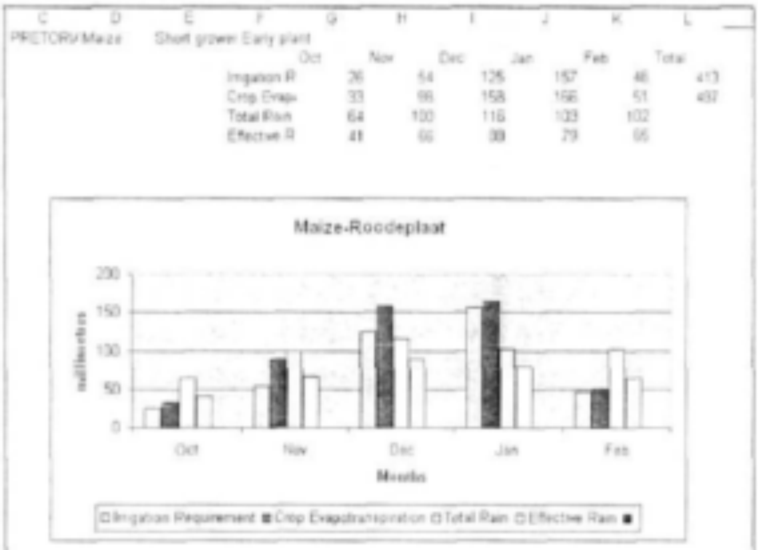


Figure 2.6 SAPWAT exported data could be manipulated and displayed in Excel.

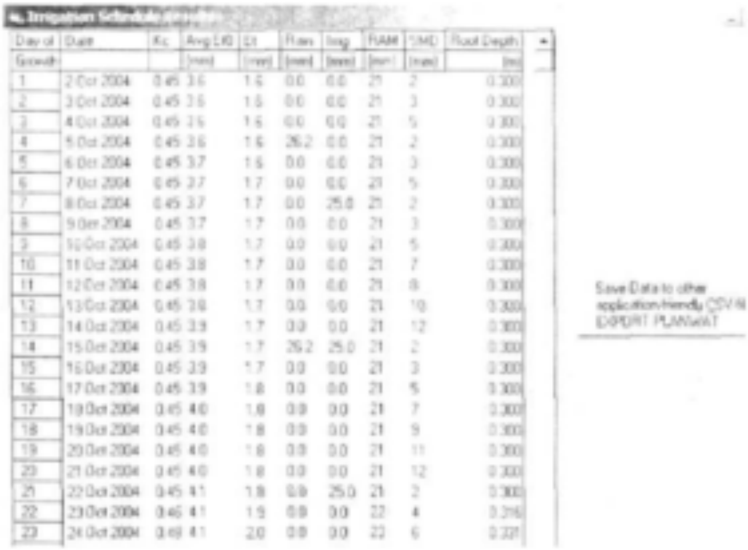
The scheduling set-up window has been renewed to make it more user-friendly. The renewed version can be seen in Figure 2.7.

Figure 2.7 The new scheduling set-up screen.

The results pane of the water management module is shown as a separate screen window, although the well-known layout of it on the previously known "blue screen" remains the same. See Figure 2.8

Figure 2.8 Screen displaying the results of a specified irrigation strategy.

The graphic representation and the cleaned up standard daily water balance table has been renewed. The table is shown in Figure 2.9.



Day of Growth	Date	Kc	Avg ETO (mm)	Et (mm)	Rain (mm)	Irrig (mm)	RAM (mm)	SMD (mm)	Root Depth (m)
1	2 Oct 2004	0.45	3.6	1.6	0.0	0.0	21	2	0.300
2	3 Oct 2004	0.45	3.6	1.6	0.0	0.0	21	3	0.300
3	4 Oct 2004	0.45	3.6	1.6	0.0	0.0	21	5	0.300
4	5 Oct 2004	0.45	3.6	1.6	26.2	0.0	21	2	0.300
5	6 Oct 2004	0.45	3.7	1.6	0.0	0.0	21	3	0.300
6	7 Oct 2004	0.45	3.7	1.7	0.0	0.0	21	5	0.300
7	8 Oct 2004	0.45	3.7	1.7	0.0	25.0	21	2	0.300
8	9 Oct 2004	0.45	3.7	1.7	0.0	0.0	21	3	0.300
9	10 Oct 2004	0.45	3.8	1.7	0.0	0.0	21	5	0.300
10	11 Oct 2004	0.45	3.8	1.7	0.0	0.0	21	7	0.300
11	12 Oct 2004	0.45	3.8	1.7	0.0	0.0	21	8	0.300
12	13 Oct 2004	0.45	3.8	1.7	0.0	0.0	21	10	0.300
13	14 Oct 2004	0.45	3.9	1.7	0.0	0.0	21	12	0.300
14	15 Oct 2004	0.45	3.9	1.7	26.2	25.0	21	2	0.300
15	16 Oct 2004	0.45	3.9	1.7	0.0	0.0	21	3	0.300
16	17 Oct 2004	0.45	3.9	1.8	0.0	0.0	21	5	0.300
17	18 Oct 2004	0.45	4.0	1.8	0.0	0.0	21	7	0.300
18	19 Oct 2004	0.45	4.0	1.8	0.0	0.0	21	9	0.300
19	20 Oct 2004	0.45	4.0	1.8	0.0	0.0	21	11	0.300
20	21 Oct 2004	0.45	4.0	1.8	0.0	0.0	21	12	0.300
21	22 Oct 2004	0.45	4.1	1.8	0.0	25.0	21	2	0.300
22	23 Oct 2004	0.46	4.1	1.9	0.0	0.0	22	4	[illegible]
23	24 Oct 2004	[illegible]	4.1	2.0	0.0	0.0	22	6	[illegible]

Save Data to other application-friendly CSV-N EXPORT PLANWAT

Figure 2.9 The cleaned up standard SAPWAT daily water balance table

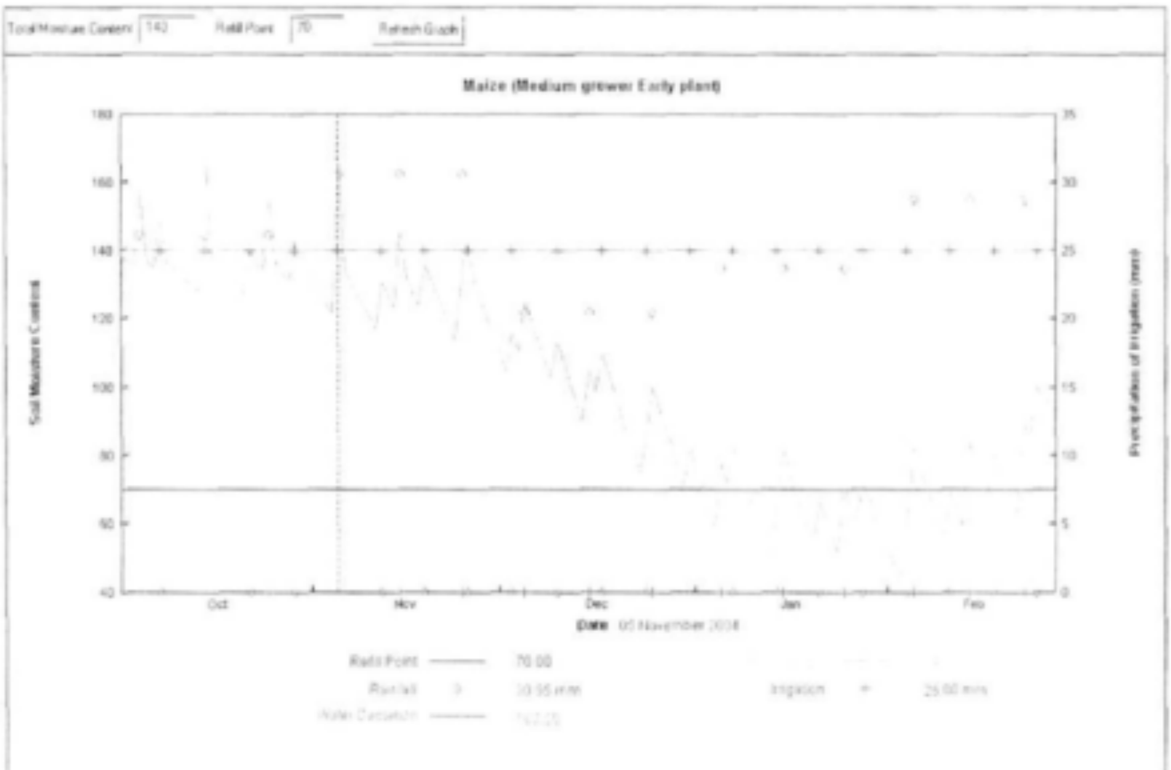


Figure 2.10 The water balance graph

2.2 SAPWAT (ADMINISTRATION)

Sapwat-Admin

The Department of Water Affairs and Forestry specified SAPWAT as the methodology to be applied in the official Pricing Strategy and this was extended to the water use registration process. In addition the final guidelines for the verification of registration incorporating Sapwat has been approved and will ultimately be projected to the licensing of agricultural water use. There is a need to establish reasonable and defensible values for crop irrigation requirements that will provide norms in the legal processes that follow. It is anticipated that many thousands of computer computations will have to be undertaken and a degree of standardisation becomes inevitable. The facility to cater for climatic differences, irrigation methods and the full range of crops produced in South Africa will be maintained. Estimates are based on the application of sound crop production and water management standards. Realistic default values for canopy cover and wetted area for a full range of practical crop and irrigation management situations have been developed as an attachment to the DWAF water use verification manual. This list will be included in the version of Sapwat-Admin downloaded from the web site to guide users who may not be specialists in agriculture or irrigation.

This module has the same starting sequence, up to Figure 2.3/2.4, of the management module. At this stage irrigation requirement data is exported for use in the registration and licensing process.

3 REVISION OF CROP FACTORS

3.1 CLIMATE

Climate plays a major role, not only in the choice of crops to be grown in any one place, but also in the choice of planting date and cultivar. Changes in daylight period, total heat units or total cold units affects the growth cycle of some crops in that the physiological processes that determine when these plants will germinate, will change from vegetative to reproductive growth and when fruit will ripen are triggered by these changes.

For the application of the FAO four-phase crop growth stages as described by Allen, Pereira, Raes & Smith, 1998, for the estimation of irrigation requirements, it is necessary that a fairly accurate determination of the length of each of these cycles be made. CROPWAT (Smith, 1992) and Allen, Pereira, Raes & Smith, 1998 provides ranges within which these periods could be determined for each site, but the problem is that the user must have a fairly good knowledge of crop reaction to climate in order to make the necessary adaptations. Another problem encountered with the CROPWAT approach is that, although a range of planting dates are implied, the effect of different planting dates on the stage lengths of the four-stage crop growth model is not directly indicated. Once again, the user must rely on his or on local knowledge to adjust stage lengths to suit local conditions.

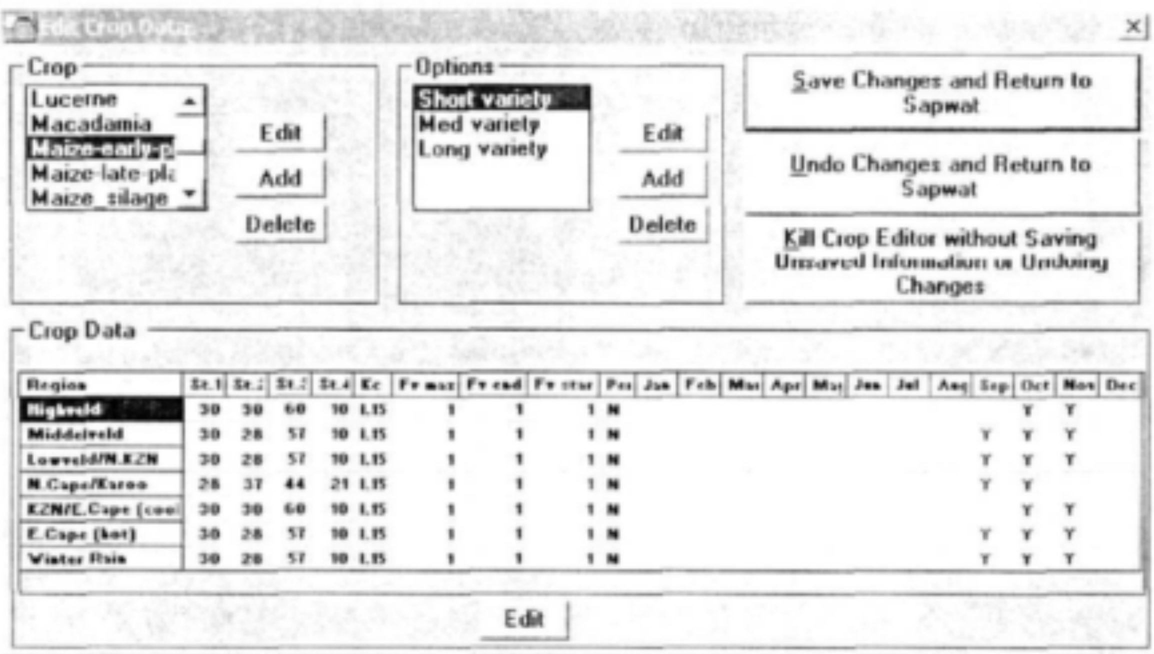


Figure 3.1 SAPWAT growth stages for different climatic conditions in South Africa for short grower maize planted in summer.

SAPWAT has tried to overcome this problem by including in its tables the values, and changes in values, reflected by different climatic conditions and also different planting times (Crosby & Crosby, 1999). A problem encountered here was that the database had to be increased substantially to accommodate the seven major climatic regions identified for the South African situation as a set of growth stage periods had to be determined for each of these areas. However, it soon became apparent that one could possibly reduce the number of climatic areas by reclassifying these into warmer and colder areas, as average temperature has a major influence on crop growth (Gardner, Pearce & Mitchell, 1985; McMahon, Kofranek &

Rubatzky, 2002), as can be seen in Figure 3.1 where the growing period for the cooler Highveld and KZN/E Cape (cool) climatic areas area generally longer than for the other, warmer Lowveld and Middelveld areas. In this respect changes in daylight-length also play a role, but that is usually accounted for in the growth patterns of crops for different climatic regions, as these are largely determined by latitude (Strahler & Strahler, 2002; Gardner, Pearce & Mitchell, 1985; McMahon, Kofranek & Rubatzky, 2002)

Figure 3.2 Köppen-Geiger climate map of Southern Africa (Strahler & Strahler, 2002)

In an effort to reclassify the South African climate scenario for SAPWAT and to make the SAPWAT data more internationally applicable, the South African situation was compared to an internationally accepted climate system, the Köppen-Geiger Climate System, seen in Figure 3.2 for Southern Africa (Strahler & Strahler, 2002). These authors describe this system as being based on a combination of temperature and precipitation, computed in terms of monthly or annual values. With several revisions, this system was for many decades the most widely used climate classification system among geographers. It features a shorthand code of letters designating major climate groups, subgroups within the major groups and further subdivisions to distinguish particular seasonal characteristics of temperature and precipitation. Five major climate groups are designated by capital letters as follows:

A: Tropical rainy climates
Average temperature of every month is above 18°C. These climates have no winter season. Annual rainfall is large and exceeds annual evaporation.

B: Dry climates
Evaporation exceeds precipitation on the average throughout the year. There is no water surplus; hence no permanent streams originate in B climate zones.

C: Mild, humid (mesothermal) climates
The coldest month has an average temperature of under 18°C but above -3°C; at least one month has an average temperature above 10°C. The climates thus have both a summer and a winter.

D: Snowy-forest (micro thermal) climates
The coldest month has an average temperature of under -3°C. The average temperature of the warmest month is above 10°C.

E: Polar climates
The average temperature of the warmest month is below 10°C. These climates have no true summer.

The defining of crop characteristics for use in SAPWAT will be limited to climate groups A, B and C because these are the climates found in Southern Africa.

Linkages between the typical South African system and the Köppen-Geiger system were established. It must be stated that the boundaries of the two climate systems do not coincide exactly but an approximation was possible and now one is able to characterise the climatic regions as can be seen in Table 3.1. What is apparent out of Table 3.1 is that most of the climate systems found in South Africa, are also found in Africa.

Table 3.1 Comparing the South African climate regions with the Köppen-Geiger climate system for application to Southern Africa.

Köppen-Geiger key	Köppen-Geiger description for the A, B and C climatic regions.	Approximate Southern African regions
Af	Tropical rainforest climate. All monthly average temperatures over 18°C. No dry season.	No Southern African equivalent. Central part of the Congo basin.
Am	Tropical rainforest climate with monsoon type rainfall. All monthly average temperatures over 18°C. Short dry season.	No Southern African equivalent. Parts of the West-Africa tropical coast.
Aw	Tropical savannah climate. All monthly average temperatures over 18°C. Dry winter.	Southern Democratic Republic of the Congo, Angola, except for the western coastal and adjacent areas, Uganda, Kenya, Tanzania, eastern Mozambique, parts of the South African lowveld.

BSh	Hot Steppe climate. A semi-arid climate characterised by grasslands, it occupies an intermediate position between the desert climate (BW) and the more humid climates of the A and C groups. Boundaries are determined by a formula based on mean annual temperature and mean annual precipitation. Mean annual temperatures exceed 18ºC.	Central and northern Namibia with exception of the Namib desert, Botswana, south western Zimbabwe, central-eastern and southern South Africa with the exception of the southern coastal and adjacent areas.
BSk	Cold Steppe climate. A semi-arid climate characterised by grasslands, it occupies an intermediate position between the desert climate (BW) and the more humid climates of the A and C groups. Boundaries are determined by a formula based on mean annual temperature and mean annual precipitation. Mean annual temperature under 18ºC.	A narrow strip along the southern South African west coast.
BWh	Hot desert climate. This arid climate has an annual precipitation of usually less than 40 cm. Boundaries with the adjacent steppe climate are determined by a formula based on mean annual temperature and mean annual precipitation. Mean annual temperature exceed 18ºC.	Central and western South Africa, southern and western Namibia.
BWk	Cold desert climate. This arid climate has an annual precipitation of usually less than 40 cm. Boundaries with the adjacent steppe climate are determined by a formula based on mean annual temperature and mean annual precipitation. Mean annual temperature under 18ºC.	A narrow strip along the South African northern west coast and the Namibian west coast.
Cfa	Mild humid climate with no dry season and hot summers. Precipitation of the driest month averages more than 3 cm. Warmest month average temperature exceed 22ºC.	Northeastern coastal and adjacent areas of South Africa.
Cfb	Mild humid climate with no dry season and warm summers. Precipitation of the driest month averages more than 3 cm. Warmest month average temperature below 22ºC.	Southeastern and southern South African coastal and adjacent areas.
Csb	Mild, humid with warm, dry summer. 70% or more of the mean annual precipitation falls in the six winter months. Warmest month average temperature below 22ºC.	Southwestern South African coastal and adjacent areas.
Cwa	Mild humid climate with dry winter and hot summer. Warmest month average temperature exceeds 22ºC. 70% or more of the mean annual precipitation falls in the six summer months.	Highlands of Southern Angola, southern Zambia, northeastern Zimbabwe, Malawi, central-west and northwest Mozambique.
Cwb	Mild, humid with dry winter and warm summers. Warmest month average temperature under 22ºC. 70% or more of the mean	Highveld of Central eastern South Africa.

	annual precipitation falls in the six summer months.	

Of course, this does not solve the problem of too many climate regions that, because of similar temperatures and changes in daylight length found in the middle latitudes and their effects on crop growth, would eventually lead to too many duplicate entries of crop characteristics for use by SAPWAT. The same experience as has been had with the present version of SAPWAT, where grouping seems to be able to take place on temperature as the main determinant, seems possible for the Köppen-Geiger climate system. It must be kept in mind that in irrigation, the availability of water, and even humidity to a limited extend, can be manipulated and therefore it become less important as a consideration for subdividing geographic areas into climatic regions for the growing of crops. Temperature therefore seems to remain the main consideration. Apparent out of Table 3.1 are the temperatures cited, annual averages above or below 18°C and warmest month averages above or below 22°C. Considering this, the broad climatic regions shown in Table 3.2 are proposed for inclusion in SAPWAT instead of the present system. The proposal is based on a broad subdivision between the major Köppen-Geiger climate systems, with further subdivisions on annual or monthly average temperatures. These proposed regions will cover Southern Africa, and as a result of similar climate systems in other parts of the world, could as a matter of course also become applicable to at least the rest of Africa, southern Middle East, India, Indonesia, Australia and most of South America.

Table 3.2 Revised climatic regions for inclusion in SAPWAT.

New SAPWAT climatic region	Main identifying characteristic	Köppen-Geiger climate regions	Approximate present SAPWAT use
Tropical	Areas with all monthly average temperatures exceeding 18°C.	Af, Am, Aw	Lowveld/N.KZN
Humid/Semi-humid, hot summers	Annual precipitation > 500 mm. Warmest month average temperature exceeds 22°C. Average annual temperature exceed 18°C.	Cfa, Cwa	Lowveld/N.KZN, Middelveld
Humid/Semi-humid, warm summers	Annual precipitation > 500 mm. Warmest month average temperature below 22°C. Average annual temperature exceed 18°C.	Cfb, Csb, Cwb	Highveld, KZN/E.Cape (cool), E.Cape (hot), Winter Rain
Arid/Semi-arid, hot summers	Annual precipitation < 500 mm. Warmest month average temperature exceeds 22°C. Average annual temperature exceed 18°C.	BSh, BWh.	N.Cape/Karoo, Middelveld, Winter Rain
Arid/Semi-arid, warm summers	Annual precipitation < 500 mm. Warmest month average temperature below 22°C. Average annual temperature exceed 18°C.	BSk, BWk	N.Cape/Karoo, Winter Rain

The proposed subdivision as shown in Table 3.2 should reduce duplication of crop characteristics for SAPWAT to a manageable number.

3.2 CROP CHARACTERISTICS

Crop characteristics for application by SAPWAT were mainly collected by means of surveys of researchers, technicians and farmers who grow the crops and, where possible, evaluated against existing published data. Crop characteristics required by SAPWAT, and by CROP-WAT, are tabled in Appendix A.

3.2.1 Methodology

One of the unfortunate things about the four-stage FAO crop factor curve is that the data required to apply it, is not necessarily included in the data that researchers usually collect. The usual pattern is that planting day, day of emergence, commencement of flowering / tasseling / earing, day when the crop is physiologically ripe are collected. And of course, reaping dates and production levels. Sometimes some more information is collected. The four-stage curve required dates of planting, 10% foliage cover, 70% to 80% foliage cover (usually when leaf area index (LAI) reaches 3, where applicable), beginning of maturity (first signs of the discolouration of leaves), last day of irrigation, the last day of growth and level of activity when growth stops (Allen, Pereira, Raes & Smith, 1998). As some these events occur in between those that are usually noted, one has to rely on the observation capacity of the researcher, technician and farmer to deduce applicable dates or periods for the stages of the four-stage growth curve.

This task can be approached in several ways, one of which is to visit knowledgeable scientists, scheduling consultants and farmers in different irrigation areas and to reproduce what they are doing in practice in the field with Sapwat simulations. This is successful where there is data available as was the case in the Riet-Orange-Vaal river areas through the offices of the Orange-Vaal and Orange-Riet WUAs and of GWK Ltd (Van Heerden, Crosby & Crosby, 2001).

Recent experience with dairy farmers and the intensive production of irrigated pastures produced two surprising results. The first is that irrigated pastures are high value crops when marketed as milk and the second is that despite the high level of technology on dairy farms, knowledge and data on irrigation is surprisingly deficient. Workshops have been held at Potchefstroom and Cedara agricultural centres with pasture and soil science specialists and the response has been most encouraging, but it was not possible to meaningfully update the crop coefficients for irrigated pastures.

What has come out of this preliminary work is that ways and means of undertaking field checks on "what is going on" under the soil surface is an important aspect of verifying crop coefficients. Only too often the information is not available.

The list of personal communications for this purpose is taken up in the source list.

The data thus collected is compared to data published in FAO 56 and in other literature, adapted as required and tabled as can be seen in Appendix A. (Allen, Pereira, Raes & Smith, 1998; Annandale, Benadé, Jovanovic, Steyn & Du Sautoy, 1999; Annandale, Van der Westhuizen & Olivier, 1996; Aucamp, 1978; Bennie, Strydom & Vrey, 1998; Bennie, Van Rensburg, Strydom & Du Preez, 1997; Cooke & Scott, 1993; Crosby & Crosby, 1999; De Jager, Mottram & Kennedy, 2001; Dickinson & Hyam (Ed), 1984; Doorenbos & Kassam, 1986; Inman-Bamber & McGlinchey, 2003; Jovanovic & Annandale, 1999; Marais, Rethman & Annandale, 2002; McMahon, Kofranek & Rubatzky, 2002; Meredith, 1959;

Morse, Robinson & Ferreira, 1996; Reader's Digest 1984; Smith, 1992; Van Heerden, Crosby & Crosby, 2001; Volschenk, De Villiers & Beukes, 2003; Ziad, 1999).

4 SUPPORT TO OTHER RESEARCH TEAMS AND LINKAGES TO OTHER PROGRAMMES

Support is given to other research groups, some of who are funded by the WRC, and who need specialist inputs relating to irrigation requirements for their projects. The most comprehensive was probably done for researchers of Agricultural Economics of the Free State University in a study on risk management in the Vaalharts area.

4.1 DETERMINING THE CROP IRRIGATION REQUIREMENTS FOR THE NORTH AND WEST CANALS OF VAALHARTS WATER USER'S ASSOCIATION

4.1.1 Introduction

A comprehensive irrigation water requirement study had to be made in the Vaalharts Irrigation area to enable the researchers to devise credible ways of planning for risk management.

4.1.2 Methodology

Surveys to determine cropping patterns for the two areas of the Vaalharts Water User's Association (Vaalharts WUA) under study and the estimation of irrigation requirements for the two areas was done as described by Van Heerden, Crosby & Crosby (2001).

4.1.3 Results and Discussion

Table 4.1 shows the scheduled areas compared to the cultivated areas. All calculations are based on the actual area cultivated and not on the scheduled area.

Table 4.1 Scheduled and cultivated areas of the two study areas within the Vaalharts WUA.

Area	Scheduled (ha)	Cultivated (ha)
North canal	22948	23400
West canal	6252	6800

These figures indicate that slightly more land is cultivated than scheduled, approximately 2% more for north canal and approximately 10% more for west canal.

The water quota for both these areas is 9140 m^3 per ha. In the present day terms it translates to an annual water use right of 209 744 720 m^3 and 57 143 280 m^3 for the north and west canals respectively.

The crop cover of the west canal cultivated area is 170,7% and that of the north canal is 147,2%. This is mainly due to double cropping: winter cereals (wheat and barley) are followed by maize and groundnuts in the summer growing season. The ratios of the wheat and barley, and that of maize and groundnuts vary according to prevailing market prices at the time of planting, as well as the farmers' interpretation of future market trends. In the same way the ratio of the early planted seasonal summer crops: maize, groundnuts and cotton, is also determined by market tends.

The seasonal water requirement of crops, based on actual irrigation strategies followed in each of these areas, can be seen in Table 4.2. To a large extent the irrigation strategies applied by the farmers are dictated by the management of the canal system by the Water User's Association and therefore substantial differences in water requirement between different irrigation systems and even differences between the same irrigation systems in different canal areas, are found. Farmers have also indicated that in cases of expected water shortages, they would water-stress some crops, mainly maize and lucerne, in order to get through with their water allocation. The differences in water requirements for crops that replace each other in the cropping pattern are such that replacing some of the area of one crop with another crop out of the same group, would result in a relatively small change in total water requirement of the cropping system. These changes in water requirement could usually be handled within the present water use right allocation.

Table 4.2 Water requirements of crops in the north and west canal areas of the Vaalharts WUA for different irrigation systems and based on the irrigation strategies followed in the different areas.

	North canal area				West canal area			
	Flood	Centre pivot	Micro	Drip	Flood	Centre pivot	Micro	Drip
Seasonal crops								
Barley	720	525			720	465		
Cotton	1020	615						
Groundnuts (early plant)	1020	645						
Groundnuts (late plant)	780	603			780	510		
Maize (early plant)	840	570						
Maize (late plant)	600	405			540	360		
Peas (dry)	720	350						
Wheat	840	585			780	555		
Perennial crops								
Citrus	1380			1005			825	
Lucerne	1500	1065			1500	1080		
Olives	1440				1440			795
Pecan nuts	1500			945	1500		855	
Plums			960					
Vineyard (wine)	1140			810	1140			810

Water requirement varies from a low 350 mm for peas under a centre pivot to as high 1500 mm for pecan nuts and lucerne under flood irrigation. Most of the annual crops require from about 400 mm to about 650 mm irrigation water under centre pivot irrigation and from about 600 mm to about 840 mm irrigation water under flood (border) irrigation. For perennial tree and vine crops, the difference in water requirement between flood irrigation systems and either drip or micro-spray systems is substantial, for example pecan nuts and lucerne under flood irrigation require 1500 mm of water, where-as pecan nuts under a micro-spray would require only 855 mm and lucerne under a centre pivot would require 1065 mm. What is obvious out of the table is that crops under centre pivot, micro or drip irrigation systems require less water than the same crops would require under flood irrigation systems. The differences indicated here are the results of different irrigation strategies farmers must follow because of limitations in the capacity of the canal system, combined with differences in efficiencies between the different irrigation systems. It is doubtful whether the management of the distribution of irrigation water through the present canal system can be improved upon.

In the north canal area, winter cereals, wheat and barley, constitute 39 % of crop cover, summer cereals and groundnuts that follow these also cover 39 %. Early planted summer cereals, groundnuts and cotton cover a further 41 %. In total these crops cover 119 % of total cultivated area, whereas the other crops, mainly perennials, cover an additional 32 %

A summation of these results in monthly water requirements and comparing that to the water requests received from the farmers, show interesting tendencies as can be seen in figures 4.1 and 4.2. Water requested could be equated as actual water use as the method of calculating the water that should be supplied to the farmers by the Vaalharts WUA does take canal losses and tail water outflows into account. In other words, the water released by the WUA is more than that requested, so that the gross releases minus losses would equate requests. The large discrepancies between water requirements, as calculated with SAPWAT, and actual water use, needs further investigation.

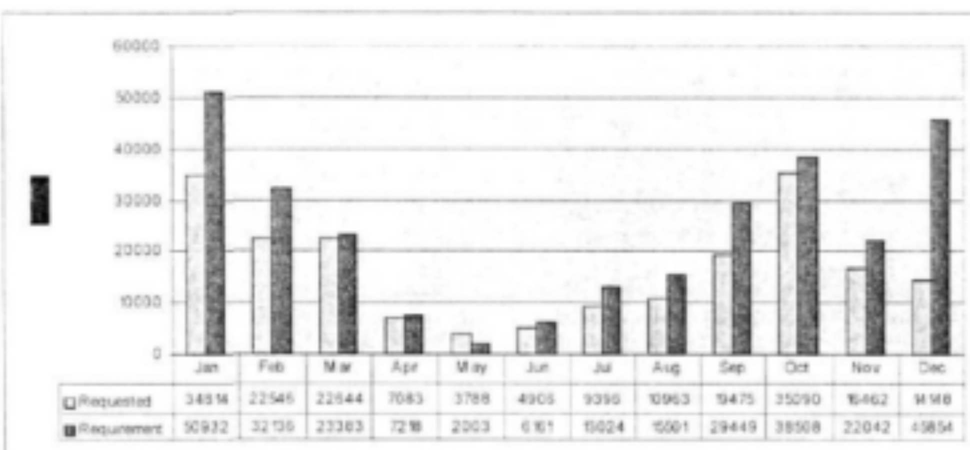


Figure 4.1 Water requirement and water requested for the north canal area.

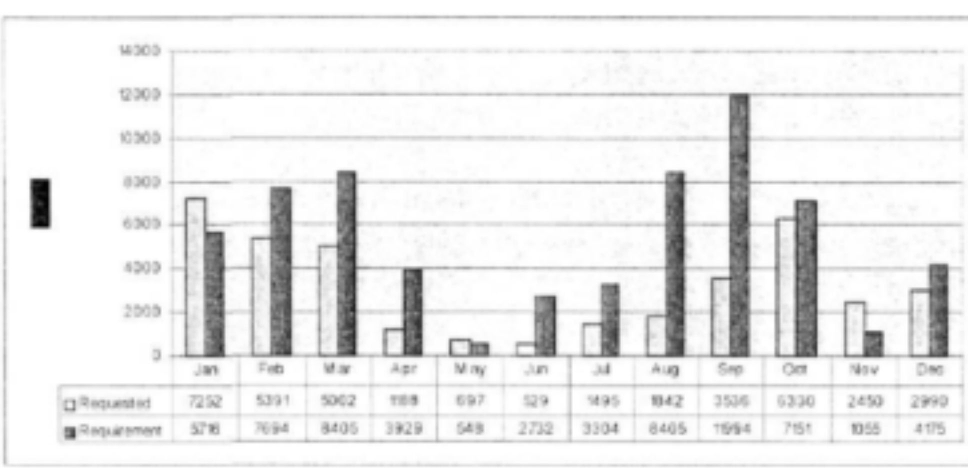


Figure 4.2 Water requirement and water requested for the west canal area.

Table 4.2 shows the water requirement for the cropping pattern, compared to the water requested and the quota

Area	Quota (m^3/ha)	Requested (m^3/ha)	Required (m^3/ha)	Requested as % of required
North canal	9140	8603	12231	70

West canal	9140	5691	9597	59

It is apparent from table 42 that the water required for both the canal areas is more than the quota. The farmers of the north canal area ordered 70% of their quota, while the west canal farmers ordered only 59% of their quota.

When comparing these figures, one must keep in mind that the requirement figures are based on long-term averages, while the extraction figures represent one year (2002) only and marked deviations could be found between a specific year's requirement and long term averages due to year on year variance in rainfall patterns and quantities. This aspect also needs further investigation.

It is interesting to note that in both cases the water requested for the summer months are, with a few exceptions, lower than the actual crop requirement. In discussions with the small groups used in the survey, a few strategies for coping with a shortage of water were mentioned. These could explain why relatively good production levels can be maintained despite an apparent water stress situation experienced during summer. These strategies are:

- Some crops are deliberately stressed if it becomes apparent that a farmer will exceed his quota. The two crops mentioned are lucerne, which goes dormant under conditions of water stress, and some of the maize fields, as maize is seen as one of the lesser income crops by some of the farmers.

- The Vaalharts irrigation area is notorious for its high water table and water logging problems. Where possible, farmers make use of the water table to supply some of their crop water requirement for crops that can use water-table water without problems of root diseases. In experiments done at the Soil Science Department of the University of the Free State, it was found that under some conditions as much as 60% of crop water requirement could be satisfied by water-table water. One olive grower said that he irrigated only to establish his trees, after that, the trees grow and produce on water-table inflow to his farm.

Roughly 10% of the farmers make use of some form of measured irrigation scheduling, be it through a scheduling service, provided by two providers, or own measurements with the aid of irrimeters and tensiometers. The rest of the farmers irrigate on an irrigating pattern that has evolved over time and is linked to the rigid canal management. This allows farmers to irrigate once a week, and although the majority have so-called overnight dams on their farms, the quantity of water stored is not enough to allow complete freedom of choice as to irrigation scheduling.

The irrigation management pattern for flood irrigation that has evolved, is as follows: during the young stages of crop growth (FAO phase 1) (Allen, Pereira, Raes & Smith, 1998), irrigate once in three to six weeks, depending on whether that stage is in summer or winter. During the crop development phase (FAO phase 2) irrigate every second week if that period falls in winter early spring or late autumn, otherwise irrigate every week. For the rest of the growing season, irrigation takes place on a weekly basis, with a lengthening of periods to two weeks towards the end of the crop growth period (FAO phase 4). It is accepted that the average irrigation depth is 60 mm for flood irrigation systems, water through the sluice. Considering the accepted default irrigation efficiency of 60%, this then implies that about 36 mm is applied per irrigation. How well this irrigation pattern slots into the actual crop water requirement, is demonstrated in figures 4.3 and 4.4.

In the case of maize, where the main growing period is during the summer rainy season, the way in which rainfall is also utilised can be clearly seen.

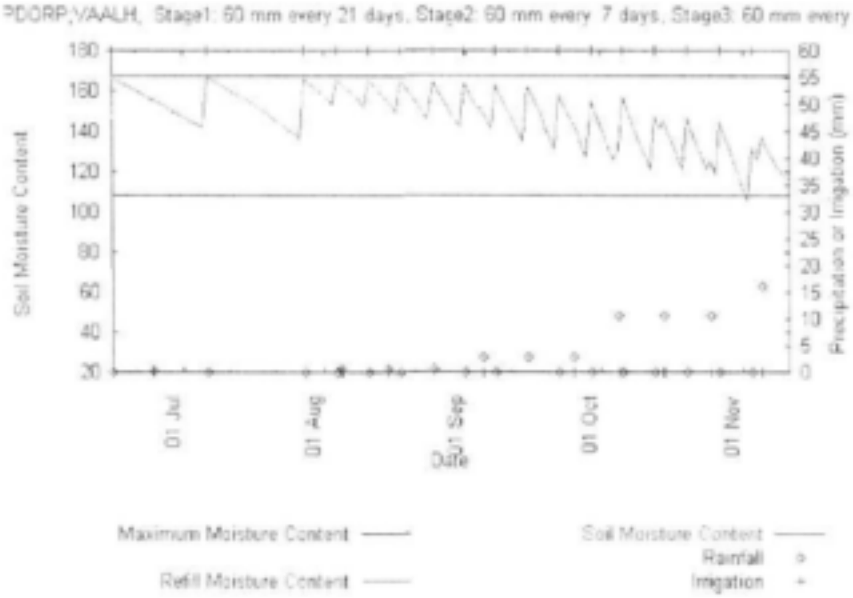


Figure 4.3 Irrigation pattern of wheat, compared to soil water content.

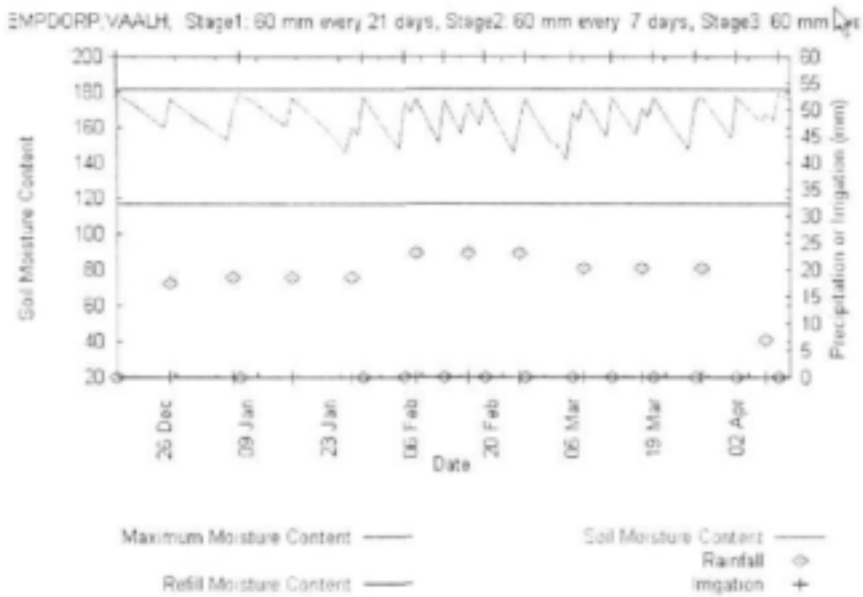


Figure 4.4 Irrigation pattern for late planted maize, short growing variety, compared to soil water content.

4.2 WATER FOR FOOD MOVEMENT

This movement initiated by Tshepo Khumbane and Marna de Lange is based on a combination of rain water harvesting, intensive vegetable production in excavated beds and the application of permaculture crop production methods allied to the mobilisation, motivation and training of rural housewives. The centre for these activities over the past few years has been concentrated on the small holding developed by Tshepo Khumbane north of Pretoria. The results achieved were revealing and the Water for Food Movement was formed and plans developed for extending activities countrywide. The current status of the project is that the Department of Water Affairs and Forestry has recently initiated a subsidy of R5000 per household to provide for rainwater harvesting and storage facilities.

The initiators of the Water for Food Movement appreciated that the motivations and action plans required to extend the pilot study had to be backed by quantified data. The Sapwat team was able to provide support and using the model and its databases, developed answers to some of the unanswered questions. In most cases it proved possible to present this information either in rule-of-thumb format, or by means of simple computer routines that were later incorporated in the Planwat model (Van Heerden, 2003).

4.2.1 Estimating irrigation requirements of a garden

The system is an intensive one and this is a one of its great strengths. In an area or where the soils may be shallow, rocky and infertile the vegetable beds have been specially prepared by trenching to a depth of one metre and refilling with soils with a high organic content, rich in nutrients and with good water holding capacity. To exploit this fertile soil to the maximum, water must not be a limiting factor.

When estimating irrigation volumes and application frequencies in the summer rainfall areas it is necessary to differentiate between irrigating in the dry winter and in the wet summer. The winter estimates are reasonably straightforward because there is a little or no rain to take into consideration. Normally the water will originate from storage and be applied to the beds either by hose or by bucket. In the summer the required supplemental irrigation can come from storage or from harvested runoff water.

The soil in a typical bed one metre deep has a capacity of about 60 mm of readily available water that can be tapped by the plants but at the beginning of the season the bed may contain less.

The crop water use is largely dependent on climatic conditions that determine crop evapotranspiration. The irrigation quantities required will vary with the stage of plant development and the climatic conditions. Matching crop water needs and irrigation applications (scheduling) can be sophisticated requiring instrumentation and record keeping but this is not essential in the context of this system.

Practical experience and a considerable number of simulations undertaken with Sapwat indicate that it is normally adequate to arrive at a weekly irrigation application value that applies throughout the growing season of the crop. This simplifies management. To illustrate this, five weather stations with widely varying climatic conditions were selected and the weekly irrigation applications required for cabbage planted in April and maize planted in December determined. Similar runs can be done for any place in the country for any crop.

Table 4.3 Weekly irrigation requirements mm

	Alice	Madibogo	Polokwani	Hoedspruit	Tweespruit
Cabbage	15	25	20	20	10
Maize	15	25	20	15	15

If the irrigation season is known, then volumes can be calculated for a square metre of garden bed. Twenty mm depth of water required on a square metre is 20 litres or one large bucket each week. If the size of the garden beds is 100 m^2, the weekly water requirement would be 2 000 litres. Assuming a seasonal irrigation period of 12 weeks the total volume of water required would be 24 000 litres or 24 cubic metres. This is the volume of water storage required for the winter crop.

4.2.2 Water required for storage

There are very few villages in areas that average less than 500 mm of rain annually. Of course there will be drought years but lets plan on 500 mm or half a metre, if there is a bad year it means the area under cultivation will have to be cut back to suit. If this rain falls on a 50 square metre roof and is stored in a covered underground tank then the volume of water harvested will be 0.5 x 50 = 25 cubic metres, enough to fill the underground storage.

The answer to this question is relatively simple, but depending on location the storage required for 100 m^2 of garden beds was found to vary from 13 to 29 cubic metres. The table was one of the first attempts to set out the principles logically. These and more complex calculations have now been incorporated in Planwat obviating the need to have to think and calculate.

Possibly two of the most important questions that must be answered are the area of impermeable surfaces required to provide sufficient water and what volume of storage is required to cater for the dry season. These questions must be answered for all the areas where there are villages, see Table 4.4 for example. In order to gain a broad picture of the situation eight weather stations that can be regarded as being representative of the conditions that pertain in the areas where most villages are located were utilised to run Sapwat simulations based on average weather conditions in both summer and winter. The crop characteristics and management strategies discussed in the section dealing with how much water is required were applied.

Table 4.4 Estimates of impermeable collection areas and storage volumes required. Calculations based on 100 m^2 gross area cultivated

	Units	Pietersb	Hoedspr	Madib	Bloem	Tweespr	Alice	Umtata	Dundee
		Limpop	Limpop	NW	FS	FS	E C	E C	KZ-N
SUMMER									
Rainfall	mm	395	444	371	430	483	416	490	640
Sup Irrig	mm	34	26	43	27	26	26	17	17
Roof area	m^2	126	86	172	93	79	90	52	39
WINTER									
Rainfall	mm	62	70	58	122	152	153	164	118
Irrigation	m^3	34	34	43	26	17	26	17	34
Roof area	m^3	97	87	130	62	35	60	34	59
Storage	m^3	27	29	37	20	13	19	13	29
Grey water									
Storage	m^3	17	19	27	11	4	10	4	19
Run-off									
Permeable Areas	%	9	8	4	7	11	9	18	12

4.2.3 Recycling grey water

The calculations have not taken account of domestic water use but the recycling of grey water can have a significant impact. This water may originate in the "free" 6 m^3 per month allowance or be wheel barrowed in from another source but the impact of using 2 m^3 grey water per month to augment irrigation requirements is significant. Noticeably storage volumes for winter irrigation are significantly reduced. As can be seen in Table 4.4 the storage requirement for Madibogo is reduced to 27 m^3 and in the case of Umtata the need for storage is virtually eliminated being calculated at 4 m^3. The Limpopo areas are now down to 17 m^3.

4.2.4 Summer season

1. The first step was to establish the volume of water required to supplement rainfall during the summer season in order to ensure that maximum production could be achieved. It was found that in most cases this was of the same order as was required for full irrigation during the dry winter months. In retrospect this is a logical if unexpected conclusion because there is a tendency to accept production levels in summer at levels determined by rainfall.

2. Sapwat provides average summer season rainfall values for 320 sites in South Africa so that it is then a simple matter to calculate the area of impermeable ("roof") run-off area supplying the volume of water supplementing rainfall. As previously explained this is normally handled as "run-on" rather than as "irrigation" and storage between events is provided by the soil profile.

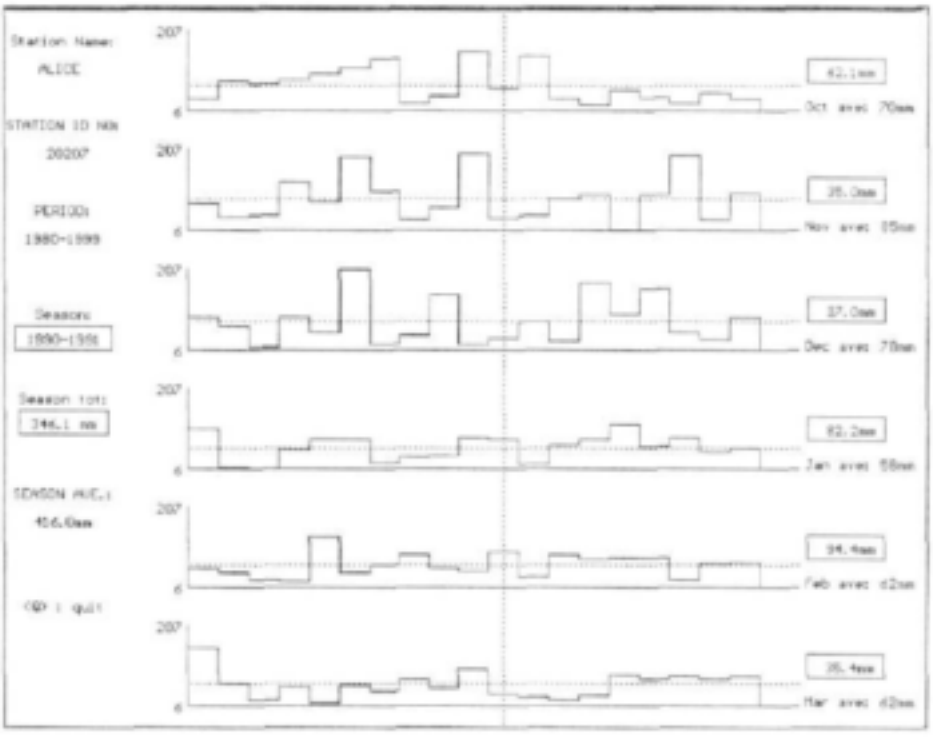


Figure 4.5 Monthly variation in precipitation for Alice. See discussion under "3"

3. One has no choice but to make use of average monthly rainfall figures for estimation purposes knowing full well that there will be years of plenty and years when average

expectations will not be met. What is certain, however, is that by following these principles villagers will be better off than would otherwise have been the case. Sapwat includes a routine that presents graphically historic monthly rainfall data over an extended period for both summer and winter seasons. This facility assists risk assessment. Figure 4.5 shows the typical summer season pattern for Alice in the Eastern Cape and covers a period of 19 years. There is considerable variation from season to season but no real disaster years. The seasonal average is 416 mm and the season represented in the window, as 1990-1991 was a poor year that had a seasonal value of 346 mm.

4. The "roof" area required to cater for this "run-on" or "supplementary irrigation" varies for the 100 m^2 garden from172 m^2 at Madibogo in the NW Province on the fringes of the Kalahari to 39 m^2 for Dundee in KZ-N and 126 m^2 for the middle veld areas of Limpopo, as can be seen in Table 4.2.2.

4.2.5 Winter season

The procedure was similar to the one followed for the summer season but it is now necessary to determine the volume of storage of summer rain required to see the crops through the dry period.

1. The first step is to establish the irrigation requirements for the winter period. Sapwat takes into consideration such factors as the water content of the soil profile at planting and the limited direct contribution of winter rain. The irrigation water is harvested for the full year but sufficient storage must be provided at the end of summer to augment the limited water harvested during winter.

2. The "roof" area required to cater for the winter is in addition to that required during the summer and is calculated from the winter irrigation requirement and the annual water harvest. The area ranges from 130 m^2 at Madibogo (together with the 172 m^2 required in summer this adds up to302 m^2) to 34 m^2 at Umtata and 97 m^2 for the Limpopo areas.

3. The proportion of the irrigation water that must be stored is a function of the ratio of summer rain to total rain. The maximum storage requirement is 37 m^3 at Madibogo while Umtata is13 m^3 and the Limpopo areas 27 m^3.

4.2.6 Calculating runoff area and storage requirements for each village

The research team was able to establish the latitude and longitude of key villages in both Limpopo and Eastern Cape and downloaded climate data from the Climatic Atlas on the IWMI website. We included Sapwat weather stations in the exercise to validate the downloaded data. The next step was to do Sapwat runs for each village to establish the net irrigation that would be required to augment rain to balance annual short grass reference evapotranspiration. It was felt that this would provide a valid indication of variability between villages. The Limpopo results follow.

LIMPOPO WATER FOR FOOD SITES

SHORT GRASS REFERENCE EVAPOTRANSPIRATION COMPARISONS-CROP FACTOR =1

SITE NO	SITE	LONG	LAT	ET	RAIN	IRRIG mm

1	SPITZKOP	29.87	23.89	1360	571	945
2	MORETHA	30.13	24.53	1420	565	1004
3	TSWAING	29.79	24.71	1441	569	1021
4	GA-TISANE	29.79	24.72	1442	570	1021
5	LORRAINE	30.42	24.19	1442	510	1065
6	TSCHEPO	28.55	25.51	1512	590	1070
7	ACORNHOEK	31.07	24.61	1451	494	1082
8	BLINKWATER	30.33	23.41	1516	570	1091
9	GA-THABA	29.62	24.11	1461	491	1094
10	GA-MATHEBA	29.27	25.32	1512	546	1101
11	STRYDKRAAL	29.71	24.47	1504	498	1129
12	GA-MODJADI	30.39	23.62	1510	488	1142
13	DUMASI	30.56	22.95	1531	576	1160
14	TSHIKONELA	30.75	22.88	1562	485	1195
15	SEKURUWE	28.94	23.94	1582	473	1220

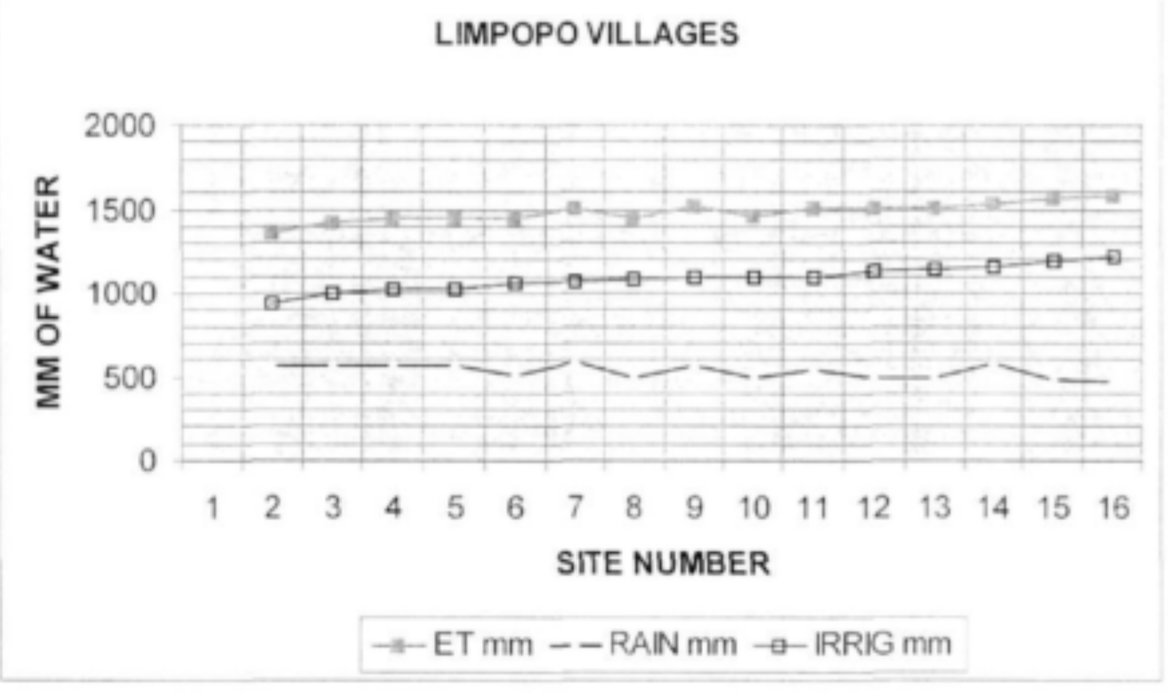


Figure 4.6 Comparison of ET, rain and irrigation requirement for villages in Limpopo province.

On the evidence of these figures it was concluded that all these villages could be grouped into those in the Lowveld characterised by the Hoedspruit weather station and those in the Middleveld by the University of the North weather station.

A similar exercise was done for the ex-Ciskei areas of the Eastern Cape below the mountains and it was found that the weather station at Alice would be adequately representative.

4.3 VERIFICATION OF EXISTING LAWFUL WATER USE BY THE DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Sapwat has been designated as the model that is to be used for estimating crop irrigation requirements in DWAF procedures. These procedures include the pricing strategy, the registration of water use and the water demand management strategy. The support of the Department and consultants has been an ongoing activity over an extended period. The inevitable progression towards compulsory licensing has taken a step forward with the approval of the ***Verification manual, a guide for the determination of existing lawful water uses*** by the Department of Water Affairs and Forestry.

The development of this manual was funded by an international organisation (DFID), and Schoeman & Partners, consultants to the Department, handled the technical aspects. Sapwat, once again, provides the methodology for evaluating irrigation water use. The **Sapwat-admin** version of Sapwat has been developed to cater for the specific requirements of the procedure. The need is for a logical and transparent methodology for developing reasonable and acceptable values for irrigation requirements. It would be impossible to evaluate the particular circumstances, and management effectiveness of individual farmers. It is anticipated that contractors and consultants in each of the water management areas throughout South Africa will undertake this process. Uniformity in approach and reconcilable outputs are essential, so that the manual concentrates on detail.

Key aspects of the procedure deal with capturing available data in GIS databases and validating registered information, identifying registered and existing water uses by means of aerial photography and satellite imagery, identifying unregistered water use, and identifying the possible lawfulness of water uses.

Section 3 of the guide deals with **crop irrigation requirements**, and comprises five paragraphs:

- define homogeneous climate zones
- identify or establish applicable Sapwat weather stations
- define standard parameters
- using Sapwat
- populating a crop irrigation requirement data base

Section 8 of the guide deals with determining **registered and possible existing water volumes**

- obtain registered water volume
- calculate Sapwat volume
- obtain the identified irrigated area from the satellite image.

Attachment B of the guide discusses the identification or establishment of Sapwat weather stations.

Attachment C of the guide specifies the accepted Sapwat parameters for each crop.

Attachment D of the guide provides detailed instructions on how to use Sapwat for this particular purpose.

The development of **Sapwat admin** means that the Sapwat related attachments would have to be updated. This was anticipated from the outset.

5 TRAINING AND ELECTRONIC AND TELEPHONIC SUPPORT SERVICES TO OTHER USERS OF SAPWAT

No complete courses were presented as it transpired that there was no apparent need for. However, a number of demonstrations were held and personal assistance was also given:

Personal assistance, usually 1 to 4 hours in duration:

- Department of Agriculture, Free State (Head office and Southwest Free State)
- Agrico, Bloemfontein
- Orange-Vaal WUA
- Orange-Riet WUA and Ninham Shand consulting engineers
- Vaalharts WUA
- Central University of Technology

Demonstrations, usually 1 to 2 hours:

- SABI Orange branch

Electronic and telephonic support

This support includes the answering of requests for specific assistance in the use of SAPWAT for the calculation of irrigation water requirements for specific situations, often problematic situations such as sandy a-horizons on clay b-horizons, high frequency with low applications, low frequency with high applications, crops grown outside their usual climatic regions, crops not listed, and design criteria.

There are surprisingly few people with a real interest in the inner workings of irrigation. This applies to farmers, engineers, agronomists, soil scientist, and agricultural economists. There are notable exceptions but irrigation is a chore; it is not a popular hobby. One exception to the rule is the scheduling consultant. They almost invariably have an encyclopaedic knowledge of irrigation practices in the areas they serve. Unfortunately, scheduling is not a particularly profitable business and practitioners have their work cut out to keep up with the procedures and advise their customers. In addition their activities are usually associated with a well-tried specific technique and instrumentation for measuring soil moisture content or with commercially developed software packages.

There is, however, a small band of general " agricultural consultants" who are becoming interested in irrigation because they suspect that present practices are having an adverse influence on crop yields or quality. A few of them, interested in understanding the processes of irrigation, read about Sapwat, downloaded the programme from the web site and liked what they saw. The Sapwat runs, however, raised new queries and they made contact to obtain more information. These interactive contacts have proved to be valuable and have lead to visits and in-depth discussions.

Several of these contacts were at one time researchers who over time became more involved in practice. Eventually they decided to become independent agricultural consultants. Usually the clientele was concentrated near where they lived and they augmented their consulting activities by having a nursery or by supplying seed and fertiliser. In two cases they were active irrigation equipment dealers. As can be expected these people tend to be operating at the cutting edge of technology. It is gratifying that they find Sapwat a useful tool. At the same time this presents a considerable challenge to the Sapwat team who become involved in analysing and interpreting innovative processes that are not yet part of the normal routine of irrigation. This interaction has led to significant modifications in Sapwat crop factor development in the case of pastures, subtropical fruit, and shade cultivation. There are indications that these people can become part of the Sapwat team and can advise users on the application of the model and contribute to the improvement and development of Sapwat.

Organisations and people provided with support:

- Department of Water Affairs central and regional offices:
  - Limpopo – irrigation requirements for registration; crops not included in SAPWAT list, crops grown outside their usual climatic region
  - Mpumalanga – irrigation requirements for registration; problems with downloading
  - Free State – irrigation requirements for registration
  - Northern Cape – irrigation requirements for registration, irrigation requirement planning
  - Eastern Cape – irrigation requirements for registration; crops not included in SAPWAT list
- Provincial Departments of Agriculture
  - Limpopo – irrigation requirements of crops
  - Free State – irrigation requirements of crops
  - Northern Cape – irrigation requirements of crops
  - Kwazulu-Natal – irrigation requirements of crops
- Water Users' Associations
  - Orange-Riet - irrigation requirements of crops for water management
  - Orange-Vaal - irrigation requirements of crops for water management; irrigation requirements of crops where production practices deviate from the normal.
  - Gamtoos - irrigation requirements of crops for water management
  - Vaalharts - irrigation requirements of crops for water management
- Tertiary Institutions, research organisations and researchers
  - University of Kwazulu-Natal – training of students
  - University of the Free State – irrigation requirements of crops, application of SAPWAT for risk assessment.
  - Central University of Technology – irrigation requirements of crops for a hydrology research project
  - University of Swaziland – training of students
  - CSIR – irrigation requirements of crops for borehole-based irrigation
  - ARC-Nietvoorbij – irrigation requirements of fruit trees on problem soils
  - IWMI – irrigation requirement planning for river basin water balances
  - Deciduous Fruit Trust – irrigation requirements along the lower Orange River system
- Consultants, consulting organisations, designers and sellers of irrigation equipment
  - MBB – Irrigation requirements, general and Orange River System
  - Ninham Shand – general irrigation requirements
  - Agrico – design criteria and approaches
  - Floppie Sprinkler – design criteria and approaches
  - Netafim – irrigation requirements
  - Schoeman and partners – irrigation requirements; verification of registrations

- Tom Daines ex Dohne E Cape - irrigated pastures
- Richard Findlay Agricol seed KZ-N - irrigated pastures
- Astrid Hattingh ex Potchefstroom Agric College - soil science and pastures
- Dries Alberts ex Levubu experimental station – tropical/subtropical fruits and nuts
- Mauritz vd Heever Nylstroom - drip irrigation and shade cultivation
- Pieter Fourie Bethlehem - apple production under shade

- Other
    - I & E Estate, Komatipoort – irrigation requirements, irrigation requirement planning and management
    - Kynoch Fertilizers – irrigation requirements of crops
    - Farmers (several) – Downloading Sapwat and installation problems

6 UPGRADING OF THE WEB SITE

The website has been fully described in earlier reports and has been upgraded to fully document the modifications and upgrades currently in progress. This will be a continuation of an on-going process. The main function has been to facilitate access to downloading the programme obviating the need to copy and distribute CDs to new users as well as enabling existing users to keep pace with new versions of Windows as well as improvements to SAPWAT. Before downloading the programme from the Web users were required to register and provide addresses so that comprehensive information is available in the website database. There are 241 entries to date. There are, however, many more other users many of whom have acquired the programme through courses and personal contacts. An important ongoing task is the rewriting of the user manuals to reflect the "new" versions of SAPWAT. These will be available for downloading from the website.

The international nature of interest in Sapwat is depicted in Table 6.1.

Table 6.1 Distribution of SAPWAT web site registrations.

Country	Number
Algeria	1
Australia	4
Barbados	1
Belgium	1
Eritrea	1
France	1
Germany	1
India	2
Kenya	1
Namibia	1
South Africa	214
Swaziland	5
Teheran	1
Thailand	1
UK	1
USA	1
Venezuela	1
Zimbabwe	3

The dedicated Sapwat web site has been successful in fulfilling the need to supply the programme to a considerable number of people both in South Africa and overseas. This greatly reduced the administrative load on the limited Sapwat team. It was initially decided, however, not to utilise the Water Research Commission website because it was anticipated that access would be necessary for editing and modification purposes at fairly frequent intervals. This would have been difficult to achieve on the WRC website without impinging on security arrangements.

In the light of experience we are suggesting that the dedicated Sapwat website be discontinued and that Sapwat be incorporated in the WRC site in a simplified form. This would make it possible to download **Sapwat-admin** and its user manual only. In addition full contact details enabling interested persons to contact the Sapwat team would be provided. People wishing to obtain the more complete **Sapwat-management** programme would then be able to order from the team, preferably, or alternatively direct from WRC a CD comprising an installation program and a comprehensive user manual.

In the earlier days of Sapwat development the interest the programme would develop amongst practitioners in irrigation processes and management was grossly overestimated. A network was envisioned where people would be able to compare notes on the irrigation characteristics of crops and that the appropriateness and effectiveness of alternate irrigation methods. The Sapwat team were also apprehensive about the acceptability of the program to engineers and irrigation practitioners. It was with this in mind that the following features were included in the website:

- Registration of users based on the assumption that proactive follow-up contacts would be required to set the ball rolling.

- The facility to download individual crop files direct from the web site was developed on the assumption that users would welcome the opportunity to update their database from time to time.

- A chat page was included to enable irrigation enthusiasts to compare notes.

- A page that was updated from time to time that briefly described the various applications of Sapwat.

The team have, however, found in practice that designers, farmers and planners want answers that are officially acceptable and are in line with the practicalities of irrigated crop production. It is only the very few that have the deeper interest than originally imagined would apply on a broad front. The team have also been pleased with the ease with which users take to the programme and with the general acceptance that it has achieved. It has even been decided, as discussed under programming, to delete the " what-to-do" help feature that was previously included for each screen.

Requiring users to register before downloading was useful in the early stages but there was not the manpower or time available to follow up with a significant number of users on an ongoing basis. Users with problems made contact, in any event, by telephone or e-mail. In addition the chore of registering was an irritant and at times caused technical problems. The intention is, therefore, to simplify the website by eliminating features that now appear to be no longer necessary or didn't really yield dividends from the outset.

7 CONCLUSIONS

The purpose of this project, *The improvement of the SAPWAT database, operational and support systems to facilitate improved performance and interaction with other irrigation management and planning programmes and users as well as extending the scope and versatility of the program*, with the following specific objectives:

- linkage to and support of other irrigation management and planning programmes by improving programme file output
- linkage to and support for irrigation water planning users and advisors, including DWAF
- editing/refining crop factors
- upgrading of SAPWAT software
- upgrading of the website, maintenance of a user register and the inclusion of additional manuals and "how to do it" user support material
- provide electronic and telephonic support to users on an ongoing basis

was satisfied during its execution. The following has been done:

- SAPWAT software has been upgraded and screens were cleaned up and simplified. Two models now exist; one (SAPWAT-Admin) specifically aimed at the registration for water use process as required by the Department of Water Affairs and Forestry, and the other (SAPWAT-Management) for water use and management planning by WUA's and farmers, design of irrigation systems and for irrigation management analysis and advice. Except for the cleaning up of the screens and changes in the handling of data, notably changing from the South African seven climate zones to the Köppen-Geiger five climate zones for the country, the management model is still the old familiar SAPWAT. The admin model for use in the registration process contains the same first screens as the management model, but does not include soils and soil water balances. This is to ensure a more uniform set of results for administration purposes, as crop irrigation requirement can vary substantially due to management practices and especially the efficiency level at which rain water is utilised in the production process. Exporting data has been expanded to the extent that the admin model now enables export in CSV format that can be imported into any spreadsheet or database programme.
- Part of the upgrading was the conversion of the climate part of SAPWAT from the South African seven-region system to the internationally accepted Köppen-Geiger five-group system, of which three groups, or 12 climate regions, are found in Southern Africa. The Köppen-Geiger classification system is based on a combination of rainfall and temperature. As rainfall can be replaced by irrigation, it virtually becomes a system based on differences in temperature and partly on humidity, therefore it becomes relatively easy to interpret and link crop growth and development to the climate zones. Five Köppen-Geiger based climate regions could be defined for Southern Africa: Tropical; Humid/sub-humid, hot summers; Humid/sub-humid, warm summers; Arid/semi-arid, hot summers; Arid/semi-arid, warm summers.

- The change in the climate approach, as well as more recent information on the growth and development of some crops, necessitated the revision of the FAO-based crop factors included in the programme. All crop data, including cultivar and type differences, as well as the differences due to climate have been reviewed. The latest version includes 316 varieties of 99 crops. The linking of these to the five Köppen-Geiger climate zones result in a detail data file that contains more than 2400 records. See Appendix A

- Support was given to the Agricultural Economics Department of the University of the Free State for a WRC-funded project that they are doing on risk analysis with the Vaalharts irrigation area as the research area. On 30 000 cultivated hectares the farmers produce 14 crops with double cropping of some crops resulting in up to 170% land coverage. Substantially less water than the quota is ordered, possibly because of the utilisation of water table water. SAPWAT output was used as input for the Free State University project.

- Support was given to the "Water for Food" project in the Limpopo province where the irrigation requirements for vegetable production in home gardens under rainwater harvesting situations were estimated and simplified to approximate weekly requirements in an easy to understand manner, for example 20 mm per week for both maize and pumpkins grown in the Polokwane area in mid-summer. These requirements were linked to water harvesting potential from roofs and other suitable areas as well as grey water out of the house, and ratios between garden area and roof and other water harvest catchment areas were calculated so that a balance could be achieved between available water and garden area. Storage requirements to bridge periods when rainfall is not adequate for the crops were calculated. SAPWAT inputs were also used as a basis for the determination of a subsidy of R5000 per household for installing rainwater harvesting and required storage facilities

- The progression towards compulsory licensing of irrigation water users has taken a step forward with the approval of the ***Verification manual, a guide for the determination of existing lawful water uses*** by the Department of Water Affairs and Forestry. Sapwat support provided the methodology for the evaluation of irrigation water use and its inputs forms the basis of this manual.

- No full courses in the use of SAPWAT were given, as potential users indicated no need. However, personal support was given to personnel of six organisations and a demonstration in its application was also given. Electronic and telephonic support was given in 35 instances to national and provincial government departments, WUA's, tertiary training institutions, research institutes, researchers, consultants and farmers.

- The role of the web site in establishing a network of SAPWAT users who could interact with each other, the main reason for establishing a web site independent of the WRC web site, was grossly overestimated. A new web site, linked to the WRC web site, needs to be investigated. Services on such a proposed new web site will be the downloading of programmes, giving contact details of where assistance could be obtained and keeping a register of users in the present format. In the mean time, the register of users was updated and names of users can now be downloaded and manipulated with a minimum of fuss. The 241 entries in the register represent 18 countries.

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Appendix A

Crop Characteristics for use with SAPWAT

Some of the development of SAPWAT took place as a further development on CROPWAT (Smith, 1992), but before the publication of FAO Irrigation and Drainage Report No 56 (Allen *et al*, 1998), therefore some deviations are found from the classical FAO four-stage crop factor approach as described in FAO 56. It is therefore necessary to consider these when interpreting the data contained in this table for application in SAPWAT and for transporting this data to CROPWAT or some other similar model.

Days: The SAPWAT and CROPWAT year totals to 360 and not to 365 days. Should the total days for a crop be more than 360, overlapping of bars on the bar-graph occurs. This makes the interpretation of the graph difficult.

Kc-max and Foliage values: SAPWAT uses a dual crop coefficient approach for calculating Kc-values. In a way, Foliage values at the start and end of the growing season could be equated to Kcb-initial and Kcb-end values, although the values for CROPWAT might not be the same as for SAPWAT. Evaporation from the soil surface (equivalent to FAO 56 Ke) is calculated and the foliage value, indicating the level of foliar activity, is then added to give an equivalent for Kc-ini. Similar results as described in FAO 56 are found. SAPWAT Kc-max approximates FAO 56 Kc-max (single crop coefficient). A further use of Foliar values could be an upwards or downwards adjustment to reflect foliar activity that deviates from normal, such as for diseased plants or in cases of stomatal control. The user is advised not to input zero-values, unexpected results might occur!

Rooting depth, Depletion, Ky and Crop Height: Applied in the same way as described in FAO 56.

Some crops, for example winter cereals, where the development of the crop is strongly influenced by combinations of changes in daylight and temperature, has the characteristic that the total growing period varies with changes in planting date. In these cases, it is not possible to give a single, generalised set of values, and because SAPWAT does not have a mathematical sub-routine for adjusting this change in growing periods, a range of planting dates, each with its own related set of stage lengths, is included. The user is advised to select a planting date closest to his own for a good estimate of crop irrigation requirements. Planting date intervals of less than 10 days are not advised as year-on-year climatic variation would probabaly be bigger than differences found by providing for planting dates of less than 10 day intervals.

Deciduous fruit, nuts and grapes are included under generic subdivisions of early, middle and late varieties and a fair approximation could be made for most cultivars. However, some cultivars deviate substantially from the accepted values, which indicates that one should approximate these crops on a cultivar, or cultivar-type, basis. Further research is needed on this aspect. A need for further research on the four-stage approach for tree crops have also been identified by Allen *et al.*, 1998 which supports this need for further research.

Climatic conditions affect crop growth. It could, for instance, be stated as a general rule that crops would develop and grow quicker in warmer climates than in colder climates. Therefore climatic regions, and their influence on crop development, have been included in this table. Climatic regions are based on the internationally accepted Koppen Climate System (Strahler & Strahler, 2002), although the names of the climatic regions are changed to more generally used terms. Full transportability of the crop characteristic data to the international arena is now possible.

The Koppen A, B and C climatic regions, as applied in SAPWAT, are briefly defined as follows:

- A: Tropical: All warm average temperatures >18°C.

- B: Arid/Semi-arid, hot summers: Rainfall < 500 mm. Average annual temperature > 18°C. Average temperature of hottest month > 22°C.

Appendix A

Crop Characteristics for use with SAPWAT

- B: Arid/Semi-arid, warm summers: Rainfall < 500 mm. Average annual temperature > 18°C. Average temperature of hottest month < 22°C.</p>

- C: Humid/Sub-humid, hot summers: Rainfall > 500 mm. Average annual temperature > 18°C. Average temperature of hottest month > 22°C.

- C: Humid/Sub-humid, warm summers: Rainfall > 500 mm. Average annual temperature > 18°C. Average temperature of hottest month < 22°C.</p>

Cereals

Barley

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.200	0.40	0.60	0.80	0.40	1.00	1.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Plant 05/25	Arid/Semi-arid, hot summers	28	110	28	3	169	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	110	28	3	169	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	103	28	3	162	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	110	28	3	169	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	103	28	3	162	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Plant 06/05	Arid/Semi-arid, hot summers	28	99	28	3	158	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	99	28	3	158	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	92	28	3	151	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	99	28	3	158	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	92	28	3	151	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Plant 06/15	Arid/Semi-arid, hot summers	28	89	28	3	148	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	89	28	3	148	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	82	28	3	141	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	89	28	3	148	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	82	28	3	141	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Plant 06/25	Arid/Semi-arid, hot summers	28	79	28	3	138	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	79	28	3	138	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	72	28	3	131	1.15	1	1.00	1	0.50	0.50	0.50

Appendix A

Crop Characteristics for use with SAPWAT

	Humid/Sub-humid, warm summers	28	79	28	3	138	1.15	1	1.00	1	0.60	0.60	0.60
Plant 06/25	Tropical	28	72	28	3	131	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 07/05	Arid/Semi-arid, hot summers	28	69	28	3	128	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	69	28	3	128	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	62	28	3	121	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	69	28	3	128	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	62	28	3	121	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 07/15	Arid/Semi-arid, hot summers	28	59	28	3	118	1.15	1	1.00	1	0.40	0.40	4.00
	Arid/Semi-arid, warm summers	28	59	28	3	118	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	52	28	3	111	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	59	28	3	118	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	52	28	3	111	1.15	1	1.00	1	0.50	0.50	0.50

Allen et al., 1998, De Kock, 2004, Otto, 2004, Smith, 1992, Van Rensburg, 2004

Cereals

Maize

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.300	0.40	0.40	1.30	0.50	1.25	2.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Long grower, Early plant	Arid/Semi-arid, hot summers	21	49	70	10	150	1.15	1	1.00	1	0.40	0.40	0.80
	Arid/Semi-arid, warm summers	21	56	73	10	160	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, hot summers	21	49	70	10	150	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, warm summers	21	56	73	10	160	1.15	1	1.00	1	0.50	0.50	0.80
	Tropical	21	49	70	10	150	1.15	1	1.00	1	0.50	0.50	0.80

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Long grower, Late plant	Arid/Semi-arid, hot summers	21	38	81	10	150	1.15	1	1.00	1	0.40	0.40	0.80
	Arid/Semi-arid, warm summers	21	43	86	10	160	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, hot summers	21	38	81	10	150	1.15	1	1.00	1	0.50	0.50	0.80

Appendix A

Crop Characteristics for use with SAPWAT

	Humid/Sub-humid, warm summers	21	43	86	10	160	1.15	1	1.00	1	0.50	0.50	0.80
Long grower, Late plant	Tropical	21	38	81	10	150	1.15	1	1.00	1	0.50	0.50	0.80

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Medium grower, Early plant	Arid/Semi-arid, hot summers	21	40	69	10	140	1.15	1	1.00	1	0.40	0.40	0.80
	Arid/Semi-arid, warm summers	21	45	74	10	150	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, hot summers	21	40	69	10	140	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, warm summers	21	45	74	10	150	1.15	1	1.00	1	0.50	0.50	0.80
	Tropical	21	40	69	10	140	1.15	1	1.00	1	0.50	0.50	0.80

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Medium grower, Late plant	Arid/Semi-arid, hot summers	21	33	76	10	140	1.15	1	1.00	1	0.40	0.40	0.80
	Arid/Semi-arid, warm summers	21	38	81	10	150	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, hot summers	21	33	76	10	140	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, warm summers	21	38	81	10	150	1.15	1	1.00	1	0.50	0.50	0.80
	Tropical	21	33	76	10	140	1.15	1	1.00	1	0.50	0.50	0.80

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Short grower, Early plant	Arid/Semi-arid, hot summers	21	35	54	10	120	1.15	1	1.00	1	0.40	0.40	0.80
	Arid/Semi-arid, warm summers	21	40	59	10	130	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, hot summers	21	35	54	10	120	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, warm summers	21	40	59	10	130	1.15	1	1.00	1	0.50	0.50	0.80
	Tropical	21	35	54	10	120	1.15	1	1.00	1	0.50	0.50	0.80

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Short grower, Late plant	Arid/Semi-arid, hot summers	21	28	61	10	120	1.15	1	1.00	1	0.40	0.40	0.80
	Arid/Semi-arid, warm summers	21	33	66	10	130	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, hot summers	21	28	61	10	120	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, warm summers	21	33	66	10	130	1.15	1	1.00	1	0.50	0.50	0.80
	Tropical	21	28	61	10	120	1.15	1	1.00	1	0.50	0.50	0.80

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Ultra short grower, Early plant	Arid/Semi-arid, hot summers	21	37	42	10	110	1.15	1	1.00	1	0.40	0.40	0.80
	Arid/Semi-arid, warm summers	21	42	47	10	120	1.15	1	1.00	1	0.50	0.50	0.80

Appendix A

Crop Characteristics for use with SAPWAT

	Humid/Sub-humid, hot summers	21	37	42	10	110	1.15	1	1.00	1	0.50	0.50	0.80
Ultra short grower, Early plant	Humid/Sub-humid, warm summers	21	42	47	10	120	1.15	1	1.00	1	0.50	0.50	0.80
	Tropical	21	37	42	10	110	1.15	1	1.00	1	0.50	0.50	0.80

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Ultra short grower, Late plant	Arid/Semi-arid, hot summers	21	30	49	10	110	1.15	1	1.00	1	0.40	0.40	0.80
	Arid/Semi-arid, warm summers	21	35	54	10	120	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, hot summers	21	30	49	10	110	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, warm summers	21	35	54	10	120	1.15	1	1.00	1	0.50	0.50	0.80
	Tropical	21	30	49	10	110	1.15	1	1.00	1	0.50	0.50	0.80

Allen et al., 1998, Ceronio, 2004, Coetzee, 2004, Crosby & Crosby, 1999, Doorenbos et al., 1986, Du PLessis, 2003, Smith, 1992

Cereals

Oats

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.200	0.40	0.60	0.80	0.40	1.00	1.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 05/15	Arid/Semi-arid, hot summers	28	120	28	3	179	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	120	28	3	179	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	113	28	3	172	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	120	28	3	179	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	113	28	3	172	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 05/25	Arid/Semi-arid, hot summers	28	110	28	3	169	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	110	28	3	169	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	103	28	3	162	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	110	28	3	169	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	103	28	3	162	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 06/05	Arid/Semi-arid, hot summers	28	99	28	3	158	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	99	28	3	158	1.15	1	1.00	1	0.50	0.50	0.50

Appendix A

Crop Characteristics for use with SAPWAT

	Humid/Sub-humid, hot summers	28	92	28	3	151	1.15	1	1.00	1	0.50	0.50	0.50
Plant 06/05	Humid/Sub-humid, warm summers	28	99	28	3	158	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	92	28	3	151	1.15	1	1.00	1	0.60	0.60	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 06/15	Arid/Semi-arid, hot summers	28	89	28	3	148	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	89	28	3	148	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	82	28	3	141	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	89	28	3	148	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	82	28	3	141	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 06/25	Arid/Semi-arid, hot summers	28	79	28	3	138	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	79	28	3	138	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	72	28	3	131	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	79	28	3	138	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	72	28	3	131	1.15	1	1.00	1	0.50	0.50	0.50

Allen et al., 1998, Otto, 2004, Van Rensburg, 2004

Cereals

Rice

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.150	0.600	1.10	1.10	1.60	0.30	1.10	1.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Non-paddy, long grower	Humid/Sub-humid, hot summers	30	30	80	40	180	1.20	1	1.00	1	0.70	0.70	0.70

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Non-paddy, short grower	Humid/Sub-humid, hot summers	30	30	60	30	150	1.20	1	1.00	1	0.70	0.70	0.70

De Kock, 2004, McMohan, Kofranek & Rubatzky, 2002

Cereals

Appendix A

Crop Characteristics for use with SAPWAT

Rye

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.200	0.40	0.60	0.80	0.40	1.00	1.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 05/25	Arid/Semi-arid, hot summers	28	101	37	3	169	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	101	37	3	169	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	94	37	3	162	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	101	37	3	169	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	94	37	3	162	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 06/05	Arid/Semi-arid, hot summers	28	90	37	3	158	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	90	37	3	158	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	83	37	3	151	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	90	37	3	158	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	83	37	3	151	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 06/15	Arid/Semi-arid, hot summers	28	80	37	3	148	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	80	37	3	148	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	73	37	3	141	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	80	37	3	148	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	73	37	3	141	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 06/25	Arid/Semi-arid, hot summers	28	70	37	3	138	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	70	37	3	138	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	63	37	3	131	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	70	37	3	138	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	63	37	3	131	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 07/05	Arid/Semi-arid, hot summers	28	60	37	3	128	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	60	37	3	128	1.15	1	1.00	1	0.50	0.50	0.50

Appendix A

Crop Characteristics for use with SAPWAT

	Humid/Sub-humid, hot summers	28	53	37	3	121	1.15	1	1.00	1	0.50	0.50	0.50
Plant 07/05	Humid/Sub-humid, warm summers	28	60	37	3	128	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	53	37	3	121	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Plant 07/15	Arid/Semi-arid, hot summers	28	50	37	3	118	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	50	37	3	118	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	43	37	3	111	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	50	37	3	118	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	43	37	3	111	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Plant 07/25	Arid/Semi-arid, hot summers	28	40	37	3	108	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	40	37	3	108	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	33	37	3	101	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	40	37	3	108	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	33	37	3	101	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Plant 08/05	Arid/Semi-arid, hot summers	28	29	37	3	97	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	29	37	3	97	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	22	37	3	90	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	29	37	3	97	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	22	37	3	90	1.15	1	1.00	1	0.50	0.50	0.50

Otto, 2004

Cereals

Sweetcorn

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.000	0.40	0.40	1.30	0.50	1.25	1.90

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Early, Autumn plant	Arid/Semi-arid, hot summers	11	49	27	1	88	1.15	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	11	49	27	1	88	1.15	1	1.00	90	0.50	0.50	0.50

Appendix A

Crop Characteristics for use with SAPWAT

	Humid/Sub-humid, warm summers	11	29	47	1	88	1.15	1	1.00	90	0.50	0.50	0.50
Early, Autumn plant	Tropical	11	49	27	1	88	1.15	1	1.00	90	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Spring plant	Arid/Semi-arid, hot summers	10	44	24	1	79	1.15	1	1.00	90	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	10	47	26	1	84	1.15	1	1.00	90	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	10	44	24	1	79	1.15	1	1.00	90	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	10	47	26	1	84	1.15	1	1.00	90	0.50	0.50	0.50
	Tropical	10	44	24	1	79	1.15	1	1.00	90	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Summer plant	Arid/Semi-arid, hot summers	10	43	24	1	78	1.15	1	1.00	90	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	10	45	25	1	81	1.15	1	1.00	90	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	10	43	24	1	78	1.15	1	1.00	90	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	10	45	25	1	81	1.15	1	1.00	90	0.50	0.50	0.50
	Tropical	10	43	24	1	78	1.15	1	1.00	90	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Winter plant	Arid/Semi-arid, hot summers	11	50	28	1	90	1.15	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	11	50	28	1	90	1.15	1	1.00	90	0.50	0.50	0.50
	Tropical	11	50	28	1	90	1.15	1	1.00	90	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Autumn plant	Arid/Semi-arid, hot summers	11	54	32	1	98	1.15	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	11	54	32	1	98	1.15	1	1.00	90	0.50	0.50	0.50
	Tropical	11	54	32	1	98	1.15	1	1.00	90	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Spring plant	Arid/Semi-arid, hot summers	10	48	29	1	88	1.15	1	1.00	90	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	10	52	31	1	94	1.15	1	1.00	90	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	10	48	29	1	88	1.15	1	1.00	90	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	10	52	31	1	94	1.15	1	1.00	90	0.50	0.50	0.50
	Tropical	10	48	29	1	88	1.15	1	1.00	90	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Summer plant	Arid/Semi-arid, hot summers	10	48	29	1	88	1.15	1	1.00	90	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	10	50	30	1	91	1.15	1	1.00	90	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	10	48	29	1	88	1.15	1	1.00	90	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	10	50	30	1	91	1.15	1	1.00	90	0.50	0.50	0.50
	Tropical	10	48	29	1	88	1.15	1	1.00	90	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Winter plant	Arid/Semi-arid, hot summers	11	56	34	1	102	1.15	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	11	56	34	1	102	1.15	1	1.00	90	0.50	0.50	0.50
	Tropical	11	56	34	1	102	1.15	1	1.00	90	0.50	0.50	0.50

Allen et al., 1998, Jovanovic & Annandale, 1999

Cereals

Wheat

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.200	0.40	0.60	0.80	0.40	1.15	1.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 02/10 (Out of season, short grower)	Humid/Sub-humid, hot summers	21	28	28	3	80	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 05/25	Arid/Semi-arid, hot summers	28	101	37	3	169	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	101	37	3	169	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	94	37	3	162	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	101	37	3	169	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	94	37	3	162	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 06/05	Arid/Semi-arid, hot summers	28	90	37	3	158	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	90	37	3	158	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	83	37	3	151	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	90	37	3	158	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	83	37	3	151	1.15	1	1.00	1	0.50	0.50	0.50

Appendix A

Crop Characteristics for use with SAPWAT

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 06/15	Arid/Semi-arid, hot summers	28	80	37	3	148	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	80	37	3	148	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	73	37	3	141	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	80	37	3	148	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	73	37	3	141	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 06/25	Arid/Semi-arid, hot summers	28	70	37	3	138	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	70	37	3	138	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	63	37	3	131	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	70	37	3	138	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	63	37	3	131	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 07/05	Arid/Semi-arid, hot summers	28	60	37	3	128	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	60	37	3	128	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	53	37	3	121	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	60	37	3	128	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	53	37	3	121	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 07/15	Arid/Semi-arid, hot summers	28	50	37	3	118	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	50	37	3	118	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	43	37	3	111	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	50	37	3	118	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	43	37	3	111	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 07/25	Arid/Semi-arid, hot summers	28	40	37	3	108	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	40	37	3	108	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	33	37	3	101	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	40	37	3	108	1.15	1	1.00	1	0.60	0.60	0.60

Appendix A

Crop Characteristics for use with SAPWAT

	Tropical	28	33	37	3	101	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Plant 08/05	Arid/Semi-arid, hot summers	28	29	37	3	97	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	29	37	3	97	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	22	37	3	90	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	29	37	3	97	1.15	1	1.00	1	0.60	0.60	0.60
	Tropical	28	22	37	3	90	1.15	1	1.00	1	0.50	0.50	0.50

Allen et al., 1998, Coetzee, 2004, Crosby & Crosby, 1999, Doorenbos et al., 1986, Otto, 2004, Van Heerden et al., 2001, Van Rensburg, 2004, Wilken, 2004

Fibre crops

Cotton

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.400	0.40	0.40	0.50	0.40	1.00	1.20

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Long growers	Arid/Semi-arid, hot summers	35	70	63	28	196	1.10	1	1.00	30	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	35	70	63	28	196	1.10	1	1.00	30	0.50	0.50	0.50
	Tropical	35	70	63	28	196	1.10	1	1.00	30	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Medium growers	Arid/Semi-arid, hot summers	35	56	56	28	175	1.10	1	1.00	30	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	35	56	56	28	175	1.10	1	1.00	30	0.50	0.50	0.50
	Tropical	35	56	56	28	175	1.10	1	1.00	30	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Short growers	Arid/Semi-arid, hot summers	35	49	42	28	154	1.10	1	1.00	30	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	35	49	42	28	154	1.10	1	1.00	30	0.50	0.50	0.50
	Tropical	35	49	42	28	154	1.10	1	1.00	30	0.50	0.50	0.50

Allen et al., 1998, Dippenaar, 2003, McMohan, Kofranek & Rubatzky, 2002, Sentrale Katoenkoöperasie, undated, Viviers, 2003

Forages

Appendix A

Crop Characteristics for use with SAPWAT

Babala (Pennisetum typhoides)

Also referred to "Pearl millet" and "Nyoloti". In the USA also known as Pennisetum Glaucum. An important grain crop in parts of Africa. Prone to bird damage.

0.300_{ri}	1.200_{rd}	0.40_{i}	0.40_{v}	1.30_{d}	0.50_{l}	1.25_{m}	2.00_{ht}

Used in a cross with P purpureum to give "Bana gras".

If planted in too cold soil, the crop takes a long time to emergeg, and the initial period could be extended any number of days. If panted too late, the second and third phases are shortened and production is low.

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early plant	Arid/Semi-arid, hot summers	21	42	29	28	120	1.15	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	42	29	28	120	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	42	29	28	120	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	42	29	28	120	1.15	1	1.00	1	0.50	0.50	0.50
	Tropical	21	42	29	28	120	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late plant	Arid/Semi-arid, hot summers	21	21	20	28	90	1.15	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	21	20	28	90	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	21	20	28	90	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	21	20	28	90	1.15	1	1.00	1	0.50	0.50	0.50
	Tropical	21	21	20	28	90	1.15	1	1.00	1	0.50	0.50	0.50

Mappledoram, 2004, Meredith, 1959

Forages

Lucerne

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	0.80	0.80	0.80	0.80	1.10	0.70

Dormant and semi-dormant varieties are found in South Africa, although a very few places in the country allows full winter growth for the non-dormant types. Level of dormancy is a result of climate, more so than of the inherent characteristics of the crop itself.

For seed production, the following production practice is recommended:

Flowering in lucerne is light induced, therefore the best time for seed production should be mid-summer. Seed colour, and to a certain extent, quality, is adversely affected by rain during the period of seed production.

Full growth is allowed and full irrigation is supplied from winter until December. Then one irrigation after cutting and allow to go to flower without further irrigation. After reaping seed, the crop can be stimulated to grow again by the resumption of normal irrigation. If water is scarce, the crop can be left in a dormant state until after the following winter. Irrigation water requirement could be halved by going for seed production instead of hay production.

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Non-dormant	Arid/Semi-arid, hot summers	60	90	150	60	360	0.85	30	1.00	30	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	60	90	150	60	360	0.85	30	1.00	30	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	60	90	150	60	360	0.85	60	1.00	60	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	60	90	150	60	360	0.85	30	1.00	30	0.60	0.60	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Seed production	Arid/Semi-arid, hot summers	60	90	60	10	220	0.85	15	1.00	1	0.40	0.40	0.80

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Semi-dormant	Arid/Semi-arid, hot summers	60	90	120	90	360	0.85	15	1.00	15	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	60	90	150	60	360	0.85	15	1.00	15	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	60	90	150	60	360	0.85	30	1.00	30	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	60	90	120	90	360	0.85	15	1.00	15	0.60	0.60	0.60

Allen et al., 1998, Crosby & Crosby, 1999, De Kock, 2004

Forages

Pastures: perennial

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.900	0.900	0.80	0.80	0.80	0.80	0.80	0.20

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Fescue	Arid/Semi-arid, hot summers	60	60	210	30	360	0.90	1	1.00	80	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	60	60	210	30	360	0.90	1	1.00	60	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	60	60	210	30	360	0.80	1	1.00	60	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	60	60	210	30	360	0.90	1	1.00	60	0.60	0.60	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Kikuyu	Arid/Semi-arid, hot summers	60	90	120	90	360	0.80	60	1.00	60	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	90	90	90	90	360	0.80	30	1.00	30	0.50	0.50	0.50

	Humid/Sub-humid, hot summers	60	90	120	90	360	0.80	60	1.00	60	0.50	0.50	0.50
Kikuyu	Humid/Sub-humid, warm summers	90	90	90	90	360	0.80	30	1.00	30	0.50	0.50	0.50
	Tropical	60	90	120	90	360	0.80	90	1.00	90	0.50	0.50	0.50
Kikuyu-Ryegrass mix	Arid/Semi-arid, warm summers	90	90	90	90	360	0.80	100	1.00	100	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	0	0	0	0	0	0.80	100	1.00	100	0.50	0.50	0.50

De Kock, 2004, Dickinson & Hyam, 1984, Marais, Rethman & Annandale, 2002, Theron, 2002

Forages

Pastures: seasonal

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.900	0.80	0.80	0.80	0.80	0.80	0.20

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Ryegrass	Arid/Semi-arid, hot summers	10	30	200	10	250	1.00	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	10	30	200	10	250	1.00	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	10	30	200	10	250	1.00	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	10	30	200	10	250	1.00	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Sorghum x Sudangrass	Arid/Semi-arid, hot summers	14	28	84	14	140	0.90	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	14	28	84	14	140	0.90	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	14	28	84	14	140	0.90	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	14	28	84	14	140	0.90	1	1.00	1	0.50	0.50	0.50
	Tropical	14	28	84	14	140	0.90	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter cereals: Plant 03/05	Arid/Semi-arid, hot summers	28	186	37	3	254	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	186	37	3	254	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	186	37	3	254	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	186	37	3	254	1.15	1	1.00	1	0.60	0.60	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter cereals: Plant 05/05	Arid/Semi-arid, hot summers	28	125	37	3	193	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	125	37	3	193	1.15	1	1.00	1	0.50	0.50	0.50

	Humid/Sub-humid, hot summers	28	125	37	3	193	1.15	1	1.00	1	0.50	0.50	0.50
Winter cereals: Plant 05/05	Humid/Sub-humid, warm summers	28	125	37	3	193	1.15	1	1.00	1	0.60	0.60	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter cereals: Plant 07/05	Arid/Semi-arid, hot summers	28	64	37	3	132	1.15	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	28	64	37	3	132	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	28	64	37	3	132	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	28	64	37	3	132	1.15	1	1.00	1	0.60	0.60	0.60

De Kock, 2004, Dickinson & Hyam, 1984, Marais, Rethman & Annandale, 2002, Theron, 2002

Forages

Saltbush

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.500	1.500	1.00	1.00	1.00	1.00	1.00	2.00

Given enough water, this drought resistant fodder crop will use water at least as lavishly as lucerne. Under water stress conditions a stomatal control is activated, so that even under those conditions good growth is found.

Where irrigated and under water scarce conditions, it is recommended that not more that 600 mm be given per annum.

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Atriplex	Arid/Semi-arid, hot summers	90	30	210	30	360	1.20	59	0.50	50	0.70	0.70	0.80
	Arid/Semi-arid, warm summers	90	30	210	30	360	1.20	50	0.50	50	0.80	0.80	0.80
	Humid/Sub-humid, hot summers	90	30	210	30	360	1.20	50	0.50	50	0.80	0.80	0.80
	Humid/Sub-humid, warm summers	90	30	210	30	360	1.20	50	0.50	50	0.80	0.80	0.80

De Kock, 2004

Forages

Sorghum

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.200	0.40	0.60	0.80	0.40	0.90	1.20

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Grain	Arid/Semi-arid, hot summers	14	28	84	14	140	1.15	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	14	28	84	14	140	1.15	1	1.00	1	0.50	0.50	0.50

	Humid/Sub-humid, hot summers	14	28	84	14	140	1.15	1	1.00	1	0.50	0.50	0.50
Grain	Humid/Sub-humid, warm summers	14	28	84	14	140	1.15	1	1.00	1	0.50	0.50	0.50
	Tropical	14	28	84	14	140	1.15	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Silage	Arid/Semi-arid, hot summers	14	28	84	14	140	1.15	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	14	28	84	14	140	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	14	28	84	14	140	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	14	28	84	14	140	1.15	1	1.00	1	0.50	0.50	0.50
	Tropical	14	26	96	14	150	1.15	1	1.00	1	0.50	0.50	0.50

Booyens, 2004

Fruit trees

Almonds

Prefers mild, wet winters and warm dry summers

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	0.80	0.80	0.80	0.80	0.80	5.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	21	77	98	28	224	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	77	98	28	224	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	77	98	28	224	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	77	98	28	224	1.00	1	1.00	10	0.50	0.50	0.50

Allen et al., 1998, McMohan, Kofranek & Rubatzky, 2002

Fruit trees

Apples

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	0.80	0.80	0.80	0.80	0.80	4.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Golden Delicious	Arid/Semi-arid, warm summers	10	75	93	98	276	1.00	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	10	75	98	93	276	1.00	1	1.00	1	0.50	0.50	0.50

Appendix A

Crop Characteristics for use with SAPWAT

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Granny Smith	Arid/Semi-arid, warm summers	10	168	84	42	304	1.00	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	10	168	84	42	304	1.00	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late	Arid/Semi-arid, warm summers	21	91	140	28	280	1.00	1	1.00	10	0.50	0.50	0.50
	Arid/Semi-arid, warm summers	21	63	112	28	224	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	91	140	28	280	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	63	112	28	224	1.00	1	1.00	10	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Middle	Arid/Semi-arid, warm summers	21	77	126	28	252	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	77	126	28	252	1.00	1	1.00	10	0.50	0.50	0.50

Allen et al., 1998, McMohan, Kofranek & Rubatzky, 2002, North, 2004, Volschenk et al., 2003

Fruit trees

Apricots

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	0.80	0.80	0.80	0.80	0.80	3.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early	Arid/Semi-arid, hot summers	21	91	140	28	280	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	91	140	28	280	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	91	140	28	280	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	91	140	28	280	1.00	1	1.00	10	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late	Arid/Semi-arid, hot summers	21	63	112	28	224	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	63	112	28	224	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	63	112	28	224	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	63	112	28	224	1.00	1	1.00	10	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late

Middle	Arid/Semi-arid, hot summers	21	77	126	28	252	1.00	1	1.00	10	0.40	0.40	0.50
Middle	Arid/Semi-arid, warm summers	21	77	126	28	252	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	77	126	28	252	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	77	126	28	252	1.00	1	1.00	10	1.00	0.50	0.50

Allen et al., 1998, McMohan, Kofranek & Rubatzky, 2002, North, 2004

Fruit trees

Cherries

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	0.80	0.80	0.80	0.80	0.80	4.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early	Arid/Semi-arid, warm summers	21	40	19	165	245	1.10	1	1.00	10	0.75	0.50	0.50
	Humid/Sub-humid, warm summers	21	40	19	165	245	1.10	1	1.00	10	0.75	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late	Arid/Semi-arid, warm summers	21	40	62	122	245	1.10	1	1.00	10	0.75	0.50	0.50
	Humid/Sub-humid, warm summers	21	40	62	122	245	1.10	1	1.00	10	0.75	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Middle	Arid/Semi-arid, warm summers	21	40	47	135	243	1.10	1	1.00	10	0.75	0.50	0.50
	Humid/Sub-humid, warm summers	21	40	47	139	247	1.10	1	1.00	10	0.75	0.50	0.50

Allen et al., 1998, McMohan, Kofranek & Rubatzky, 2002

Fruit trees

Citrus

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.200	1.200	0.50	0.80	1.00	1.00	1.20	4.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Above average	Arid/Semi-arid, hot summers	60	90	120	90	360	1.00	100	0.80	100	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	60	90	120	90	360	1.00	100	0.80	100	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	60	90	120	90	360	1.00	100	0.80	100	0.50	0.50	0.50

	Humid/Sub-humid, warm summers	60	90	120	90	360	1.00	100	0.80	100	0.60	0.60	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Average	Arid/Semi-arid, hot summers	60	90	120	90	360	1.00	100	0.70	100	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	60	90	120	90	360	1.00	100	0.70	100	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	60	90	120	90	360	1.00	100	0.70	100	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	60	90	120	90	360	1.00	100	0.70	100	0.60	0.60	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Below average	Arid/Semi-arid, hot summers	60	90	120	90	360	1.00	100	0.60	100	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	60	90	120	90	360	1.00	100	0.60	100	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	60	90	120	90	360	1.00	100	0.60	100	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	60	90	120	90	360	1.00	100	0.60	100	0.60	0.60	0.60

Allen et al., 1998, Childs, 2002, Crosby & Crosby, 1999, McMohan, Kofranek & Rubatzky, 2002, Smith, 1992

Fruit trees

Guavas

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.900	0.900	0.80	0.80	0.80	0.80	0.80	4.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Estimate cover	Humid/Sub-humid, hot summers	165	60	105	30	360	1.10	100	1.00	100	0.50	0.50	0.50
	Tropical	165	60	105	30	360	1.10	100	1.00	100	0.50	0.50	0.50

Du Preez, 2003, McMohan, Kofranek & Rubatzky, 2002

Fruit trees

Macadamia nuts

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	1.00	1.00	1.00	1.00	1.00	5.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
	Arid/Semi-arid, hot summers	90	90	90	90	360	1.00	100	1.00	100	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	90	90	90	90	360	1.00	100	1.00	100	0.50	0.50	0.50

	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
	Tropical	90	90	90	90	360	1.00	100	1.00	100	0.50	0.50	0.50

Albertse, 2004, McMohan, Kofranek & Rubatzky, 2002

Fruit trees

Nectarine

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	0.80	0.80	0.80	0.80	0.80	3.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early	Arid/Semi-arid, hot summers	21	119	116	28	284	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	119	116	28	284	1.10	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	119	116	28	284	1.10	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	119	116	28	284	1.10	1	1.00	10	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late	Arid/Semi-arid, hot summers	21	102	63	28	214	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	102	63	28	214	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	102	63	28	214	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	102	63	28	214	1.00	1	1.00	10	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Middle	Arid/Semi-arid, hot summers	21	112	84	28	245	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	112	84	28	245	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	112	84	28	245	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	112	84	28	245	1.00	1	1.00	10	0.50	0.50	0.50

Allen et al., 1998, McMohan, Kofranek & Rubatzky, 2002, North, 2004

Fruit trees

Olives

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.500	1.500	1.00	1.00	1.00	1.00	1.00	4.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late

Appendix A

Crop Characteristics for use with SAPWAT

Estimate cover	Arid/Semi-arid, hot summers	120	90	60	90	360	1.10	1	1.00	30	0.60	0.60	0.70
Estimate cover	Arid/Semi-arid, warm summers	120	90	60	90	360	1.10	1	1.00	30	0.70	0.70	0.70

Allen et al., 1998, Netafim, 2002

Fruit trees

Peaches

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	0.80	0.80	0.80	0.80	0.80	3.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early	Arid/Semi-arid, hot summers	21	119	116	28	284	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	119	116	28	284	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	119	116	28	284	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	119	116	28	284	1.00	1	1.00	10	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Keisie & Neethling	Arid/Semi-arid, hot summers	33	102	113	29	277	1.00	1	1.00	1	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late	Arid/Semi-arid, hot summers	21	102	63	0	186	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	102	63	28	214	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	102	63	28	214	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	102	63	28	214	1.00	1	1.00	10	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Middle	Arid/Semi-arid, hot summers	21	112	84	28	245	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	112	84	28	245	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	112	84	28	245	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	112	84	28	245	1.00	1	1.00	10	0.50	0.50	0.50

Allen et al., 1998, North, 2004, Volschenk et al., 2003

Fruit trees

Appendix A

Crop Characteristics for use with SAPWAT

Pears

	Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
	1.000	1.000	0.80	0.80	0.80	0.80	0.80	4.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early	Arid/Semi-arid, warm summers	21	63	133	63	280	1.00	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	63	133	63	280	1.00	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late	Arid/Semi-arid, warm summers	21	49	84	66	220	1.00	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	49	84	66	220	1.00	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Middle	Arid/Semi-arid, warm summers	21	56	112	62	251	1.00	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	56	112	62	251	1.00	1	1.00	1	0.50	0.50	0.50

Allen et al., 1998, McMohan, Kofranek & Rubatzky, 2002, North, 2004, Volschenk et al., 2003

Fruit trees

Pecan nuts

	Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
	1.000	1.000	1.00	1.00	1.00	1.00	1.00	5.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Estimate cover	Arid/Semi-arid, hot summers	21	30	90	120	261	1.00	1	1.00	1	0.40	0.40	0.80
	Humid/Sub-humid, hot summers	21	30	90	120	261	1.00	1	1.00	1	0.50	0.50	0.80

McMohan, Kofranek & Rubatzky, 2002

Fruit trees

Pistachio nuts

	Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
	1.000	1.000	0.80	0.80	0.80	0.80	0.80	4.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
	Arid/Semi-arid, hot summers	21	30	135	75	261	1.00	1	1.00	10	0.65	0.40	0.50

Appendix A

Crop Characteristics for use with SAPWAT

	Arid/Semi-arid, warm summers	21	30	135	75	261	1.10	1	1.00	10	0.75	0.50	0.50

Allen et al., 1998, McMohan, Kofranek & Rubatzky, 2002

Fruit trees

Plums

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	0.80	0.80	0.80	0.80	0.80	4.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Early	Arid/Semi-arid, hot summers	21	91	140	28	280	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	91	140	28	280	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	91	140	28	280	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	91	140	28	280	1.00	1	1.00	10	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Late	Arid/Semi-arid, hot summers	21	63	112	28	224	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	83	112	28	244	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	63	112	28	224	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	63	112	28	224	1.00	1	1.00	10	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Middle	Arid/Semi-arid, hot summers	21	77	126	28	252	1.00	1	1.00	10	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	77	126	28	252	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	77	126	28	252	1.00	1	1.00	10	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	77	126	28	252	1.00	1	1.00	10	0.50	0.50	0.50

Allen et al., 1998, McMohan, Kofranek & Rubatzky, 2002, North, 2004

Fruit trees

Walnuts

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
2.000	2.000	1.00	1.00	1.00	1.00	1.00	5.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late

Appendix A

Crop Characteristics for use with SAPWAT

Estimate cover	Arid/Semi-arid, hot summers	10	10	130	30	180	1.00	1	1.00	1	0.40	0.40	0.80
Estimate cover	Arid/Semi-arid, warm summers	10	10	130	30	180	1.10	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, hot summers	10	10	130	30	180	1.10	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, warm summers	10	10	130	30	180	1.10	1	1.00	1	0.50	0.50	0.80

Allen et al., 1998, McMohan, Kofranek & Rubatzky, 2002

Grapes and Berries

Berries

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	0.20	0.70	0.85	0.40	0.85	1.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, warm summers	120	40	110	90	360	1.10	1	1.00	30	0.75	0.40	0.40
	Humid/Sub-humid, warm summers	120	40	110	90	360	1.10	1	1.00	30	0.75	0.40	0.40

Allen et al., 1998, McMohan, Kofranek & Rubatzky, 2002

Grapes and Berries

Grapes

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.500	1.500	0.20	0.70	0.85	0.40	0.85	0.20

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Table, Early	Arid/Semi-arid, hot summers	125	35	96	104	360	0.80	1	1.00	10	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	125	35	96	104	360	0.80	1	1.00	10	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	125	35	96	104	360	0.80	1	1.00	10	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Table, Late	Arid/Semi-arid, hot summers	133	35	136	56	360	0.80	1	1.00	10	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	133	35	136	56	360	0.80	1	1.00	10	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	133	35	136	56	360	0.80	1	1.00	10	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Table, Middle	Arid/Semi-arid, hot summers	129	35	116	80	360	0.80	1	1.00	10	0.40	0.40	0.40

Appendix A

Crop Characteristics for use with SAPWAT

	Arid/Semi-arid, warm summers	129	35	96	100	360	0.80	1	1.00	10	0.40	0.40	0.40
Table, Middle	Humid/Sub-humid, hot summers	129	35	116	80	360	0.80	1	1.00	10	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Wine, Early	Arid/Semi-arid, hot summers	129	35	116	80	360	0.65	1	1.00	10	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	129	35	116	80	360	0.65	1	1.00	10	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	125	35	96	104	360	0.65	1	1.00	10	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Wine, Late	Arid/Semi-arid, hot summers	133	35	136	56	360	0.65	1	1.00	10	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	133	35	136	56	360	0.65	1	1.00	10	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	133	35	136	56	360	0.65	1	1.00	10	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Wine, Middle	Arid/Semi-arid, hot summers	133	35	136	56	360	0.65	1	1.00	1	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	133	35	136	56	360	0.65	1	1.00	10	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	129	35	116	80	360	0.65	1	1.00	10	0.40	0.40	0.40

Allen et al., 1998

Legumes

Beans Bush	Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
	0.300	0.900	0.20	0.60	1.00	0.40	1.15	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Dry, Long	Arid/Semi-arid, hot summers	20	20	55	5	100	1.15	1	1.00	1	0.45	0.45	0.60
	Arid/Semi-arid, warm summers	20	30	50	5	105	1.15	1	1.00	1	0.45	0.45	0.60
	Humid/Sub-humid, hot summers	20	20	55	5	100	1.15	1	1.00	1	0.45	0.45	0.60
	Humid/Sub-humid, warm summers	20	30	50	5	105	1.15	1	1.00	1	0.45	0.45	0.60
	Tropical	20	20	55	5	100	1.15	1	1.00	1	0.45	0.45	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Dry, Medium	Arid/Semi-arid, hot summers	20	17	48	5	90	1.15	1	1.00	1	0.45	0.45	0.60
	Arid/Semi-arid, warm summers	20	25	45	5	95	1.15	1	1.00	1	0.45	0.45	0.60

Dry, Medium	Humid/Sub-humid, hot summers	20	17	48	5	90	1.15	1	1.00	1	0.45	0.45	0.60
	Humid/Sub-humid, warm summers	20	25	45	5	95	1.15	1	1.00	1	0.45	0.45	0.60
	Tropical	20	17	48	5	90	1.15	1	1.00	1	0.45	0.45	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Dry, Short	Arid/Semi-arid, hot summers	20	15	40	5	80	1.15	1	1.00	1	0.45	0.45	0.60
	Arid/Semi-arid, warm summers	20	20	40	5	85	1.15	1	1.00	1	0.45	0.45	0.60
	Humid/Sub-humid, hot summers	20	15	40	5	80	1.15	1	1.00	1	0.45	0.45	0.60
	Humid/Sub-humid, warm summers	20	20	40	5	85	1.15	1	1.00	1	0.45	0.45	0.60
	Tropical	20	15	40	5	80	1.15	1	1.00	1	0.45	0.45	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Green	Arid/Semi-arid, hot summers	14	28	27	1	70	1.00	1	1.00	85	0.45	0.45	0.60
	Arid/Semi-arid, warm summers	14	28	27	1	70	1.00	1	1.00	85	0.45	0.45	0.60
	Humid/Sub-humid, hot summers	14	28	27	1	70	1.00	1	1.00	85	0.45	0.45	0.60
	Humid/Sub-humid, warm summers	14	28	27	1	70	1.00	1	1.00	85	0.45	0.45	0.60
	Tropical	14	28	27	1	70	1.00	1	1.00	85	0.45	0.45	0.60

Allen et al., 1998, Jovanovic & Annandale, 1999, Liebenberg, 2002, Van Wyk, 1992

Legumes

Beans Runner

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.900	0.20	0.60	1.00	0.40	11.15	1.20

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	7	35	28	7	77	1.05	1	1.00	85	0.45	0.45	0.45
	Arid/Semi-arid, warm summers	7	35	28	7	77	1.05	1	1.00	85	0.45	0.45	0.45
	Humid/Sub-humid, hot summers	7	35	28	7	77	1.05	1	1.00	85	0.45	0.45	0.45
	Humid/Sub-humid, warm summers	7	35	28	7	77	1.05	1	1.00	85	0.00	0.00	0.00
	Tropical	7	35	28	7	77	1.05	1	1.00	85	0.45	0.45	0.45

Allen et al., 1998, Jovanovic & Annandale, 1999, Van Wyk, 1992

Appendix A

Crop Characteristics for use with SAPWAT

Legumes

Cow peas

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.000	0.40	0.80	1.00	0.40	0.85	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	21	28	28	21	98	1.10	1	1.00	45	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	28	28	21	98	1.10	1	1.00	45	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	28	28	21	98	1.10	1	1.00	45	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	28	28	21	98	1.10	1	1.00	45	0.50	0.50	0.50
	Tropical	21	28	28	21	98	1.10	1	1.00	45	0.50	0.50	0.50

Allen et al., 1998

Legumes

Groundnuts

The types of groundnuts grown in South Africa, the so-called spanish types, have a growing season that could reach 180 days. The growing season can be shortened because of the influence of diseases, etc. In SA the crop is usually "pulled" at 150 to 160 days and stacked in small heaps to dry out. Under irrigation the exact time of pulling is usually determined by the planting date of the following crop, or the incidence of first frost in the case of the growing of the crop in areas prone to frost.

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.800	0.40	0.60	0.80	0.40	0.70	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
	Arid/Semi-arid, hot summers	28	35	90	7	160	1.10	1	1.00	70	0.45	0.45	0.50
	Humid/Sub-humid, hot summers	28	35	90	7	160	1.10	1	1.00	70	0.45	0.45	0.50
	Tropical	28	35	90	7	160	1.10	1	1.00	70	0.45	0.45	0.50

Allen et al., 1998, Jansen, 2004, McMohan, Kofranek & Rubatzky, 2002

Legumes

Lentils

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.700	0.20	0.60	1.00	0.40	1.15	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
	Arid/Semi-arid, hot summers	25	35	70	40	170	1.10	1	1.00	1	0.45	0.45	0.60

Appendix A

Crop Characteristics for use with SAPWAT

	Arid/Semi-arid, warm summers	25	35	70	40	170	1.10	1	1.00	1	0.45	0.45	0.60
Standard	Humid/Sub-humid, hot summers	25	35	70	40	170	1.10	1	1.00	1	0.45	0.45	0.60
	Humid/Sub-humid, warm summers	25	35	70	40	170	1.10	1	1.00	1	0.45	0.45	0.60

Allen et al., 1998

Legumes

Peas

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	1.000	0.20	0.90	0.70	0.20	1.15	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
General	Arid/Semi-arid, hot summers	20	30	35	15	100	1.10	1	1.00	90	0.30	0.40	0.40
	Arid/Semi-arid, warm summers	20	30	35	15	100	1.10	1	1.00	90	0.30	0.40	0.40
	Humid/Sub-humid, hot summers	20	30	35	15	100	1.10	1	1.00	90	0.30	0.40	0.40
	Humid/Sub-humid, warm summers	20	30	35	15	100	1.10	1	1.00	90	0.30	0.40	0.40
	Tropical	20	30	35	15	100	1.10	1	1.00	90	0.30	0.40	0.40

Allen et al., 1998, Van Wyk, 1992

Legumes

Soybeans

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.000	0.40	0.80	1.00	0.40	0.85	0.75

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Long	Arid/Semi-arid, hot summers	21	35	77	7	140	1.10	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	35	77	7	140	1.10	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	35	77	7	140	1.10	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	35	77	7	140	1.10	1	1.00	1	0.50	0.50	0.50
	Tropical	21	35	77	7	140	1.10	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Medium	Arid/Semi-arid, hot summers	21	28	70	7	126	1.10	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	28	70	7	126	1.10	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	28	70	7	126	1.10	1	1.00	1	0.50	0.50	0.50

Medium	Humid/Sub-humid, warm summers	21	28	70	7	126	1.10	1	1.00	1	0.50	0.50	0.50
	Tropical	21	28	70	7	126	1.10	1	1.00	1	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Short	Arid/Semi-arid, hot summers	21	21	63	7	112	1.10	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	21	63	7	112	1.10	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	21	63	7	112	1.10	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	21	63	7	112	1.10	1	1.00	1	0.50	0.50	0.50
	Tropical	21	21	63	7	112	1.10	1	1.00	1	0.50	0.50	0.50

Allen et al., 1998, Hagan, Haise & Edminster, 1967, McMohan, Kofranek & Rubatzky, 2002, Smit, 2003

Oil crops

Canola

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.900	1.00	1.00	1.00	1.00	1.00	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	30	40	30	20	120	1.15	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	30	40	30	20	120	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	30	40	30	20	120	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	30	40	30	20	120	1.15	1	1.00	1	0.50	0.50	0.50

De Kock, 2004

Oil crops

Sunflower

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.300	0.40	0.60	0.80	0.80	0.95	2.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
	Arid/Semi-arid, hot summers	21	35	42	21	119	1.15	1	1.00	1	0.40	0.40	0.80
	Arid/Semi-arid, warm summers	21	35	42	21	119	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, hot summers	21	35	42	21	119	1.15	1	1.00	1	0.50	0.50	0.80
	Humid/Sub-humid, warm summers	21	35	42	21	119	1.15	1	1.00	1	0.50	0.50	0.80

Appendix A

Crop Characteristics for use with SAPWAT

	Tropical	21	35	42	21	110	1.15	1	1.00	1	0.50	0.50	0.80

Allen et al., 1998. Nel, 2003

Other

Cut flowers

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.900	0.900	0.80	0.80	0.80	0.80	0.80	0.90

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	60	30	240	30	360	1.10	60	1.00	60	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	60	30	240	30	360	1.10	60	1.00	60	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	60	30	240	30	360	1.10	60	1.00	60	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	60	30	240	30	360	1.10	60	1.00	60	0.50	0.50	0.50
	Tropical	60	30	240	30	360	1.10	60	1.00	60	0.50	0.50	0.50

Other

Opuntia

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.750	0.750	1.00	1.00	1.00	1.00	1.00	1.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Spineless cactus	Arid/Semi-arid, hot summers	90	60	60	150	360	0.50	30	1.00	30	0.70	0.70	0.80
	Arid/Semi-arid, warm summers	90	60	60	150	360	0.50	30	1.00	30	0.80	0.80	0.80

De Kock, 2004

Other

Tobacco

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	1.000	0.40	1.00	1.00	0.50	0.90	2.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
All areas	Arid/Semi-arid, hot summers	25	30	35	30	120	1.10	1	1.00	50	0.40	0.40	0.65

	Humid/Sub-humid, hot summers	25	30	35	30	120	1.10	1	1.00	50	0.40	0.50	0.65
All areas	Tropical	30	30	60	15	135	1.10	1	1.00	50	0.40	0.50	0.65

Roots and Tubers

Beetroot

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.800	0.50	0.80	1.20	1.00	1.10	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer crop	Arid/Semi-arid, hot summers	15	25	30	10	80	1.00	1	1.00	90	0.40	0.50	0.60
	Arid/Semi-arid, warm summers	15	25	30	10	80	1.00	1	1.00	90	0.50	0.60	0.60
	Humid/Sub-humid, hot summers	15	25	30	10	80	1.00	1	1.00	90	0.50	0.60	0.60
	Humid/Sub-humid, warm summers	15	25	30	10	80	1.00	1	1.00	90	0.50	0.60	0.60
	Tropical	15	25	30	10	80	1.00	1	1.00	90	0.50	0.60	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter crop	Arid/Semi-arid, hot summers	25	25	35	5	90	1.00	1	1.00	90	0.40	0.50	0.60
	Arid/Semi-arid, warm summers	25	25	35	5	90	1.00	1	1.00	90	0.50	0.60	0.60
	Humid/Sub-humid, hot summers	25	25	35	5	90	1.00	1	1.00	90	0.50	0.60	0.60
	Humid/Sub-humid, warm summers	25	25	35	5	90	1.00	1	1.00	90	0.50	0.60	0.60
	Tropical	25	25	35	5	90	1.00	1	1.00	90	0.50	0.60	0.60

Allen et al., 1998, Jovanovic & Annandale, 1999, Van Wyk, 1992

Roots and Tubers

Chicory

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.200	0.50	0.80	1.20	1.00	1.10	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Autumn plant	Arid/Semi-arid, warm summers	56	56	112	56	280	1.00	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	56	56	112	56	280	1.00	1	1.00	1	0.50	0.50	0.50

Appendix A

Crop Characteristics for use with SAPWAT

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Spring plant	Arid/Semi-arid, warm summers	56	49	77	98	280	1.10	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	56	49	77	98	280	1.10	1	1.00	1	0.50	0.50	0.50

Aucamp, 1978, De Kock, 2004, Luckman, 2002

Roots and Tubers

Potatoes

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.600	0.45	0.80	0.80	0.30	1.10	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Medium growers, Autumn/Winter plant	Humid/Sub-humid, hot summers	28	35	50	15	128	1.15	1	1.00	40	0.50	0.50	0.50
	Tropical	28	35	50	15	128	1.15	1	1.00	40	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Medium growers, Spring plant	Arid/Semi-arid, hot summers	25	28	45	15	113	1.15	1	1.00	40	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	25	28	45	15	113	1.15	1	1.00	40	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	25	28	45	15	113	1.15	1	1.00	40	0.50	0.50	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Medium growers, Summer plant	Arid/Semi-arid, hot summers	21	24	45	15	105	1.15	1	1.00	40	0.40	0.40	0.50

Allen et al., 1998, Steyn, 2004, Van Wyk, 1992

Roots and Tubers

Radishes

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.500	0.50	0.80	1.20	1.00	1.10	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer crop	Arid/Semi-arid, hot summers	7	14	14	7	42	1.10	1	1.00	1	0.40	0.50	0.60
	Arid/Semi-arid, warm summers	7	14	14	7	42	1.10	1	1.00	1	0.50	0.60	0.60
	Humid/Sub-humid, hot summers	7	14	14	7	42	1.10	1	1.00	1	0.50	0.60	0.60
	Humid/Sub-humid, warm summers	7	14	14	7	42	1.10	1	1.00	1	0.50	0.60	0.60

Appendix A

Crop Characteristics for use with SAPWAT

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
	Tropical	7	14	14	7	42	1.10	1	1.00	1	0.50	0.60	0.60

Allen et al., 1998, Van Wyk, 1992

Roots and Tubers

Sugar-beet

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.000	0.75	0.50	0.10	1.00	1.00	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, warm summers	30	60	150	1	241	1.15	1	1.00	90	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	30	60	150	1	241	1.15	1	1.00	90	0.50	0.60	0.60

Allen et al., 1998, Cooke & Scott, 1993, De Kock, 2004

Roots and Tubers

Sweet potatoes

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.300	0.40	0.40	1.30	0.50	1.25	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer	Arid/Semi-arid, hot summers	20	30	60	40	150	1.10	1	1.00	70	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	20	30	60	40	150	1.10	1	1.00	70	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	15	30	50	30	125	1.10	1	1.00	70	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	20	30	60	40	150	1.10	1	1.00	70	0.50	0.50	0.50
	Tropical	15	30	50	30	125	1.10	1	1.00	70	0.50	0.50	0.50

Allen et al., 1998

Roots and Tubers

Turnips

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.800	0.40	0.40	0.40	0.50	0.85	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	10	30	60	1	101	1.00	1	1.00	90	0.25	0.40	0.50

	Arid/Semi-arid, warm summers	10	30	60	1	101	1.00	1	1.00	90	0.25	0.50	0.50
Standard	Humid/Sub-humid, hot summers	10	30	60	1	101	1.00	1	1.00	90	0.25	0.50	0.50
	Humid/Sub-humid, warm summers	10	30	60	1	101	1.00	1	1.00	90	0.25	0.50	0.50
	Tropical	10	30	60	1	101	1.00	1	1.00	90	0.25	0.50	0.50

Allen et al., 1998

Sugar-cane

Sugar-cane

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.500	1.500	0.75	0.50	0.10	1.00	1.20	3.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Autumn harvest	Humid/Sub-humid, hot summers	30	170	100	60	360	1.20	1	1.00	70	0.50	0.50	0.90
	Tropical	30	170	100	60	360	1.20	1	1.00	70	0.50	0.50	0.90

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Spring harvest	Humid/Sub-humid, hot summers	30	110	180	40	360	1.20	1	1.00	70	0.50	0.50	0.90
	Tropical	30	110	180	41	361	1.20	1	1.00	70	0.50	0.50	0.90

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer harvest	Humid/Sub-humid, hot summers	20	100	190	50	360	1.20	1	1.00	70	0.50	0.50	0.90
	Tropical	20	100	190	50	360	1.20	1	1.00	70	0.50	0.50	0.90

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter harvest	Humid/Sub-humid, hot summers	40	140	130	70	380	1.20	1	1.00	70	0.50	0.50	0.90
	Tropical	40	140	130	70	380	1.20	1	1.00	70	0.50	0.50	0.90

Allen et al., 1998, Inman-Bamber & McGlinchey, 2003, Lecler, 2004, Olivier, 2004

Tropical fruits and trees

Avocado

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.750	0.750	0.80	0.80	0.80	0.80	0.80	3.00

Appendix A

Crop Characteristics for use with SAPWAT

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Estimate cover	Humid/Sub-humid, hot summers	180	60	60	60	360	1.20	35	1.00	35	0.30	0.30	0.30
	Tropical	180	60	60	60	360	1.20	35	1.00	35	0.30	0.30	0.30

Allen et al., 1998, Hoffman, 2004, McMohan, Kofranek & Rubatzky, 2002

Tropical fruits and trees

Bananas

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.800	0.800	1.30	1.30	1.30	1.30	1.30	2.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
First year	Arid/Semi-arid, hot summers	120	90	120	30	360	1.05	1	1.00	55	0.35	0.35	0.35
	Humid/Sub-humid, hot summers	120	90	120	30	360	1.05	1	1.00	55	0.35	0.35	0.35
	Tropical	120	90	120	30	360	1.05	1	1.00	55	0.35	0.35	0.35

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Ratoon	Arid/Semi-arid, hot summers	120	60	179	1	360	1.10	65	1.00	65	0.35	0.35	0.35
	Humid/Sub-humid, hot summers	120	60	179	1	360	1.10	65	1.00	65	0.35	0.35	0.35
	Tropical	120	60	179	1	360	1.10	65	1.00	65	0.35	0.35	0.35

Allen et al., 1998, Morse et al., 1996

Tropical fruits and trees

Coffee

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	1.00	1.00	1.00	1.00	1.00	3.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Estimate cover	Humid/Sub-humid, hot summers	180	60	60	60	360	1.20	100	1.00	100	0.50	0.50	0.80
	Tropical	180	60	60	60	360	1.20	100	1.00	100	0.50	0.50	0.80

Allen et al., 1998

Appendix A

Crop Characteristics for use with SAPWAT

Tropical fruits and trees

Date palm

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
2.000	2.000	0.80	0.80	0.80	0.80	0.80	8.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	150	30	150	30	360	1.20	60	1.00	60	0.40	0.40	0.50

Allen et al., 1998, Gerber, 2003, Ziad, 1999

Tropical fruits and trees

Grenadella

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	*1.000*	*0.20*	*0.70*	*0.85*	*0.40*	*0.85*	*1.50*

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
	Humid/Sub-humid, hot summers	60	30	240	30	360	1.00	100	1.00	100	0.60	0.60	0.60
	Tropical	60	30	240	30	360	1.00	100	1.00	100	0.60	0.60	0.60

McMohan, Kofranek & Rubatzky, 2002

Tropical fruits and trees

Litchi

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	1.00	1.00	1.00	1.00	1.00	3.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Estimate cover	Tropical	30	60	120	150	360	1.10	1	1.00	70	0.50	0.50	0.80

Tolmay & Kruger, Undated

Tropical fruits and trees

Mangoes

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	1.00	1.00	1.00	1.00	1.00	5.00

Appendix A

Crop Characteristics for use with SAPWAT

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Estimate cover	Arid/Semi-arid, hot summers	45	60	90	165	360	1.00	100	1.00	100	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	45	60	90	165	360	1.00	100	1.00	100	0.50	0.50	0.50
	Tropical	45	60	90	165	360	1.00	100	1.00	100	0.50	0.50	0.50

Albertse, 2004, Hoffman, 2004

Tropical fruits and trees

Papaya

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.800	0.800	1.00	1.00	1.00	1.00	1.00	5.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
	Tropical	90	90	150	30	360	1.15	100	1.00	100	0.50	0.50	0.50

McMohan, Kofranek & Rubatzky, 2002

Tropical fruits and trees

Tea

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.000	1.000	1.00	1.00	1.00	1.00	1.00	1.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
All areas	Tropical	90	90	90	90	360	0.90	1	1.00	100	0.40	0.40	0.40

Allen et al., 1998

Vegetables - Cucumber family

Butternut squash

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.800	0.80	0.80	0.80	0.80	1.10	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Autumn plant	Arid/Semi-arid, hot summers	8	39	33	28	108	1.00	1	1.00	50	0.35	0.35	0.35
	Humid/Sub-humid, hot summers	8	39	33	28	108	1.00	1	1.00	50	0.35	0.35	0.35

Appendix A

Crop Characteristics for use with SAPWAT

	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
	Tropical	8	39	33	28	108	1.00	1	1.00	50	0.35	0.35	0.35

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Spring plant	Arid/Semi-arid, hot summers	7	33	28	24	92	1.00	1	1.00	50	0.35	0.35	0.35
	Arid/Semi-arid, warm summers	7	37	32	26	102	1.00	1	1.00	50	0.35	0.35	0.35
	Humid/Sub-humid, hot summers	7	33	28	24	92	1.00	1	1.00	50	0.35	0.35	0.35
	Humid/Sub-humid, warm summers	8	38	33	27	106	1.00	1	1.00	50	0.35	0.35	0.35
	Tropical	7	33	28	24	92	1.00	1	1.00	50	0.35	0.35	0.35

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer plant	Arid/Semi-arid, hot summers	6	31	26	22	85	1.00	1	1.00	50	0.35	0.35	0.35
	Arid/Semi-arid, warm summers	7	35	30	25	97	1.00	1	1.00	50	0.35	0.35	0.35
	Humid/Sub-humid, hot summers	6	31	26	22	85	1.00	1	1.00	50	0.35	0.35	0.35
	Humid/Sub-humid, warm summers	7	35	30	25	97	1.00	1	1.00	50	0.35	0.35	0.35
	Tropical	6	31	26	22	85	1.00	1	1.00	50	0.35	0.35	0.35

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter plant	Arid/Semi-arid, hot summers	8	39	34	28	109	1.00	1	1.00	50	0.35	0.35	0.35
	Arid/Semi-arid, warm summers	8	40	35	29	112	1.00	1	1.00	50	0.35	0.35	0.35
	Humid/Sub-humid, hot summers	8	39	34	28	109	1.00	1	1.00	50	0.35	0.35	0.35
	Tropical	8	39	34	28	109	1.00	1	1.00	50	0.35	0.35	0.35

Allen et al., 1998, Jovanovic & Annandale, 1999, Van Wyk, 1992

Vegetables - Cucumber family

Cucumber

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.000	0.50	0.60	1.10	0.80	1.05	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	25	35	50	20	130	1.10	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	25	35	50	20	130	1.10	1	1.00	1	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	25	35	50	20	130	1.10	1	1.00	1	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	25	35	50	20	130	1.10	1	1.00	1	0.40	0.40	0.50
	Tropical	25	35	50	20	130	1.10	1	1.00	1	0.40	0.40	0.50

Appendix A

Crop Characteristics for use with SAPWAT

Allen et al., 1998

Vegetables - Cucumber family

Cucurbits

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.000	0.50	0.60	1.10	0.80	1.05	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Autumn plant	Arid/Semi-arid, hot summers	8	66	33	33	140	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	66	33	33	140	1.00	1	1.00	50	0.40	0.40	0.50
	Tropical	8	66	33	33	140	0.90	1	1.00	50	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Spring plant	Arid/Semi-arid, hot summers	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	65	32	32	137	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	65	32	32	137	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer plant	Arid/Semi-arid, hot summers	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	62	31	31	131	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	7	62	31	31	131	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter plant	Arid/Semi-arid, hot summers	8	68	34	34	144	0.90	1	1.00	50	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	72	36	36	152	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	68	34	34	144	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	72	36	36	152	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	8	68	34	34	144	0.90	1	1.00	50	0.40	0.40	0.50

Appendix A

Crop Characteristics for use with SAPWAT

Van Wyk, 1992

Vegetables - Cucumber family

Gourds

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.000	0.50	0.60	1.10	0.80	1.05	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Spring plant	Arid/Semi-arid, hot summers	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	65	32	32	137	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	65	32	32	137	0.90	1	1.00	50	0.40	0.40	0.40
	Tropical	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer plant	Arid/Semi-arid, hot summers	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	62	31	31	131	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	7	62	31	31	131	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50

Vegetables - Cucumber family

Hubbard squash

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.000	0.50	0.60	1.10	0.80	1.05	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Autumn plant	Arid/Semi-arid, hot summers	8	66	33	33	140	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	66	33	33	140	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	8	66	33	33	140	0.90	1	1.00	50	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Spring plant	Arid/Semi-arid, hot summers	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	65	32	32	137	0.90	1	1.00	50	0.40	0.40	0.50

Appendix A

Crop Characteristics for use with SAPWAT

	Humid/Sub-humid, hot summers	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50
Spring plant	Humid/Sub-humid, warm summers	8	65	32	32	137	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer plant	Arid/Semi-arid, hot summers	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	62	31	31	131	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	7	62	31	31	131	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter plant	Arid/Semi-arid, hot summers	8	68	34	34	144	0.90	1	1.00	50	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	72	36	36	152	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	68	34	34	144	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	72	36	36	152	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	8	68	34	34	144	0.90	1	1.00	50	0.40	0.40	0.50

Allen et al., 1998, Van Wyk, 1992

Vegetables - Cucumber family

Melon

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.000	0.50	0.60	1.10	0.80	1.05	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Autumn plant	Arid/Semi-arid, hot summers	8	33	30	33	104	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	33	30	33	104	1.05	1	1.00	75	0.40	0.40	0.50
	Tropical	8	33	30	33	104	1.05	1	1.00	75	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Spring plant	Arid/Semi-arid, hot summers	7	28	26	28	89	1.05	1	1.00	75	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	31	29	31	98	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	28	26	28	89	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	7	31	29	31	98	1.05	1	1.00	75	0.40	0.40	0.50

Appendix A

Crop Characteristics for use with SAPWAT

	Tropical	7	28	26	28	89	1.05	1	1.00	75	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Summer plant	Arid/Semi-arid, hot summers	6	25	24	25	80	1.05	1	1.00	75	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	29	27	29	92	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	6	25	24	25	80	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	7	29	27	29	92	1.05	1	1.00	75	0.40	0.40	0.50
	Tropical	6	25	24	25	80	1.05	1	1.00	75	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Winter plant	Arid/Semi-arid, hot summers	8	34	31	34	107	1.05	1	1.00	75	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	35	33	35	111	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	34	31	34	107	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	35	33	35	111	1.05	1	1.00	75	0.40	0.40	0.50
	Tropical	8	34	31	34	107	1.05	1	1.00	75	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Autumn plant	Arid/Semi-arid, hot summers	8	43	36	33	120	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	43	36	33	120	1.05	1	1.00	75	0.40	0.40	0.50
	Tropical	8	43	36	33	120	1.05	1	1.00	75	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Spring plant	Arid/Semi-arid, hot summers	7	37	31	28	103	1.05	1	1.00	75	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	41	34	31	113	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	37	31	28	103	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	7	41	34	31	113	1.05	1	1.00	75	0.40	0.40	0.50
	Tropical	7	37	31	28	103	1.05	1	1.00	75	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Summer plant	Arid/Semi-arid, hot summers	6	34	28	25	93	1.05	1	1.00	75	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	39	32	29	107	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	6	34	28	25	93	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	7	39	32	29	107	1.05	1	1.00	75	0.40	0.40	0.50
	Tropical	6	34	28	25	93	1.05	1	1.00	75	0.40	0.40	0.50

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Crop Characteristics for use with SAPWAT

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Winter plant	Arid/Semi-arid, hot summers	8	45	37	34	124	1.05	1	1.00	75	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	47	39	35	129	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	45	37	34	124	1.05	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	47	39	35	129	1.05	1	1.00	75	0.40	0.40	0.50
	Tropical	8	45	37	34	124	1.05	1	1.00	75	0.40	0.40	0.50

Allen et al., 1998, Van Wyk, 1992

Vegetables - Cucumber family

Pumpkin

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.800	0.50	0.60	1.10	0.80	1.05	0.70

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Autumn plant	Arid/Semi-arid, hot summers	8	66	33	33	140	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	66	33	33	140	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	8	66	33	33	140	0.90	1	1.00	50	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Spring plant	Arid/Semi-arid, hot summers	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	65	32	32	137	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	65	32	32	137	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	7	59	30	30	126	0.90	1	1.00	50	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer plant	Arid/Semi-arid, hot summers	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	62	31	31	131	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	7	62	31	31	131	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	7	58	29	29	123	0.90	1	1.00	50	0.40	0.40	0.50

Appendix A

Crop Characteristics for use with SAPWAT

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter plant	Arid/Semi-arid, hot summers	8	68	34	34	144	0.90	1	1.00	50	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	72	36	36	152	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	68	34	34	144	0.90	1	1.00	50	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	72	36	36	152	0.90	1	1.00	50	0.40	0.40	0.50
	Tropical	8	68	34	34	144	0.90	1	1.00	50	0.40	0.40	0.50

Allen et al., 1998, Jovanovic & Annandale, 1999, Van Wyk, 1992

Vegetables - Cucumber family

Squash

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.800	0.50	0.60	1.10	0.80	1.05	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Baby, Autumn plant	Arid/Semi-arid, hot summers	8	39	33	28	108	0.90	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	39	33	28	108	0.90	1	1.00	75	0.40	0.40	0.50
	Tropical	80	39	33	28	180	0.90	1	1.00	75	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Baby, Spring plant	Arid/Semi-arid, hot summers	7	33	28	24	92	0.90	1	1.00	75	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	37	32	26	102	0.90	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	33	28	24	92	0.90	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	7	37	32	26	102	0.90	1	1.00	75	0.40	0.40	0.50
	Tropical	7	33	28	24	92	0.90	1	1.00	75	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Baby, Summer plant	Arid/Semi-arid, hot summers	6	31	26	22	85	0.90	1	1.00	75	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	35	30	25	97	0.90	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	6	31	26	22	85	0.90	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	7	35	30	25	97	0.90	1	1.00	75	0.40	0.40	0.50
	Tropical	6	31	26	22	85	0.90	1	1.00	75	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Baby, Winter plant	Arid/Semi-arid, hot summers	8	39	34	28	109	0.90	1	0.80	75	0.40	0.40	0.50

Appendix A

Crop Characteristics for use with SAPWAT

Baby, Winter plant	Arid/Semi-arid, warm summers	8	40	35	29	112	0.90	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	39	34	28	109	0.90	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	40	35	35	118	0.90	1	1.00	75	0.40	0.40	0.50
	Tropical	8	39	34	28	109	0.90	1	1.00	75	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Bush & vine	Arid/Semi-arid, hot summers	10	45	30	20	105	0.90	1	1.00	75	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	10	45	30	20	105	0.90	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	10	45	30	20	105	0.90	1	1.00	75	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	10	45	30	20	105	0.90	1	1.00	75	0.40	0.40	0.50
	Tropical	10	45	30	20	105	0.90	1	1.00	75	0.40	0.40	0.50

Allen et al., 1998, Jovanovic & Annandale, 1999, Van Wyk, 1992

Vegetables - Cucumber family

Watermelon

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	1.000	0.50	0.60	1.10	0.80	1.10	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Autumn plant	Arid/Semi-arid, hot summers	8	33	33	25	99	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	33	33	25	99	1.00	1	1.00	90	0.40	0.40	0.50
	Tropical	8	33	33	25	99	1.00	1	1.00	90	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Spring plant	Arid/Semi-arid, hot summers	7	29	29	22	87	1.00	1	1.00	90	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	32	32	25	97	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	29	29	22	87	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	32	32	25	97	1.00	1	1.00	90	0.40	0.40	0.50
	Tropical	7	29	29	22	87	1.00	1	1.00	90	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Summer plant	Arid/Semi-arid, hot summers	7	30	30	23	90	1.00	1	1.00	90	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	31	31	24	93	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	30	30	23	90	1.00	1	1.00	90	0.40	0.40	0.50

Appendix A

Crop Characteristics for use with SAPWAT

	Humid/Sub-humid, warm summers	7	31	31	24	93	1.00	1	1.00	90	0.40	0.40	0.50
Early, Summer plant	Tropical	7	30	30	23	90	1.00	1	1.00	90	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Winter plant	Arid/Semi-arid, hot summers	8	34	34	26	102	1.00	1	1.00	90	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	36	36	28	108	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	34	34	26	102	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	36	36	28	108	1.00	1	1.00	90	0.40	0.40	0.50
	Tropical	8	34	34	26	102	1.00	1	1.00	90	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late, Autumn plant	Arid/Semi-arid, hot summers	8	39	39	25	111	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	39	39	25	111	1.00	1	1.00	90	0.40	0.40	0.50
	Tropical	8	39	39	25	111	1.00	1	1.00	90	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late, Spring plant	Arid/Semi-arid, hot summers	7	34	34	22	97	1.00	1	1.00	90	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	38	38	25	109	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	34	34	22	97	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	38	38	25	109	1.00	1	1.00	90	0.40	0.40	0.50
	Tropical	7	34	34	22	97	1.00	1	1.00	90	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late, Summer plant	Arid/Semi-arid, hot summers	7	35	35	23	100	1.00	1	1.00	90	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	7	36	36	24	103	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	7	35	35	23	100	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	7	36	36	24	103	1.00	1	1.00	90	0.40	0.40	0.50
	Tropical	7	35	35	23	100	1.00	1	1.00	90	0.40	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late, Winter plant	Arid/Semi-arid, hot summers	8	39	39	26	112	1.00	1	1.00	90	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	8	42	42	28	120	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, hot summers	8	39	39	26	112	1.00	1	1.00	90	0.40	0.40	0.50
	Humid/Sub-humid, warm summers	8	42	42	28	120	1.00	1	1.00	90	0.40	0.40	0.50

	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
	Tropical	8	39	39	26	112	1.00	1	1.00	90	0.40	0.40	0.50

Allen et al., 1998, Van Wyk, 1992

Vegetables - Perennial

Artichokes

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.800	0.800	1.00	1.00	1.00	1.00	1.00	0.70

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Globe	Arid/Semi-arid, hot summers	40	40	250	30	360	1.00	1	1.00	30	0.50	0.50	0.60
	Arid/Semi-arid, warm summers	40	40	250	30	360	1.00	1	1.00	30	0.60	0.60	0.60
	Humid/Sub-humid, hot summers	40	40	250	30	360	1.00	1	1.00	30	0.60	0.60	0.60
	Humid/Sub-humid, warm summers	40	40	250	30	360	1.00	1	1.00	30	0.60	0.60	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Jerusalem	Arid/Semi-arid, hot summers	30	30	70	50	180	1.00	1	1.00	1	0.50	0.50	0.60
	Arid/Semi-arid, warm summers	30	30	70	50	180	1.00	1	1.00	1	0.60	0.60	0.60
	Humid/Sub-humid, hot summers	30	30	70	50	180	1.00	1	1.00	1	0.60	0.60	0.60
	Humid/Sub-humid, warm summers	30	30	70	50	180	1.00	1	1.00	1	0.60	0.60	0.60
	Tropical	30	30	70	50	180	1.00	1	1.00	1	0.60	0.60	0.60

Allen et al., 1998, De Kock, 2004, Van Wyk, 1992

Vegetables - Perennial

Asparagus

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
1.200	1.200	0.40	0.40	0.50	0.50	0.95	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Humid/Sub-humid, warm summers	50	30	100	50	230	0.95	1	1.00	1	0.90	0.50	0.50

Allen et al., 1998

Vegetables - Small

Appendix A

Crop Characteristics for use with SAPWAT

Broccoli

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.500	0.40	0.40	0.50	0.50	0.95	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Autumn plant	Arid/Semi-arid, hot summers	7	37	16	1	61	1.00	1	1.00	60	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	8	38	16	1	63	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	7	37	16	1	61	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	8	38	16	1	63	1.00	1	1.00	60	0.40	0.40	0.40
	Tropical	7	37	16	1	61	1.00	1	1.00	60	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Spring plant	Arid/Semi-arid, hot summers	6	32	14	1	53	1.00	1	1.00	60	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	6	32	14	1	53	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	6	32	14	1	53	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	6	32	14	1	53	1.00	1	1.00	60	0.40	0.40	0.40
	Tropical	6	32	14	1	53	1.00	1	1.00	60	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Summer plant	Arid/Semi-arid, hot summers	6	32	14	1	53	1.00	1	1.00	60	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	7	34	14	1	56	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	6	32	14	1	53	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	7	33	14	1	55	1.00	1	1.00	60	0.40	0.40	0.40
	Tropical	6	32	14	1	53	1.00	1	1.00	60	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Winter plant	Arid/Semi-arid, hot summers	7	37	16	1	61	1.00	1	1.00	60	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	8	38	16	1	63	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	7	37	16	1	61	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	8	38	16	1	63	1.00	1	1.00	60	0.40	0.40	0.40
	Tropical	7	37	16	1	61	1.00	1	1.00	60	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Autumn plant	Arid/Semi-arid, hot summers	7	63	16	1	87	1.00	1	1.00	60	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	7	63	16	1	87	1.00	1	1.00	60	0.40	0.40	0.40

	Humid/Sub-humid, hot summers	7	63	16	1	87	1.00	1	1.00	60	0.40	0.40	0.40
Main, Autumn plant	Humid/Sub-humid, warm summers	7	63	16	1	87	1.00	1	1.00	60	0.40	0.40	0.40
	Tropical	7	63	16	1	87	1.00	1	1.00	60	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Spring plant	Arid/Semi-arid, hot summers	6	54	14	1	75	1.00	1	1.00	60	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	6	54	14	1	75	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	6	54	14	1	75	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	6	54	14	1	75	1.00	1	1.00	60	0.40	0.40	0.40
	Tropical	6	54	14	1	75	1.00	1	1.00	60	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Summer plant	Arid/Semi-arid, hot summers	7	57	14	1	79	1.00	1	1.00	60	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	7	58	14	1	80	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	7	57	14	1	79	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	7	58	14	1	80	1.00	1	1.00	60	0.40	0.40	0.40
	Tropical	7	57	14	1	79	1.00	1	1.00	60	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Winter plant	Arid/Semi-arid, hot summers	7	63	16	1	87	1.00	1	1.00	60	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	8	65	16	1	90	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	7	63	16	1	87	1.00	1	1.00	60	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	8	65	16	1	90	1.00	1	1.00	60	0.40	0.40	0.40
	Tropical	7	63	16	1	87	1.00	1	1.00	60	0.40	0.40	0.40

Allen et al., 1998, Van Wyk, 1992

Vegetables - Small

Brussels sprouts

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.500	0.40	0.40	0.50	0.50	0.95	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	30	40	50	15	135	1.10	1	1.00	1	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	30	40	50	15	135	1.10	1	1.00	1	0.25	0.40	0.40

	Humid/Sub-humid, hot summers	30	40	50	15	135	1.10	1	1.00	1	0.25	0.40	0.40
Standard	Humid/Sub-humid, warm summers	30	40	50	15	135	1.10	1	1.00	1	0.25	0.40	0.40
	Tropical	30	40	50	15	135	1.10	1	1.00	1	0.25	0.40	0.40

Van Wyk, 1992

Vegetables - Small

Cabbage

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.800	0.40	0.40	0.50	0.50	0.95	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Autumn plant	Arid/Semi-arid, hot summers	11	43	33	1	88	1.00	1	1.00	90	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	11	45	34	1	91	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, hot summers	11	43	33	1	88	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	11	45	34	1	91	1.00	1	1.00	90	0.25	0.40	0.40
	Tropical	11	43	33	1	88	1.00	1	1.00	90	0.25	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Spring plant	Arid/Semi-arid, hot summers	9	36	27	1	73	1.00	1	1.00	90	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	10	40	30	1	81	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, hot summers	9	36	27	1	73	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	10	40	30	1	81	1.00	1	1.00	90	0.25	0.40	0.40
	Tropical	9	36	27	1	73	1.00	1	1.00	90	0.25	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Summer plant	Arid/Semi-arid, hot summers	8	33	25	1	67	1.00	1	1.00	90	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	10	39	29	1	79	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, hot summers	8	33	25	1	67	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	10	39	29	1	79	1.00	1	1.00	90	0.25	0.40	0.40
	Tropical	8	33	25	1	67	1.00	1	1.00	90	0.25	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Winter plant	Arid/Semi-arid, hot summers	11	44	33	1	89	1.00	1	1.00	90	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	11	46	34	1	92	1.00	1	1.00	90	0.25	0.40	0.40

Appendix A

Crop Characteristics for use with SAPWAT

	Humid/Sub-humid, hot summers	11	44	33	1	89	1.00	1	1.00	90	0.25	0.40	0.40
Early, Winter plant	Humid/Sub-humid, warm summers	11	46	34	1	92	1.00	1	1.00	90	0.25	0.40	0.40
	Tropical	11	44	33	1	89	1.00	1	1.00	90	0.25	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late, Autumn plant	Arid/Semi-arid, hot summers	11	65	43	1	120	1.00	1	1.00	90	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	11	65	43	1	120	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, hot summers	11	65	43	1	120	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	11	65	43	1	120	1.00	1	1.00	90	0.25	0.40	0.40
	Tropical	11	65	43	1	120	1.00	1	1.00	90	0.25	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late, Spring plant	Arid/Semi-arid, hot summers	9	54	36	1	100	1.00	1	1.00	90	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	10	60	40	1	111	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, hot summers	9	54	36	1	100	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	10	60	40	1	111	1.00	1	1.00	90	0.25	0.40	0.40
	Tropical	9	54	36	1	100	1.00	1	1.00	90	0.25	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late, Summer plant	Arid/Semi-arid, hot summers	8	50	33	1	92	1.00	1	1.00	90	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	10	58	39	1	108	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, hot summers	8	50	33	1	92	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	10	58	39	1	108	1.00	1	1.00	90	0.25	0.40	0.40
	Tropical	8	50	33	1	92	1.00	1	1.00	90	0.25	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Late, Winter plant	Arid/Semi-arid, hot summers	11	65	44	1	121	1.00	1	1.00	90	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	11	68	46	1	126	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, hot summers	11	65	44	1	121	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	11	68	46	1	126	1.00	1	1.00	90	0.25	0.40	0.40
	Tropical	11	65	44	1	121	1.00	1	1.00	90	0.25	0.40	0.40

Allen et al., 1998, Jovanovic & Annandale, 1999, Van Wyk, 1992

Appendix A
Crop Characteristics for use with SAPWAT

Vegetables - Small

Carrots

Roots ini	Roots mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.800	0.40	0.40	0.50	0.50	0.95	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Autumn plant	Arid/Semi-arid, hot summers	20	59	20	1	100	1.00	1	1.00	70	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	22	65	22	1	110	1.00	1	1.00	70	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	20	59	20	1	100	1.00	1	1.00	70	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	22	65	22	1	110	1.00	1	1.00	70	0.40	0.40	0.40
	Tropical	20	59	20	1	100	1.00	1	1.00	70	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Spring plant	Arid/Semi-arid, hot summers	19	56	19	1	95	1.00	1	1.00	70	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	19	58	19	1	97	1.00	1	1.00	70	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	19	56	19	1	95	1.00	1	1.00	70	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	19	58	19	1	97	1.00	1	1.00	70	0.40	0.40	0.40
	Tropical	19	56	19	1	95	1.00	1	1.00	70	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer plant	Arid/Semi-arid, hot summers	19	56	19	1	95	1.00	1	1.00	70	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	19	57	19	1	96	1.00	1	1.00	70	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	19	56	19	1	95	1.00	1	1.00	70	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	19	57	19	1	96	1.00	1	1.00	70	0.40	0.40	0.40
	Tropical	19	56	19	1	95	1.00	1	1.00	70	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter plant	Arid/Semi-arid, hot summers	21	64	21	1	107	1.00	1	1.00	70	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	23	68	23	1	115	1.00	1	1.00	70	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	21	64	21	1	107	1.00	1	1.00	70	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	23	70	23	1	117	1.00	1	1.00	70	0.40	0.40	0.40
	Tropical	21	64	21	1	107	1.00	1	1.00	70	0.40	0.40	0.40

Allen et al., 1998, Crosby & Crosby, 1999, Jovanovic & Annandale, 1999, Van Wyk, 1992

Appendix A

Crop Characteristics for use with SAPWAT

Vegetables - Small

Cauliflower

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.500	0.40	0.40	0.50	0.50	0.95	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Autumn plant	Arid/Semi-arid, hot summers	10	40	30	1	81	1.00	1	1.00	80	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	11	46	34	1	92	1.00	1	1.00	80	0.25	0.40	0.40
	Humid/Sub-humid, hot summers	10	40	30	1	81	1.00	1	1.00	80	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	11	46	34	1	92	1.00	1	1.00	80	0.25	0.40	0.40
	Tropical	10	40	30	1	81	1.00	1	1.00	80	0.25	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Spring plant	Arid/Semi-arid, warm summers	9	35	27	1	72	1.00	1	1.00	80	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	9	35	27	1	72	1.00	1	1.00	80	0.25	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Summer plant	Arid/Semi-arid, hot summers	8	33	25	1	67	1.00	1	1.00	80	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	10	40	30	1	81	1.00	1	1.00	80	0.25	0.40	0.40
	Humid/Sub-humid, hot summers	8	33	25	1	67	1.00	1	1.00	80	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	10	40	30	1	81	1.00	1	1.00	80	0.25	0.40	0.40
	Tropical	8	33	25	1	67	1.00	1	1.00	80	0.25	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Early, Winter plant	Arid/Semi-arid, hot summers	8	36	27	1	72	1.00	1	1.00	80	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	11	44	33	1	89	1.00	1	1.00	80	0.25	0.40	0.40
	Humid/Sub-humid, hot summers	8	36	27	1	72	1.00	1	1.00	80	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	11	44	33	1	89	1.00	1	1.00	80	0.25	0.40	0.40
	Tropical	8	36	27	1	72	1.00	1	1.00	80	0.25	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Autumn plant	Arid/Semi-arid, hot summers	10	61	40	1	112	1.00	1	1.00	80	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	11	69	46	1	127	1.00	1	1.00	80	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	10	61	40	1	112	1.00	1	1.00	80	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	11	69	46	1	127	1.00	1	1.00	80	0.40	0.40	0.40

Appendix A

Crop Characteristics for use with SAPWAT

Main, Autumn plant	Tropical	10	61	41	1	113	1.00	1	1.00	80	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Spring plant	Arid/Semi-arid, warm summers	9	53	27	1	90	1.00	1	1.00	80	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	9	53	35	1	98	1.00	1	1.00	80	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Summer plant	Arid/Semi-arid, hot summers	8	50	33	1	92	1.00	1	1.00	80	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	10	60	40	1	111	1.00	1	1.00	80	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	8	50	33	1	92	1.00	1	1.00	80	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	10	60	40	1	111	1.00	1	1.00	80	0.40	0.40	0.40
	Tropical	8	50	33	1	92	1.00	1	1.00	80	0.40	0.40	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Main, Winter plant	Arid/Semi-arid, hot summers	9	54	36	1	100	1.00	1	1.00	80	0.40	0.40	0.40
	Arid/Semi-arid, warm summers	11	66	44	1	122	1.00	1	1.00	80	0.40	0.40	0.40
	Humid/Sub-humid, hot summers	9	54	36	1	100	1.00	1	1.00	80	0.40	0.40	0.40
	Humid/Sub-humid, warm summers	11	66	44	1	122	1.00	1	1.00	80	0.40	0.40	0.40
	Tropical	9	54	36	1	100	1.00	1	1.00	80	0.40	0.40	0.40

Allen et al., 1998, Van Wyk, 1992

Vegetables - Small

Celery

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.500	0.40	0.40	0.50	0.50	0.95	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	25	40	45	15	125	1.00	1	1.00	90	0.25	0.40	0.40
	Arid/Semi-arid, warm summers	25	40	45	15	125	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, hot summers	25	40	45	15	125	1.00	1	1.00	90	0.25	0.40	0.40
	Humid/Sub-humid, warm summers	25	40	45	15	125	1.00	1	1.00	90	0.25	0.40	0.40
	Tropical	25	45	45	15	130	1.00	1	1.00	90	0.25	0.40	0.40

Appendix A

Crop Characteristics for use with SAPWAT

Allen et al., 1998

Vegetables - Small

Coriander

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.500	0.80	0.80	0.80	0.80	0.80	1.00

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	25	25	20	20	90	1.20	1	1.00	1	0.40	0.40	0.50

Vegetables - Small

Garlic

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.600	0.45	0.80	0.80	0.30	1.10	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Seeded	Arid/Semi-arid, hot summers	80	50	35	20	185	1.00	1	1.00	1	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	80	50	35	20	185	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	80	50	35	20	185	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	80	50	35	20	185	1.00	1	1.00	1	0.30	0.30	0.30
	Tropical	80	35	50	20	185	1.00	1	1.00	1	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Transplant August	Arid/Semi-arid, hot summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Tropical	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Transplant May	Arid/Semi-arid, hot summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30

	Tropical	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30

Allen et al., 1998, Jovanovic & Annandale, 1999, Van Wyk, 1992

Vegetables - Small

Leeks

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.600	0.45	0.80	0.80	0.30	1.10	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Seeded	Arid/Semi-arid, hot summers	80	50	35	20	185	1.00	1	1.00	1	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	80	50	35	20	185	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	80	50	35	20	185	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	80	50	35	20	185	1.00	1	1.00	1	0.30	0.30	0.30
	Tropical	80	50	35	20	185	1.00	1	1.00	1	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Transplant August	Arid/Semi-arid, hot summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Tropical	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Transplant May	Arid/Semi-arid, hot summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30
	Tropical	60	50	35	20	165	1.00	1	1.00	1	0.30	0.30	0.30

Allen et al., 1998

Vegetables - Small

Appendix A

Crop Characteristics for use with SAPWAT

Lettuce

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.600	0.80	0.40	1.20	1.00	1.00	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Summer Crop	Arid/Semi-arid, hot summers	20	30	15	10	75	0.95	1	1.00	90	0.30	0.45	0.50
	Arid/Semi-arid, warm summers	25	35	30	10	100	0.95	1	1.00	90	0.30	0.45	0.50
	Humid/Sub-humid, hot summers	20	30	15	10	75	0.95	1	1.00	90	0.30	0.45	0.50
	Humid/Sub-humid, warm summers	25	35	30	10	100	0.95	1	1.00	90	0.30	0.45	0.50
	Tropical	20	30	15	10	75	0.95	1	1.00	90	0.30	0.45	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Winter Crop	Arid/Semi-arid, hot summers	25	35	30	10	100	0.95	1	1.00	90	0.30	0.45	0.50
	Arid/Semi-arid, warm summers	25	35	30	10	100	0.95	1	1.00	90	0.30	0.45	0.50
	Humid/Sub-humid, hot summers	25	35	30	10	100	0.95	1	1.00	90	0.30	0.45	0.50
	Humid/Sub-humid, warm summers	25	35	30	10	100	0.95	1	1.00	90	0.30	0.45	0.50
	Tropical	20	30	15	10	75	0.95	1	1.00	90	0.30	0.45	0.50

Allen et al., 1998, Jovanovic & Annandale, 1999, Van Wyk, 1992

Vegetables - Small

Onion

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.800	0.45	0.80	0.80	0.30	1.10	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Seeded	Arid/Semi-arid, hot summers	80	50	35	20	185	1.00	1	1.00	50	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	80	50	35	20	185	1.00	1	1.00	50	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	80	50	35	20	185	1.00	1	1.00	50	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	80	50	35	20	185	1.00	1	1.00	50	0.30	0.30	0.30
	Tropical	80	50	35	20	185	1.00	1	1.00	50	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Trnsplnt Autumn	Arid/Semi-arid, hot summers	60	50	35	20	165	1.00	1	1.00	50	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	60	50	35	20	165	1.00	1	1.00	50	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	60	50	35	20	165	1.00	1	1.00	50	0.30	0.30	0.50

Appendix A

Crop Characteristics for use with SAPWAT

	Humid/Sub-humid, warm summers	60	50	35	20	165	1.00	1	1.00	50	0.30	0.30	0.30
Trnsplnt Autumn	Tropical	60	50	35	20	165	1.00	1	1.00	50	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Trnsplnt Spring	Arid/Semi-arid, hot summers	60	50	35	20	165	1.00	1	1.00	50	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	60	50	35	20	165	1.00	1	1.00	50	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	60	50	35	20	165	1.00	1	1.00	50	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	60	50	35	20	165	1.00	1	1.00	50	0.30	0.30	0.30
	Tropical	60	50	35	20	165	1.00	1	1.00	50	0.30	0.30	0.30

Allen et al., 1998, Jovanovic & Annandale, 1999, Van Heerden et al., 2001, Van Wyk, 1992

Vegetables - Small

Parsley

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.500	0.20	0.60	1.00	0.40	1.15	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	21	14	200	30	265	1.15	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	21	14	200	30	265	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	21	14	200	30	265	1.15	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	21	14	200	30	265	1.15	1	1.00	1	0.50	0.50	0.50
	Tropical	21	14	200	30	265	1.15	1	1.00	1	0.50	0.50	0.50

Vegetables - Small

Spinach

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.500	0.80	0.40	1.20	1.00	1.00	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Option 1	Arid/Semi-arid, hot summers	30	70	60	30	190	1.00	1	1.00	90	0.30	0.45	0.50
	Arid/Semi-arid, warm summers	30	70	60	30	190	1.00	1	1.00	90	0.30	0.45	0.50
	Humid/Sub-humid, hot summers	30	70	60	30	190	1.00	1	1.00	90	0.30	0.45	0.50
	Humid/Sub-humid, warm summers	30	70	60	30	190	1.00	1	1.00	90	0.30	0.45	0.50

Appendix A

Crop Characteristics for use with SAPWAT

Option 1	Tropical	30	70	60	30	190	1.00	1	1.00	90	0.30	0.45	0.50

Allen et al., 1998, Van Wyk, 1992

Vegetables - Small

Strawberries

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.300	0.300	1.00	1.00	1.00	1.00	1.00	0.20

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
General	Arid/Semi-arid, hot summers	180	60	60	60	360	0.85	1	1.00	1	0.40	0.40	0.50
	Arid/Semi-arid, warm summers	180	60	60	60	360	0.85	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, hot summers	180	60	60	60	360	0.85	1	1.00	1	0.50	0.50	0.50
	Humid/Sub-humid, warm summers	180	60	60	60	360	0.85	1	1.00	1	0.50	0.50	0.50
	Tropical	180	60	60	60	360	0.85	1	1.00	1	0.50	0.50	0.50

Allen et al., 1998

Vegetables - Small

Swiss chard

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.800	0.80	0.80	0.80	0.80	0.80	0.40

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	30	45	165	1	241	1.00	1	1.00	90	0.30	0.45	0.50
	Arid/Semi-arid, warm summers	30	45	165	1	241	1.00	1	1.00	90	0.30	0.45	0.50
	Humid/Sub-humid, hot summers	30	45	165	1	241	1.00	1	1.00	90	0.30	0.45	0.50
	Humid/Sub-humid, warm summers	30	45	165	1	241	1.00	1	1.00	90	0.30	0.45	0.50
	Tropical	30	45	165	1	241	1.00	1	1.00	90	0.30	0.45	0.50

Vegetables - Small

Appendix A

Crop Characteristics for use with SAPWAT

Vegetables

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	1.000	0.80	0.40	1.20	1.00	1.00	

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer mix	Arid/Semi-arid, hot summers	30	30	50	40	150	1.00	1	1.00	1	0.30	0.45	0.50
	Arid/Semi-arid, warm summers	30	30	30	60	150	1.00	1	1.00	1	0.30	0.45	0.50
	Humid/Sub-humid, hot summers	30	30	50	40	150	1.00	1	1.00	1	0.30	0.45	0.50
	Humid/Sub-humid, warm summers	30	30	50	40	150	1.00	1	1.00	1	0.30	0.45	0.50
	Tropical	30	30	50	40	150	1.00	1	1.00	1	0.30	0.45	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter mix	Arid/Semi-arid, hot summers	30	30	45	75	180	1.00	1	1.00	1	0.30	0.45	0.50
	Arid/Semi-arid, warm summers	30	30	45	75	180	1.00	1	1.00	1	0.30	0.45	0.50
	Humid/Sub-humid, hot summers	30	30	45	75	180	1.00	1	1.00	1	0.30	0.45	0.50
	Humid/Sub-humid, warm summers	30	30	45	75	180	1.00	1	1.00	1	0.30	0.45	0.50
	Tropical	30	30	45	75	180	1.00	1	1.00	1	0.30	0.45	0.50

Vegetables - Solanum family

Brinjals

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.600	0.50	0.60	1.10	0.80	1.05	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Standard	Arid/Semi-arid, hot summers	30	40	40	30	140	1.15	1	1.00	1	0.30	0.40	0.50
	Arid/Semi-arid, warm summers	30	40	40	30	140	1.15	1	1.00	1	0.30	0.40	0.50
	Humid/Sub-humid, hot summers	30	40	40	30	140	1.15	1	1.00	1	0.30	0.40	0.50
	Humid/Sub-humid, warm summers	30	40	40	30	140	1.15	1	1.00	1	0.30	0.40	0.50
	Tropical	30	40	40	30	140	1.15	1	1.00	1	0.30	0.40	0.50

Allen et al., 1998, Jovanovic & Annandale, 1999

Appendix A

Crop Characteristics for use with SAPWAT

Chillies

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.600	0.50	0.60	1.10	0.80	1.05	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Autumn plant	Arid/Semi-arid, hot summers	11	68	68	1	148	1.00	1	1.00	85	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	11	68	68	1	148	1.00	1	1.00	85	0.30	0.30	0.30
	Tropical	11	68	68	1	148	1.00	1	1.00	85	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Spring plant	Arid/Semi-arid, hot summers	9	56	56	1	122	1.00	1	1.00	85	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	11	63	63	1	138	1.00	1	1.00	85	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	9	56	56	1	122	1.00	1	1.00	85	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	11	63	63	1	138	1.00	1	1.00	85	0.30	0.30	0.30
	Tropical	9	56	56	1	122	1.00	1	1.00	85	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Summer plant	Arid/Semi-arid, hot summers	10	59	59	1	129	1.00	1	1.00	85	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	11	65	65	1	142	1.00	1	1.00	85	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	10	59	59	1	129	1.00	1	1.00	85	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	11	65	65	1	142	1.00	1	1.00	85	0.30	0.30	0.30
	Tropical	10	59	59	1	129	1.00	1	1.00	85	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Winter plant	Arid/Semi-arid, hot summers	11	68	68	1	148	1.00	1	1.00	85	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	11	66	66	1	144	1.00	1	1.00	85	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	11	68	68	1	148	1.00	1	1.00	85	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	11	66	66	1	144	1.00	1	1.00	85	0.30	0.30	0.30
	Tropical	11	68	68	1	148	1.00	1	1.00	85	0.30	0.30	0.30

Allen et al., 1998

Vegetables - Solanum family

Appendix A

Crop Characteristics for use with SAPWAT

Paprika

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.800	1.40	0.60	1.20	0.60	1.10	0.70

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Autumn plant	Arid/Semi-arid, hot summers	11	68	68	1	148	1.00	1	1.00	80	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	11	68	68	1	148	1.00	1	1.00	80	0.30	0.30	0.30
	Tropical	11	68	68	1	148	1.00	1	1.00	80	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Spring plant	Arid/Semi-arid, hot summers	9	56	56	1	122	1.00	1	1.00	80	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	11	63	63	1	138	1.00	1	1.00	80	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	9	56	56	1	122	1.00	1	1.00	80	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	11	63	63	1	138	1.00	1	1.00	80	0.30	0.30	0.30
	Tropical	9	56	56	1	122	1.00	1	1.00	80	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Summer plant	Arid/Semi-arid, hot summers	10	59	59	1	129	1.00	1	1.00	80	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	11	65	65	1	142	1.00	1	1.00	80	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	10	59	59	1	129	1.00	1	1.00	80	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	11	65	65	1	142	1.00	1	1.00	80	0.30	0.30	0.30
	Tropical	10	59	59	1	129	1.00	1	1.00	80	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Winter plant	Arid/Semi-arid, hot summers	11	68	68	1	148	1.00	1	1.00	80	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	11	66	66	1	144	1.00	1	1.00	80	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	11	68	68	1	148	1.00	1	1.00	80	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	11	66	66	1	144	1.00	1	1.00	80	0.30	0.30	0.30
	Tropical	11	68	68	1	148	1.00	1	1.00	80	0.30	0.30	0.30

Vegetables - Solanum family

Appendix A

Crop Characteristics for use with SAPWAT

Peppers

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.600	0.50	0.60	1.10	0.80	1.10	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Autumn plant	Arid/Semi-arid, hot summers	11	68	68	1	148	1.10	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	11	68	68	1	148	1.10	1	1.00	1	0.30	0.30	0.30
	Tropical	11	68	68	1	148	1.10	1	1.00	1	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Spring plant	Arid/Semi-arid, hot summers	9	56	56	1	122	1.10	1	1.00	1	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	11	63	63	1	138	1.10	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	9	56	56	1	122	1.10	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	11	63	63	1	138	1.10	1	1.00	1	0.30	0.30	0.30
	Tropical	9	56	56	1	122	1.10	1	1.00	1	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Summer plant	Arid/Semi-arid, hot summers	10	59	59	1	129	1.10	1	1.00	1	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	11	65	65	1	142	1.10	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	10	59	59	1	129	1.10	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	11	65	65	1	142	1.10	1	1.00	1	0.30	0.30	0.30
	Tropical	10	59	59	1	129	1.10	1	1.00	1	0.30	0.30	0.30

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fy-start	Fy-max	Fy-end	Depl-ini	Depl-mid	Depl-late
Winter plant	Arid/Semi-arid, hot summers	11	68	68	1	148	1.10	1	1.00	1	0.30	0.30	0.30
	Arid/Semi-arid, warm summers	11	66	66	1	144	1.10	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, hot summers	11	68	68	1	148	1.10	1	1.00	1	0.30	0.30	0.30
	Humid/Sub-humid, warm summers	11	66	66	1	144	1.10	1	1.00	1	0.30	0.30	0.30
	Tropical	11	68	68	1	148	1.10	1	1.00	1	0.30	0.30	0.40

Allen et al., 1998, Jovanovic & Annandale, 1999, Van Wyk, 1992

Vegetables - Solanum family

Appendix A

Crop Characteristics for use with SAPWAT

Tomatoes

Roots-ini	Roots-mid	Ky-ini	Ky-dev	Ky-mid	Ky-late	Ky-season	Crop height
0.250	0.800	0.50	0.60	1.10	0.80	1.05	0.60

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Canning, Early, Autumn plant	Arid/Semi-arid, hot summers	8	45	57	28	138	1.10	1	1.00	60	0.30	0.40	0.50
	Humid/Sub humid, hot summers	8	45	57	28	138	1.10	1	1.00	60	0.30	0.40	0.50
	Tropical	8	45	57	28	138	1.10	1	1.00	60	0.30	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Canning, Early, Spring plant	Arid/Semi-arid, hot summers	7	37	46	23	113	1.10	1	1.00	60	0.30	0.40	0.50
	Arid/Semi-arid, warm summers	7	40	50	25	122	1.10	1	1.00	60	0.30	0.40	0.50
	Humid/Sub-humid, hot summers	7	37	46	23	113	1.10	1	1.00	60	0.30	0.40	0.50
	Humid/Sub-humid, warm summers	7	40	50	25	122	1.10	1	1.00	60	0.30	0.40	0.50
	Tropical	7	37	46	23	113	1.10	1	1.00	60	0.30	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Canning, Early, Summer plant	Arid/Semi-arid, hot summers	7	40	49	25	121	1.10	1	1.00	60	0.30	0.40	0.50
	Arid/Semi-arid, warm summers	8	43	54	27	132	1.10	1	1.00	60	0.30	0.40	0.50
	Humid/Sub-humid, hot summers	7	40	49	25	121	1.10	1	1.00	60	0.30	0.40	0.50
	Humid/Sub-humid, warm summers	8	43	54	27	132	1.10	1	1.00	60	0.30	0.40	0.50
	Tropical	7	40	49	25	121	1.10	1	1.00	60	0.30	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Canning, Early, Winter plant	Arid/Semi-arid, hot summers	8	45	56	28	137	1.10	1	1.00	60	0.30	0.40	0.50
	Arid/Semi-arid, warm summers	8	44	55	28	135	1.10	1	1.00	60	0.30	0.40	0.50
	Humid/Sub-humid, hot summers	8	45	56	28	137	1.10	1	1.00	60	0.30	0.40	0.50
	Humid/Sub-humid, warm summers	8	44	55	28	135	1.10	1	1.00	60	0.30	0.40	0.50
	Tropical	8	45	56	28	137	1.10	1	1.00	60	0.30	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Table, Autumn/Winter plant	Arid/Semi-arid, hot summers	8	104	69	1	182	1.10	1	1.00	60	0.30	0.40	0.50
	Arid/Semi-arid, warm summers	8	99	66	1	174	1.10	1	1.00	60	0.30	0.40	0.50
	Humid/Sub-humid, hot summers	8	104	69	1	182	1.10	1	1.00	60	0.30	0.40	0.50
	Humid/Sub-humid, warm summers	8	99	66	1	174	1.10	1	1.00	60	0.30	0.40	0.50

Appendix A

Crop Characteristics for use with SAPWAT

	Tropical	8	104	69	1	182	1.10	1	1.00	60	0.30	0.40	0.50

Crop option	Climate	Ini	Dev	Mid	Late	Total	Kc-max	Fv-start	Fv-max	Fv-end	Depl-ini	Depl-mid	Depl-late
Table, Spring/Summer plant	Arid/Semi-arid, hot summers	7	84	56	1	148	1.10	1	1.00	60	0.30	0.40	0.50
	Arid/Semi-arid, warm summers	7	90	60	1	158	1.10	1	1.00	60	0.30	0.40	0.50
	Humid/Sub-humid, hot summers	7	84	56	1	148	1.10	1	1.00	60	0.30	0.40	0.50
	Humid/Sub-humid, warm summers	7	90	60	1	158	1.10	1	1.00	60	0.30	0.40	0.50
	Tropical	7	84	56	1	148	1.10	1	1.00	60	0.30	0.40	0.50

Allen et al., 1998, Jovanovic & Annandale, 1999, Van Wyk, 1992