PRACTICAL SCHEDULING OF IRRIGATION IN THE NORTHERN TRANSVAAL

VOLUME ONE

By M S BURGERS & R D KIRK

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DEPARTMENT OF PLANT PRODUCTION

UNIVERSITY OF THE NORTH

FINAL REPORT

VOL I

OF

CONTRACT RESEARCH PROJECT

SPONSORED BY THE

WATER RESEARCH COMMISSION

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PRACTICAL SCHEDULING OF IRRIGATION IN THE NORTHERN TRANSVAAL

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1. INTRODUCTION

The demand for more efficient water use by irrigation farmers is now as urgent as it was in 1967 (during the National Irrigation Symposium) and in 1970 (during the proclamation of the Water Year). Researchers have responded well and many research projects, sponsored by the now Department of Agricultural Development and the Water Research Commission, have been carried out. Consequently, information on water requirements of crops and on scheduling procedures have been piling up. It can be stated that quite a number of uncertainties that existed during the compilation of the "Green Book" (Besproeiingsbehoeftes van gewasse in S.A.) in 1970 to 1973, have been cleared up since then. Very little progress has, however, been noticed in the adoption of scientific scheduling methods by irrigation farmers.

One of the reasons for the poor response of irrigation farmers to extension programmes, may be attributed to the incompatibility of recommendations with the farm situation. Many of the recommended irrigation programmes and scheduling procedures which have been developed, are not adapted to the following:

* Managerial limitations of the farmer
* limitations of irrigation equipment
* water distribution system and water quotas
* managerial requirements of a complex farm situation which may include different soil types, different irrigation systems and different crops - all operating at the same time.

It is true that the water requirements of crops have to be investigated under controlled experimental conditions before they can be converted into workable programmes for the farm. The time has arrived, however, for the researcher to go to the farm and become acquainted with the practical problems that the farmer will experience during the application of the irrigation programme. Adjustments to the programme can then be made to suit the particular situation and this may lead to general guidelines which are more compatible with the farm situation.

The Pietersburg district is ideally suited for this kind of research project because of its proximity to the University of the North and the fact that a large number of irrigation farmers are found within a radius of 30 km, operating irrigation systems which include conventional sprinkler systems, boom systems, swing beam systems and centre pivot systems. Here, ground water is a common source of irrigation water. Provided that quantity and quality are acceptable, this source provides sufficient flexibility for sound irrigation scheduling. The greatest need for scheduling guidelines is probably in the management of centre pivot systems, and the far Northern Transvaal is one of the areas with the highest concentrations of centre pivot systems per unit land area in South Africa.

It is generally agreed that centre pivot systems tend to lead to excessive water use by crops. At the same time, however, the frequent light applications often do not meet the water requirements of the crop, resulting in a steady depletion of moisture reserves from the deeper soil layers. The crop is then left extremely vulnerable and even a short interruption of the irrigation programme due to breakages, may cause complete crop failure. Any improvement in the management guidelines for these systems, that would reduce or prevent such occurrences, will therefore result in a tremendous boost towards more efficient usage of irrigation water.

With this as background, the following objectives were formulated:

1 *To investigate the applicability of irrigation scheduling methods in the on-farm situation.*

2 *To promote the use of scientific scheduling methods by involving farmer study groups in the research programme.*

3 *To establish scheduling criteria for automated linear and centre pivot irrigation systems.*

The project was undertaken with the objective of really finding the root problem of the lack of farmer adoption of recommendations regarding scientific methods of irrigation scheduling. As such it was welcomed by everybody involved and results were awaited with great expectation.

Five farmers from the Pietersburg Agronomy Study Group volunteered to take part in this project. The idea was to install instruments on the farmer's irrigation fields through which soil water status could be monitored on a continuous basis, in order to assess the success or failure of the farmer's own way of scheduling in meeting the water requirements of the crop.

The monitoring process was supposed to continue for a year or two, after which the farmer would have been guided into a more scientific way of scheduling in order to remove the general uncertainty prevailing amongst farmers as to whether they are doing it right or not.

At the same time the experimental farm of the University of the North (Unin) provided an excellent opportunity for testing scheduling methods like the Irrograph (Burgers, 1982), under careful supervision and monitoring conditions. It was also hoped that this facility would provide opportunities for refinements of crop factors and adjustments to the Irrograph method.

The mass of data accumulated over 5 years from the farmer collaborators can, at the most, serve as a record of what happens under normal, unscientific farmer-scheduling of irrigation applications. However, valuable information and first hand experience were obtained regarding the problems that farmers may encounter, should scientific methods of scheduling be introduced on their farms. All this information and experiences were very useful during the design of the proposal for practical on-farm scheduling, presented in this report.

The work on Unin's experimental farm, Syferkuil, was done much more intensively and the farm manager Mr van As was guided in the use of the Irrograph. However, even here, practical problems, specific to the linear system and cropping programme, led to the abandonment of the Irrograph in favour of the IRRISCHED method proposed in this report.

While the data obtained from the farmer collaborators will be presented to illustrate the extent to which the farmers managed, or failed, to maintain the soil water balance, the major part of this report will be devoted to the development of the IRRISCHED program as well as the results of a trial run thereof.

2. GENERAL RESEARCH PROCEDURE

Farmer collaborators

The project was initiated in discussions of the Pietersburg Agronomy Study Group, attended by the project leader during 1983 and 1984. When the project was finally approved and the contract signed, five farmers operating centre pivot irrigation systems, volunteered to collaborate in the project.

Soil Surveys

Profile descriptions and laboratory analyses were carried out in cooperation with the Soil Science Department at Unin. It was obvious that none of the sites on which the centre pivot systems were installed, consisted of *ideal irrigation soils*. Huge variations in depth and texture occurred and two sites (G. Jansen and one section of Dr Scheepers' site) were so stony, that installation and calibration of the neutron moisture probe were extremely difficult. Many of the soils could be described as sub-optimal with regard to their irrigibility, however, these kinds of soils are quite often used by farmers in the region for irrigation purposes and may thus be regarded as fairly representative.

Measuring Procedure

Seamless steel access tubes for the Neutron Moisture Probe (NMP) of lengths ranging from 700 to 1 200 mm, depending on soil depth, were installed at, at least 3 stations on each farm site. At each measuring station a rain gauge as well as two or three tensiometers (at depths of 300 and 600 mm and in some instances also at 900 mm) were also installed. A USWB class A evaporation pan was installed on each farm and the farmers agreed to keep their own record of daily pan evaporation. On the farm Papkuil of dr Scheepers a Kent flow meter was installed to monitor the volume of water applied with each application. During the irrigation period, each farm was visited 3 times a week and readings of the NMP and tensiometers were recorded on recording forms designed for this purpose, while class A pan readings for the week were obtained from the farmer.

Impact survey

At the end of the project the impact which the project had on the farmers, was assessed through a questionnaire which was completed with each individual farmer.

Syferkuil

An automated linear irrigation system was installed on Syferkuil, experimental farm of the University of the North in 1985. The system covered an irrigated area of 77 ha of which 63 ha was devoted to wheat in winter and maize or soyabeans in summer. These three crops were subsequently included in this study. All crops were grown under a system of zero tillage and the whole field was not tilled once, through-out the duration of the project.

The linear system consists of a 350 m, seven tower, Valley Model 500, which covers a field, 2 200 m in length (77 ha) with a centrally placed control carriage. The system is equipped with a flow meter and with each application the total volume of water applied on a particular hydrant block was recorded.

The experimental site was divided into 9 blocks (No's 3 to 11) of 7 ha each, i.e. the area covered by each hydrant (200 m by 350 m), and each block was subdivided into two sections (A & B) by the carriage-way running through the centre of the field. The same instruments described under Farmer Collaborators, were installed on both sections A and B of blocks 3 to 11 and readings were taken 3 times a week.

Processing of field data

Vast volumes of field data were gathered during the course of the project and in order to expedite the processing of the data into a form that would facilitate interpretation and conclusions, Mr J.P. Burgers of P C LINE CONSULTANTS was contracted to develop an appropriate computer program for that purpose, which culminated in the development of the program **WATERCALC**.

The program was specifically designed to facilitate the processing of the kind of data gathered in this project. However, it could easily be adapted to accommodate other situations. After having entered appropriate calibration coefficients and daily or weekly probe readings, the program would automatically calculate soil water extraction and soil water balance which are then displayed in a graph. When tensiometer readings are available, these are also displayed as a graph. The ease with which soil water extraction or soil water status, as indicated by NMP or tensiometer readings, can be monitored and displayed on a daily basis, makes this program extremely useful to any researcher working in the field of soil water studies or irrigation.

3. RESULTS

Results with farmer collaborators

Most farmers practised *a rule of thumb* kind of scheduling approach, although some did make use of tensiometers and one farmer even started using the A-pan as soon as the project commenced. There was however a lack of clear guidelines on how to use these tools and in all cases they eventually returned to their own *rule of thumb* approach.

Examples of typical neutron probe readings and resultant soil water extraction curves according to **WATERCALC**, for two of the farms are presented in Fig 1 to 4.

From these results it is clear that a general tendency for under irrigation existed amongst most farmers which led to progressive depletion of soil water from the deeper soil layers. Mr Mckechnie, however, managed to maintain the SWB near full capacity through frequent light applications on his garlic crop (see Fig 3 & 4).

These findings were pointed out to the farmers but due to insurmountable staff problems and an impossible administrative commitment of the project leader, it could unfortunately not be followed up with intensive guidance towards more appropriate schedules.

Impact of the Project

Generally speaking, the collaborating farmers had gained considerable knowledge about irrigation scheduling from this project. The equipment provided had been adequately utilized to aid them in scheduling. The farmers didn't always agree with the crop factors provided but with one exception they were satisfied with results achieved.

The project got off to a magnificent start with much enthusiasm from all concerned. However, when contact was lost due to staff shortages, their enthusiasm waned and farmers became disillusioned with the project. This fact was indeed unfortunate because in their opinion, they could have derived much benefit from regular visits, crop monitoring, group discussions and meetings with the project team.

Only two of the collaborators interviewed, would be prepared to cooperate again in a similar project, if approached, but then only on condition that agreements are honoured and regular feedback could be guaranteed.

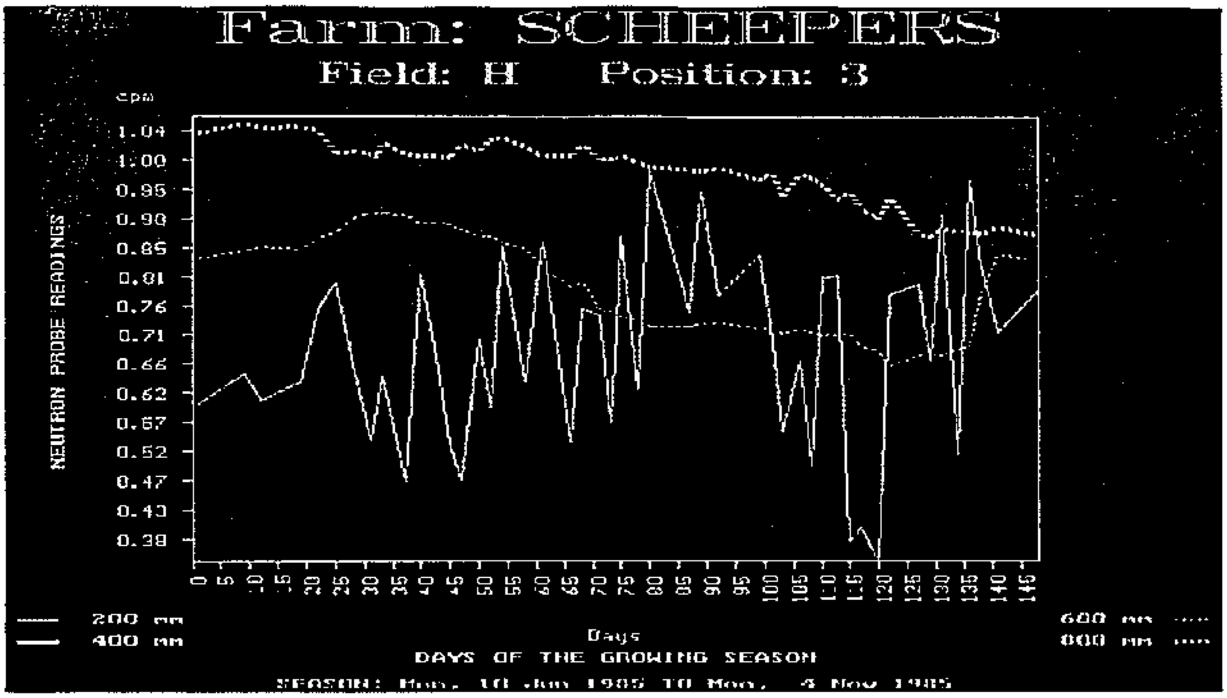

Figure 1 Neutron probe readings for wheat on dr Scheepers' farm - 1985

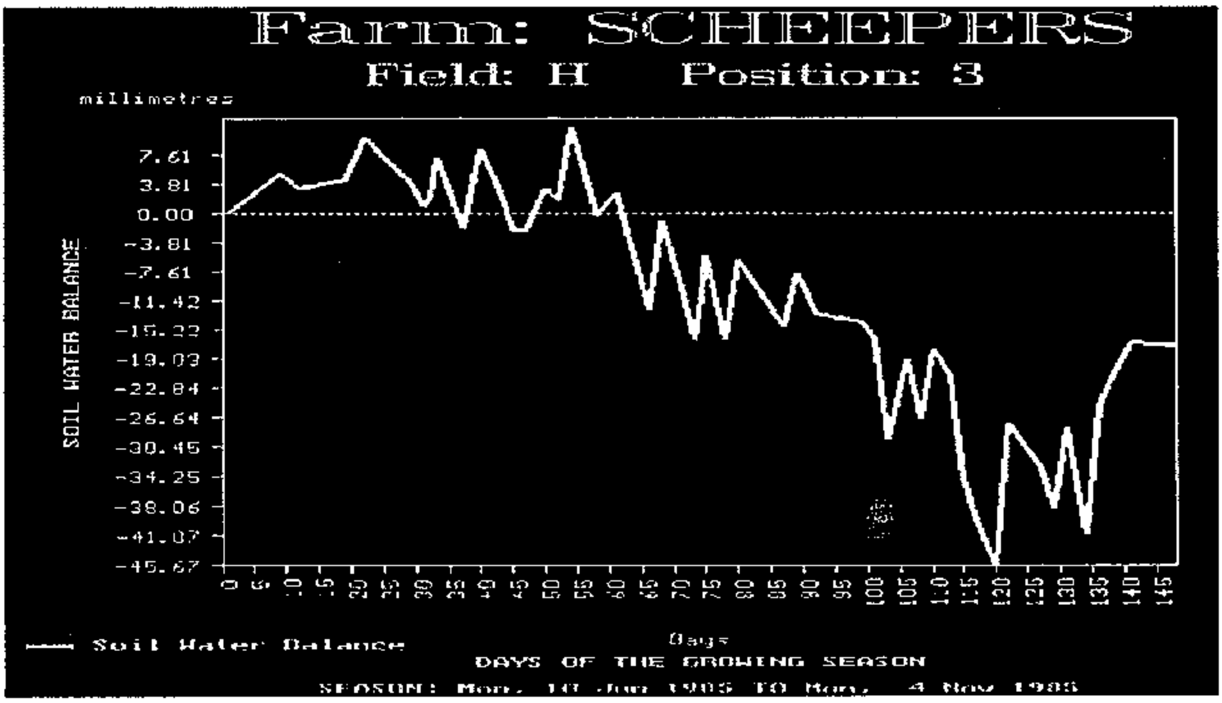

Figure 2 Soil water balance curve for wheat on dr Scheepers' farm - 1985

Results on Syferkuil

Typical soil water extraction curves for wheat grown on Syferkuil are presented in Fig 5 & 6. Neutron probe readings proceded untill harvest time in order to monitor soil water movement in the off-season.

It is clear that even under these well controlled conditions, progressive depletion of soil water from deeper layers was not uncommon.

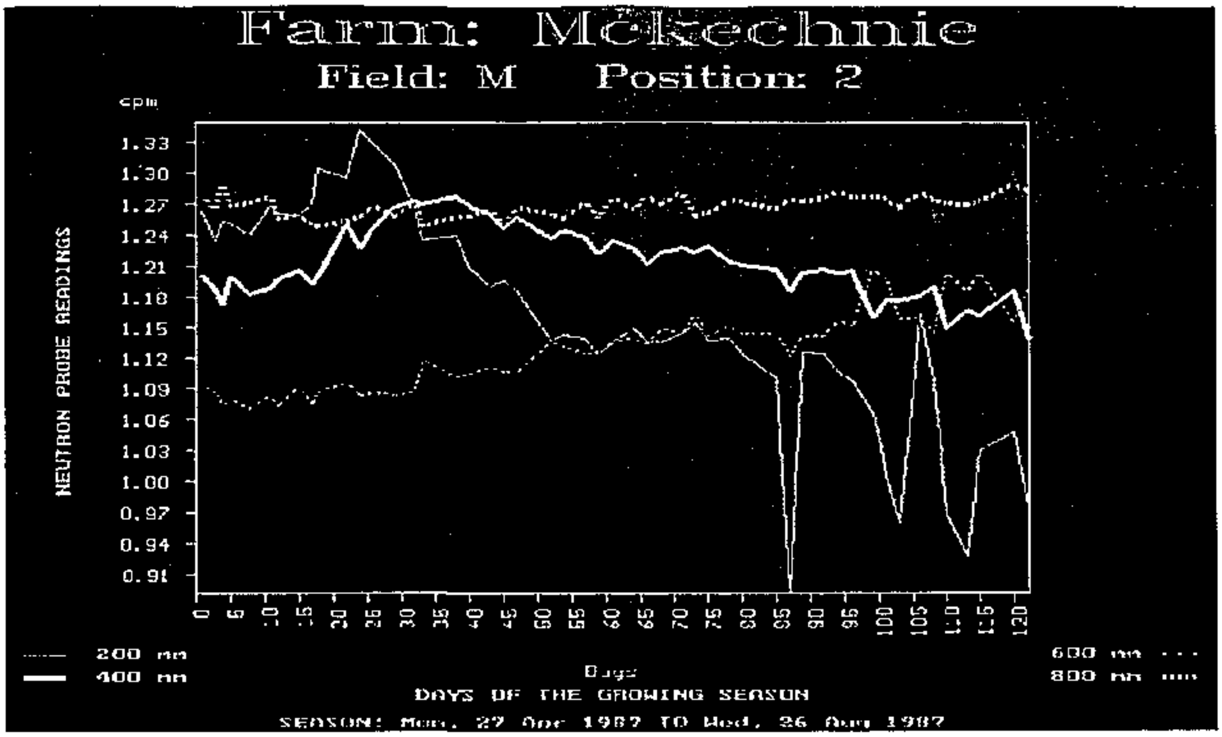

Figure 3 Neutron probe readings for garlic on Mr McKechnie's farm - 1987

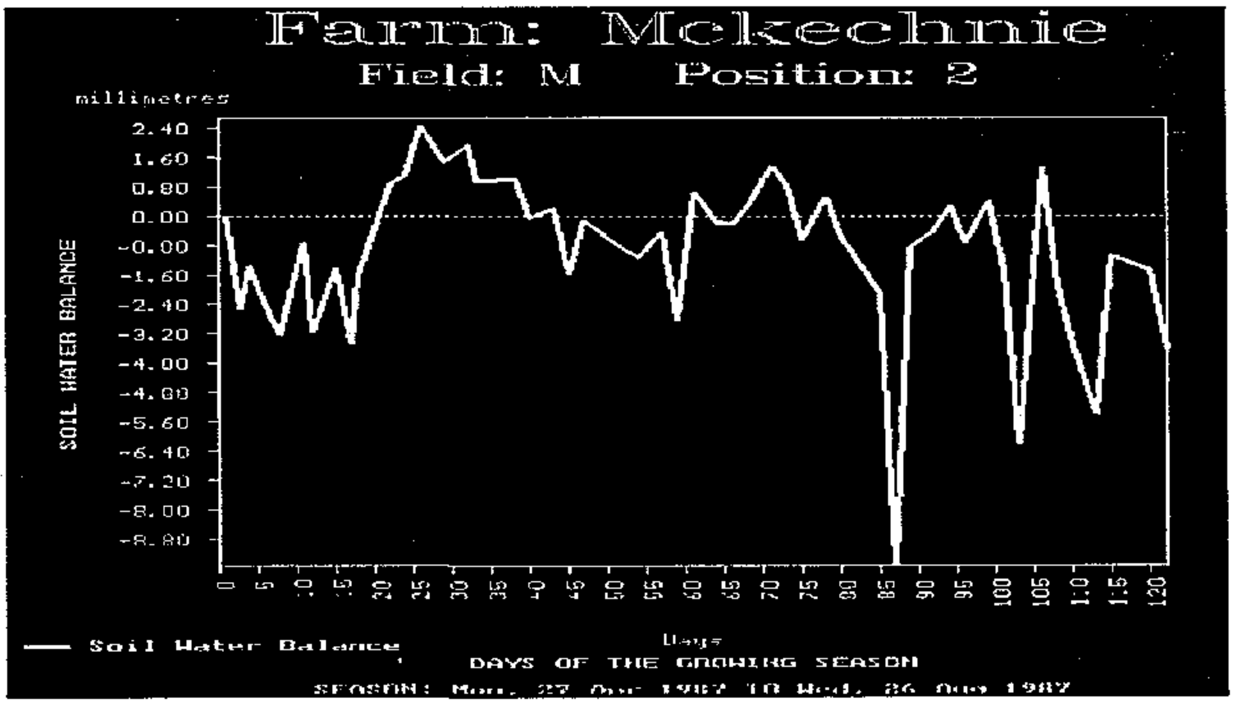

Figure 4 Soil water balance curve for garlic Mr McKechnie's farm - 1987

Most of these situations could however be ascribed to either lack of irrigation water due to subsiding bore hole levels or breakages of the irrigation system and pumps.

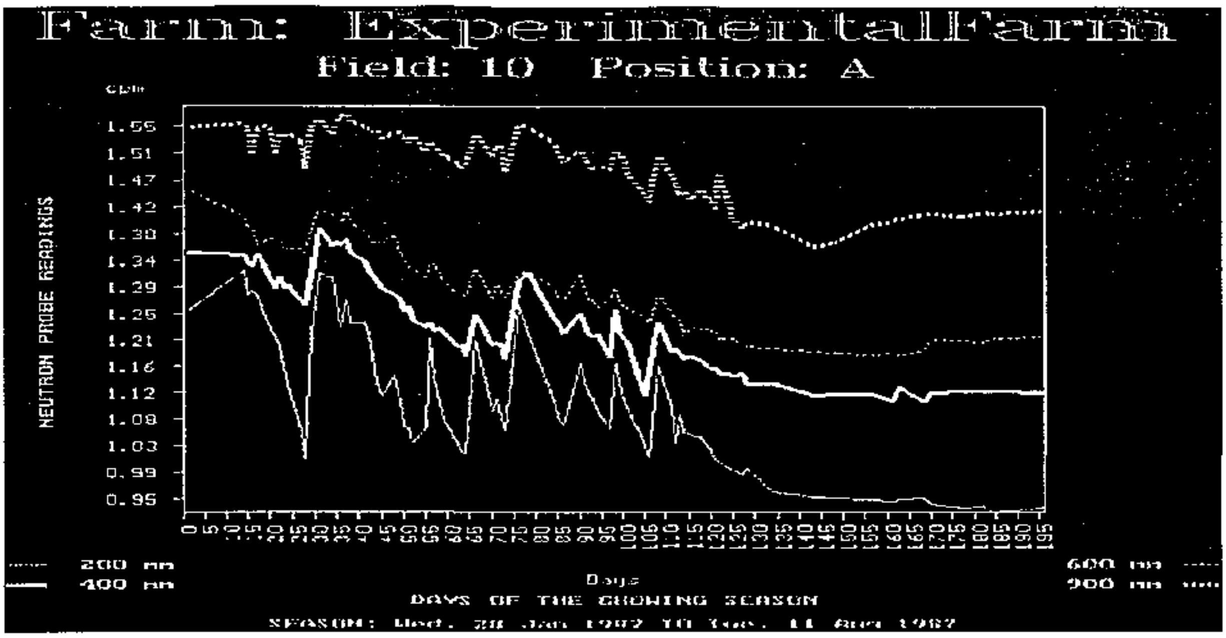

Figure 5 **Neutron probe readings for maize on Syferkuil - 1987**

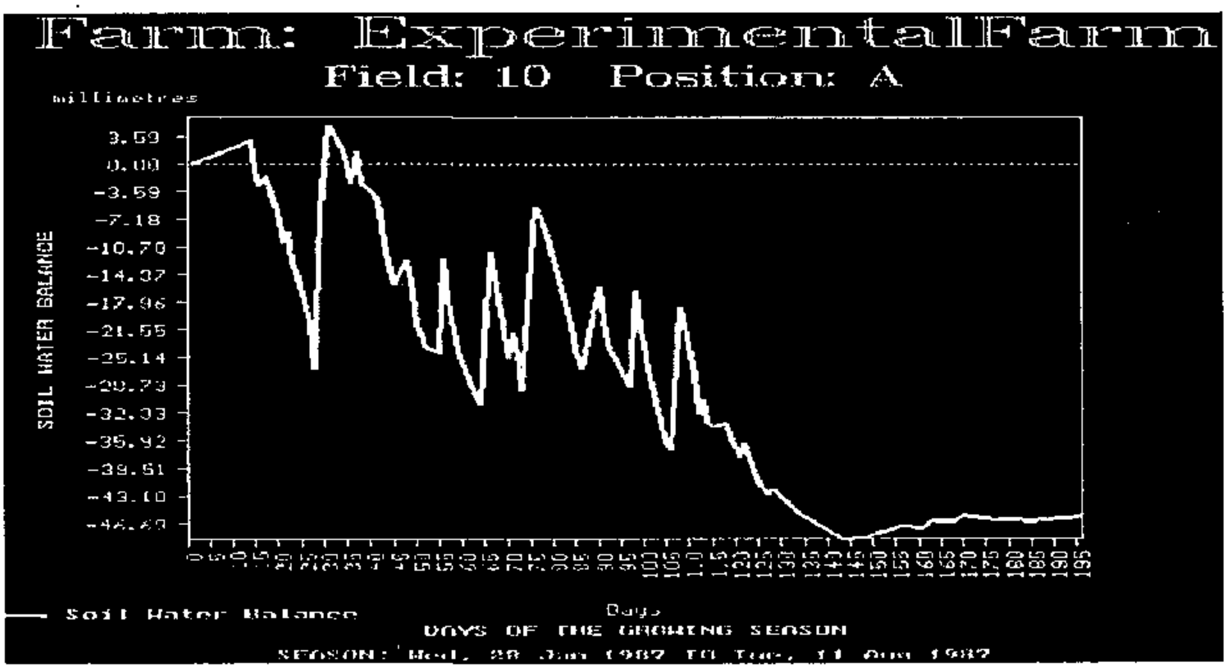

Figure 6 **Soil water balance curve for maize on Syferkuil - 1987**

During times when it was possible to stick to the schedule, it was clear that recommended crop factors from the *Green Book* were too high for the zero tillage system - a tillage system which left a thick mulch of crop residue on the soil surface.

The situation did not allow for accurate comparisons with conventional tillage, but it was estimated that water applications could be reduced by as much as 30% during the early stages of the growing period.

The most remarkable feature of the zero tillage practice was, however, the dramatic improvement in infiltration rate. The linear system was designed to apply water at a constant rate of 45 $mm.h^{-1}$ and during the first maize crop, which was tilled and planted conventionally, it was estimated that run-off amounted to at least 50% of applied water. As soon as zero tillage commenced and the soil surface was mulched, however, **run-off was completely eliminated.**

The implementation of the **Irrograph** as proposed by Burgers(1982) was a disaster. Even under strict control and supervision, it was soon evident that this scheduling tool, as most other scheduling tools, works well in the on-farm situation only when the farmer/manager has to deal with only one irrigated field which can be irrigated in one day. The dire need for an improved scheduling tool which will be able to deal with all the peculiar problems in the on-farm situation, as well as the particular requirements of the farmer, and at the same time remains simple and easy to use, became increasingly evident.

Proposed computer based scheduling method

It appears that most farmers would prefer to schedule irrigation applications conveniently according to routine farm activities and in a more or less fixed time schedule. At the same time, however, they would like to have the assurance that they are meeting the water requirements of their crops.

A fixed schedule which is well planned according to:

* the average atmospheric evaporative demand for the time of the year.
* the soil profile water retention characteristics; and
* the design features of the irrigation system,

could work well, provided the correct amount of water is applied at each of the scheduled dates.

An accurate estimate of soil water extraction since the previous scheduled application, taking into account any effective rain during the same period, would be essential to such a scheduling procedure. Any such estimates would necessarily involve fairly complicated calculations, which may not be acceptable to most farmers. However, computers are fast becoming an essential facility on farms, and a user-friendly program which computes the amount of water to be applied on each of the scheduled dates, may well be the answer to the farmer's scheduling problems.

Mr J.P. Burgers was also contracted to develop a computer program which would facilitate the day to day management of centre pivot and linear irrigation systems on a predetermined time schedule, which resulted in the program called, **IRRISCHED.**

Irrisched

Irrisched is a practical irrigation scheduling tool which is the culmination of 25 years of research on irrigation scheduling methods and is believed to eliminate most of the practical problems encountered with other on-farm methods such as the Irrograph, the Balance Sheet, the Scheepers-pan etc.

The main purpose of the program is to estimate **crop evaporation** (E) on a continuous basis, provide for effective rain and indicate the estimated **soil water deficit** (SWD) when the irrigation system arrives at the starting point of a section of the field to be irrigated. The farmer may then decide on an **application amount** (d) equal to, or smaller than the SWD (as in deficit irrigation as described by Vanassche & Laker, 1989) or larger than the SWD (in order to meet the leaching requirements of the soil).

The program would then indicate the corresponding **speed setting** for the control panel of the irrigation system which would allow the chosen d-value to be applied. Finally the program would display a graph indicating the daily march of the soil **water balance** as influenced by application amounts and effective rain.

The main features of the program can be summarised as follows:

* **On-board Data files** - The program contains the following on-board data files:

  I Long term average pan evaporation data for the region for every week of the year.

  II Average crop factors for as many crops as required as per irrigation/drying cycle for the whole growing season - growth stages being identified by the percentage of growing season that has lapsed since planting.

III Daily crop factors within each drying cycle - the specific stage within a particular drying cycle is identified by the cumulative pan evaporation since the previous wetting by irrigation or rain (Burgers & Nel, 1984)

IV Speed setting values (%) for the control panel of the irrigation system which would allow the application of any application amount from a minimum of say 3 mm to a maximum of say 70 mm, depending on the capacity of the system.

All these on-board data files may be edited or adjusted to suit different situations.

* **Master schedule**

  Using on-board data files I, II & III, the program would simulate a complete irrigation schedule for the whole growing season of the crop as soon as the **planting date** and the **design application amount** are entered by the operator. This schedule can now be adjusted manually to suit the on-farm situation with respect to the number of hours per day available for irrigation, week-end irrigation, application of chemicals etc., as well as design features of the irrigation system and peak crop water requirements during different growth stages of the crop.

* **Easy day-to-day Operation**

  The only action required from the farmer/manager is to enter daily A-pan readings (before and after regulation) as well as any rain that may have occurred. The program then:

  - calculates the day's crop evaporation by selecting the appropriate *daily crop factor* from the column under the particular growth stage's average crop factor corresponding with the value of accumulated pan-evaporation since the previous wetting, which is then multiplied with the day's pan evaporation.
  - subtracts the day's crop evaporation from the soil water balance.
  - when rain occurs: first checks how much room there is for rain water storage in the profile and then add the *effective rain* to the soil water balance and then
  - gives a print-out of all the blocks in the field that should be irrigated that day, the amounts to be applied and the speed setting which would allow these amounts to be applied

* **Graphic display**

  Finally a graph is displayed of the daily march of the soil water balance, showing also all effective precipitation and applications of irrigation water (see Fig 7).

The display in Fig 7 depicts a situation where actual data has been entered up to day 50 of the growing season. From day 51 onwards the graph displays the projected schedule if no rain should occur, allowing for a deficit of 51 mm to develop in the soil profile. This may be supplemented by rain, or it could be rectified by increasing the application amount from 40 to 50 mm

4. DISCUSSION AND RECOMMENDATIONS

It is obvious that the project suffered a great deal because of the difficulties experienced in recruiting properly qualified research fellows as well as the limited time that the Project leader could spend on the project due to increased administrative duties in the executive management of the University of the North. All these problems led to lack of continuity in the management of the project and eventually also the loss of opportunities to take important actions due to the fact that data could not be processed and interpreted on a day to day basis.

Nevertheless, the project did produce some worthwhile results and valuable lessons were learnt with regards to on-farm research and technology transfer in the field of irrigation management.

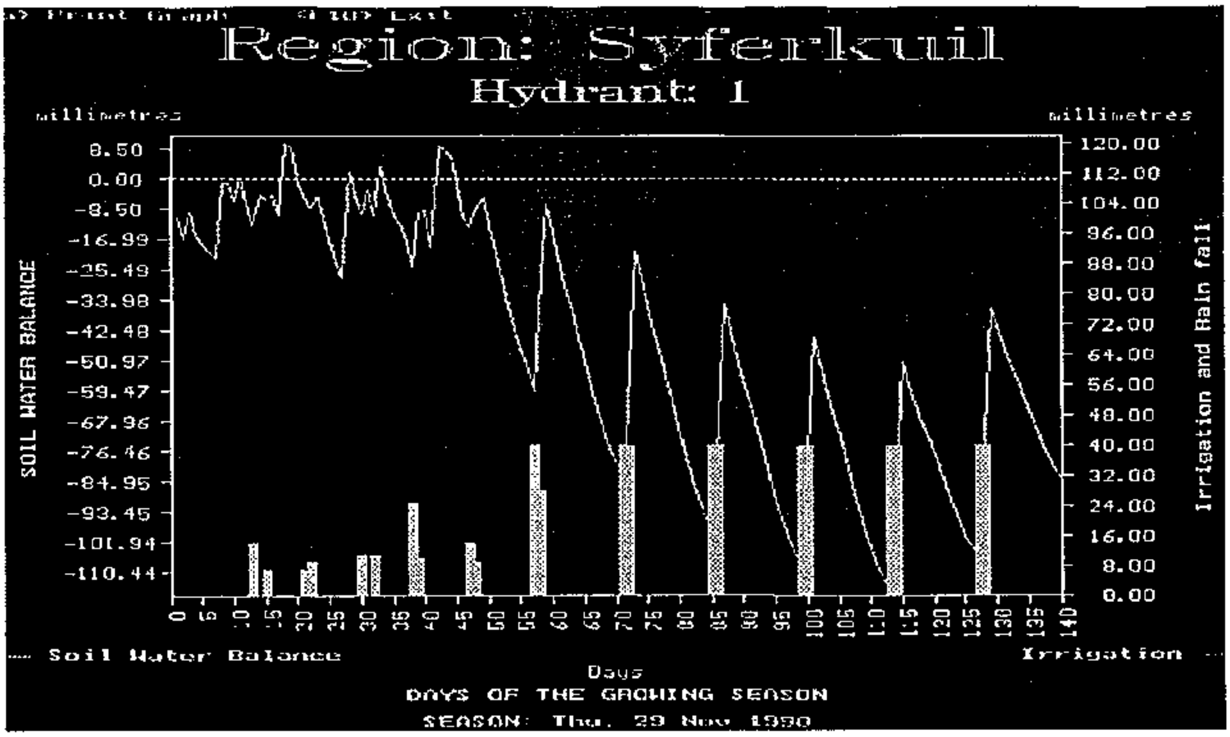

Figure 7 Actual and projected irrigation schedule for soyabeans - 1990/91

1. **The importance of on-farm research**

The experience gathered during this project clearly showed that recommendations with respect to practical irrigation scheduling will have no value unless it has been extensively tested in the on-farm situation with various farmer collaborators. Problems which may be experienced with the day-to-day running of the recommended programme, can only be identified in the real farm situation. However, it is important to emphasize that such on-farm research will capture and retain the interest and co-operation of the farmer only for as long as the researcher maintains intimate contact with, and provides regular feedback about progress to the farmer.

The results obtained from farmer collaborators emphasised the tremendous need for proper information about and efficient but simple tools for irrigation management. Although the farmers seemed to be coping well and obtained reasonable results under the circumstances, it was clear that they had no idea of how close or how far off the mark they were with their irrigation programmes.

In general there was a tendency to under-irrigate with most farmers that were monitored, which led to a progressive decline in soil water status and it should be regarded as a great pity that this could not be followed up with constructive recommendations and guidance towards more efficient programmes.

2. **Conservation tillage under irrigation**

Much of the work for this project was done with an automated linear irrigation system under which maize, wheat and soyabeans have been grown under a system of zero tillage for the past 8 years (15 crops). The results pertaining to yields and economic aspects of the conservation tillage practices were reported in the following ways:

* Video film broadcasted on TV1 on September 12th and December 4th, 1988 in the programmes 50/50 and Agriforum.
* Paper presented at the Annual Conference of the Crop Science Society of South Africa held at the Wild Coast Sun from 23-25 January 1989.
* Paper presented at a Farmer's Day on Conservation Tillage, held at the University of the North Experimental Farm on April 20, 1989, which was attended by close to 200

farmers and officials from all over Transvaal.

* The principles and practices of Conservation Tillage with specific reference to these results form an integral part of several courses offered at the University of the North in the Faculty of Agriculture.

Besides the obvious advantages with respect to cost savings and timeliness of Conservation Tillage, it was emphasized in all reports that the system resulted in tremendous savings in irrigation water due to a remarkable improvement in infiltration and reduction in run-off and evaporation. Irrigation schedules had to be adjusted - in some instances by as much as 30% - in order to prevent severe over-irrigation and waterlogging.

3. **Development of Computer Software**

Two computer programs **Watercalc** and **Irrisched**, were developed during the course of this project - both having the potential for wide-spread marketing amongst irrigation researchers and practitioners.

* **Watercalc** is a program which facilitates the processing of results obtained from a neutron moisture probe. After having entered appropriate calibration constants and daily or weekly Probe readings, the program would automatically calculate soil water extraction and soil water balance which are then displayed in a graph and when tensiometer readings are available these are also displayed as a graph.

* **Irrisched** is a practical irrigation scheduling tool which is the culmination of 25 years of research on irrigation scheduling methods and is believed to eliminate most of the practical problems encountered with other on-farm methods such as the Irrograph, the Balance Sheet, the Scheepers-pan etc. Although **Irrisched** is designed to work with pan evaporation data, only minor adjustments would be required to make use of other methods of estimating crop evaporation.

Irrisched was reported in a poster paper, presented at the Southern African Irrigation Symposium held at the Elangeni Hotel in Durban from 4-6 June 1991, as well as at a Wheat Farmer's day held at the University's experimental farm on 11 September 1991.

Ever since these presentations, we were inundated with enquiries regarding the availability of **Irrisched** on the market and **TSB Sugar and Citrus** estates have requested the development of a program which would facilitate irrigation scheduling on all their farms.

Both programs, **Watercalc** and **Irrisched** have been incorporated in the course PLNP 300 which deals with Agrometeorology and Irrigation Principles and Practices. Students are taught the principles on which the programs are based and given opportunities of operating the programs in a real on-farm situation.

##

ACKNOWLEDGEMENTS

The research on which this Report is based, emanated from a project funded by the WATER RESEARCH COMMISSION. This generous financial contribution which amounted to R360 000 over a period of five years, is acknowledged gratefully because without it, no research would have been possible. The following persons were members of, or either replaced or substituted for other members of the **STEERING COMMITTEE** which were responsible for supervision of the project:

Mr D S van der Merwe	:	Water Research Commission (Chairman)
Dr G C Green	:	Water Research Commission
Dr P C Reid	:	Water Research Commission
Mr G R Backeberg	:	Dept of Agricultural Development
Dr A Streutker	:	Dept of Agricultural Development
Dr D M Scotney	:	Dept of Agricultural Development
Dr A J van der Merwe	:	Dept of Agricultural Development
Mr D F M Korff	:	Dept of Water Affairs
Mr B G Seyfferdt	:	Northern Transvaal Agricultural Cooperative
Prof D R J van Vuuren	:	University of the North
Prof C v d Ryst	:	University of the Orange Free State
Mr F P Marais	:	Water Research commission (Secretary)

All members of the Steering Committee made valuable contributions to the research process through comments, advice or constructive criticism. All these contributions were highly appreciated and are acknowledged gratefully.

The University of the North provided the necessary physical, and administrative infrastructure within which the research was conducted and the contributions of the Research Committee, Transport Section, the Finance Department and faculty administration are gratefully acknowledged. The firm Murray Biesenbach & Badenhorst was also, for a while, intimately involved with the project and the work of and consultations with Johan Badenhorst and Geert Bloem were valuable and highly appreciated.

Professional and technical assistance were provided by Yve Houben (from Belgium), Robin Kirk and Martin Mononela as well as student assistants like Philip Sako, B Ramafoko, Ezekiel Diyani and Barend Burgers. Their dedicated service and support are gratefully acknowledged. Mr Mononela in particular, had to run the project for several months virtually on his own and he deserves a special word of thanks. The practical on-farm experience of Bossie van As, Farm Manager (Plant Production) on Syferkuil, was also invaluable to the project and deserve many thanks.

It is with grateful pride that I acknowledge the contribution of my son Cobus, who developed both computer programmes that are presented in this report, which is regarded as major achievements, that may in future play an important role in soil water research and irrigation scheduling.

The collaborating farmers, Dr Scheepers, Mr v d Merwe, Mr McKechnie, Mr Jansen and Mr Bezuidenhout deserve a special word of thanks. I realise that they have expected more from the project and I can understand their disappointment. They have nevertheless, given their full support throughout the duration of the project and I will be for ever in their debt.

My wife, Annemarie, had to bear with many inconveniences due to my commitments to the project, particularly during the preparation of the final report, and I wish to express my heartfelt appreciation for her patience and support.

CHAPTER 1

INTRODUCTION

In the original proposal for this project, which was submitted to the WRC in 1983 the following substantiation was given:

The demand for more efficient water use by irrigation farmers is now as urgent as it was in 1967 (during the National Irrigation Symposium) and in 1970 (during the proclamation of the Water Year). Researchers have responded well and many research projects, sponsored by the Department of Agriculture and the Water Research Commission, have been carried out. Consequently, information on water requirements of crops and on scheduling procedures have been piling up. It can be stated that quite a number of uncertainties that existed during the compilation of the "Green Book" (Besproeiingsbehoeftes van gewasse in S.A.) in 1970 to 1973, have been cleared up since then. Very little progress has, however, been noticed in the adoption of scientific scheduling methods by irrigation farmers.

One of the reasons for the poor response of irrigation farmers to extension programmes may be attributed to the incompatibility of recommendations with the farm situation. Many of the recommended irrigation programmes and scheduling procedures which have been developed, are not adapted to the following:

- *Managerial limitations of the farmer*
- *limitations of irrigation equipment*
- *water distribution system and water quotas*
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It is true that the water requirements of crops have to be investigated under controlled experimental conditions before they can be converted into workable programmes for the farm. The time has arrived, however, for the researcher to go to the farm and become acquainted with the practical problems that the farmer will experience during the application of the irrigation programme. Adjustments to the programme can then be made to suit the particular situation and this may lead to general guidelines which are more compatible with the farm situation.

The Pietersburg district is ideally suited for this kind of research project because of its proximity to the University of the North and the fact that a large number of irrigation farmers are found within a radius of 30 km, operating irrigation systems which include conventional sprinkler systems, boom systems, swing beam systems and centre pivot systems. Here ground water is a common source of irrigation water. Provided that quantity and quality are acceptable, this source provides sufficient flexibility for sound irrigation scheduling. The greatest need for scheduling guidelines is probably in the management of centre pivot systems, and the far Northern Transvaal is one of the areas with the highest concentrations of centre pivot systems per unit land area in South Africa.

It is generally agreed that centre pivot systems tend to lead to excessive water use by crops. At the same time, however, the frequent light applications often do not meet the water requirements of the crop, resulting in a steady depletion of moisture reserves from the deeper soil layers. The crop is then left extremely vulnerable and even a short interruption of the irrigation programme due to breakages, may cause complete crop failure. Any improvement in the management guidelines for these systems, that would reduce or prevent such occurrences, will therefore result in a tremendous boost towards more efficient usage of irrigation water.

With this as background the following objectives were formulated:

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2 To promote the use of scientific scheduling methods by involving farmer study groups in the research programme.

3 To establish scheduling criteria for automated linear and centre pivot irrigation systems.

The project was thus undertaken with the aim of finding the root problem with the lack of farmer adoption of recommendations regarding scientific methods of irrigation scheduling. As such it was welcomed by everybody involved and results were awaited with great expectations.

Five farmers from the Pietersburg Agronomy Study Group volunteered to take part in this project. The idea was to install instruments on the farmer's irrigation field through which soil water status could be monitored on a continuous basis, in order to assess the success or failure of the farmer's own way of scheduling in meeting the water requirements of the crop.

The monitoring process was supposed to continue for a year or two, after which he would have been guided into a more scientific way of scheduling in order to remove the general uncertainty prevailing amongst farmers as to whether they are doing it right or not.

At the same time the experimental farm of the University of the North (Unin) provided an excellent opportunity for testing scheduling methods like the Irrograph (Burgers, 1982) under careful supervision and monitoring conditions. It was also hoped that this facility would provide opportunities for refinements of crop factors and adjustments to the Irrograph method.

This Report contains a description of the **Research procedure** followed throughout the project in Chapter 2, **Results** obtained on the farms of the collaborators (Chapter 3) and on Syferkuil (Chapter 4), conclusions and recommendations which are presented in Chapter 5, a description of the recommended **Irrisched** programme provided in Chapter 6 as well as **Appendices** which contain Soil characteristics and Neutron probe calibration curves (Appendix A), the questionnaire used and individual responses of farmers in an impact survey (Appendix B) , a **reprint of a paper** delivered at the Southern African Irrigation Symposium as a poster (Appendix C), and finally, the user **manuals** and **source codes** of the Watercalc and Irrisched programmes (Appendices D, E, F, & G).

CHAPTER 2

GENERAL RESEARCH PROCEDURE

2.1 FARMER COLLABORATORS

The project was initiated during discussions of the Pietersburg Agronomy Study Group, attended by the project leader during 1983 and 1984. When the project was finally approved and the contract signed, five farmers volunteered to collaborate in the project. They were:

1. Dr. H.J. Scheepers, Papkuil
2. Mr J. van der Merwe, Fort Klipdam
3. Mr M.A. Jansen, Doringkraal
4. Mr P. Bezuidenhout, Kalkfontein
5. Mr A McKechnie, Balhambra Grove.

Agreements were then signed between the University and each of these farmer collaborators.

2.1.1 Soil Characteristics

Profile descriptions and laboratory analyses were carried out in co-operation with the Soil Science Department at University of the North (Unin). Detailed results of these analyses are given in Appendix A. It was obvious that none of the sites on which the centre pivot systems were installed, consisted of ideal irrigation soils. Huge variations in depth and texture occurred and two sites (G. Jansen and one section of Dr Scheepers' site) were so stony that installation and calibration of the neutron moisture probe were extremely difficult.Many of the soils could be described as sub-optimal with regard to their irrigibility, however, these kinds of soils are quite often used by farmers in the region for irrigation purposes and may thus be regarded as fairly representative.

2.1.2 Measuring Procedure

Seamless steel access tubes for the Neutron Moisture Probe (NMP) with lengths ranging from 700 to 1 200 mm, depending on soil depth, were installed at at least 3 sites on each farm. At each measuring station a rain gauge as well as two or three tensiometers (at depths of 300 and 600 mm and in some instances also at 900 mm) were also installed. A USWB class A evaporation pan was installed on each farm and the farmers agreed to keep their own record of daily pan evaporation. The linear system on Syferkuil is equipped with an electronic flow meter and with each application the total volume of water applied on a particular hydrant block was recorded. On the farm Papkuil of dr Scheepers a Kent flow meter was installed to carry out similar measurements. No measurements of application volumes were done on the other three farms. During the irrigation season, each farm was visited 3 times a week and readings of the NMP and tensiometers were recorded on recording forms designed for this purpose, while class A pan readings for the week were obtained from the farmer.

2.1.3 Irrigation Systems and CU determinations

Design features of the irrigation systems of the various collaborators and of Syferkuil were as follows: The Christianson Uniformity Coefficients (CU) of the various irrigation systems were determined according to prescribed procedures and the results appear in Table 2.1.

TABLE 2.1 Cu - values for irrigation systems of farmer collaborators as well as of Syferkuil

FARM	DATE	MEAN*	CU
VAN DER MERWE	86-10-01	5,3 mm	90,3 %
	86-10-06	3,9 mm	85,8 %
JANSEN	86-12-06	14,3 mm	82,5 %
MCKECHNIE	86-08-22	8,8 mm	86,9 %
	86-08-25	11,7 mm	85,5 %
	86-08-29	11,4 mm	87,2 %
SCHEEPERS	86-10-03	23,9 mm	84,0 %
	86-10-04	21,1 mm	89,2 %
BEZUIDENHOUT	86-10-09	6,1 mm	84,8 %
	86-10-14	6,1 mm	78,9 %
	86-10-17	7,3 mm	86,2 %
	86-10-20	8,6 mm	82,8 %
SYFERKUIL**	86-09-22	43,8 mm	82,5 %
	86-09-29	43,1 mm	86,8 %
	92-11-09(H10)	21,3mm(24,4mm)	89,1 %
	92-11-10(H10)	20,6mm(24,4mm)	80,0 %
	92-11-12(H1)	27,4mm(28,5mm)	88,1 %
	92-11-13(H1)	24,8mm(28,5mm)	86,5 %

* Mean application values are the mathematical average of the readings of all rain gauges used in the test and in the case of Syferkuil the values in parenthesis represent the mean application depth as calculated from the flow meter reading on the linear system.

** The CU-index determinations repeated on Syferkuil in 1992 were done in duplicate at both sites (Hydrant 1 & Hydrant 10).

The results depicted in Table 2.1 suggest that most systems comply with the accepted norm of 84 % (Reinders, 1984). However, according to Van der Ryst (1990), the CU - value is an unreliable indicator of uniformity of application of a centre pivot system. He then went on and suggested a new index called the Emittor-CU which is based on the discharge rate of each emittor without the need to compensate for the area covered by each emittor. In the absence of an *emittor-CU* index, van der Ryst stated that:

> *"....The water distribution pattern on the ground can be evaluated by graphically plotting observed distributions of water depth in relation to the simple mathematical average...."*

Since not enough data were available for the systems used in this study, to calculate the *Emittor-CU* indices, water distribution patterns were plotted as suggested. Examples of some of the patterns are depicted in Figures 2.1 & 2.2 while all distribution patterns of all systems are provided in Figures 5 to 14 of Appendix A. It is clear that while the distribution patterns are satisfactory in most cases, isolated emittors showed extreme deviations of between 50 and 105%, and should be rectified.

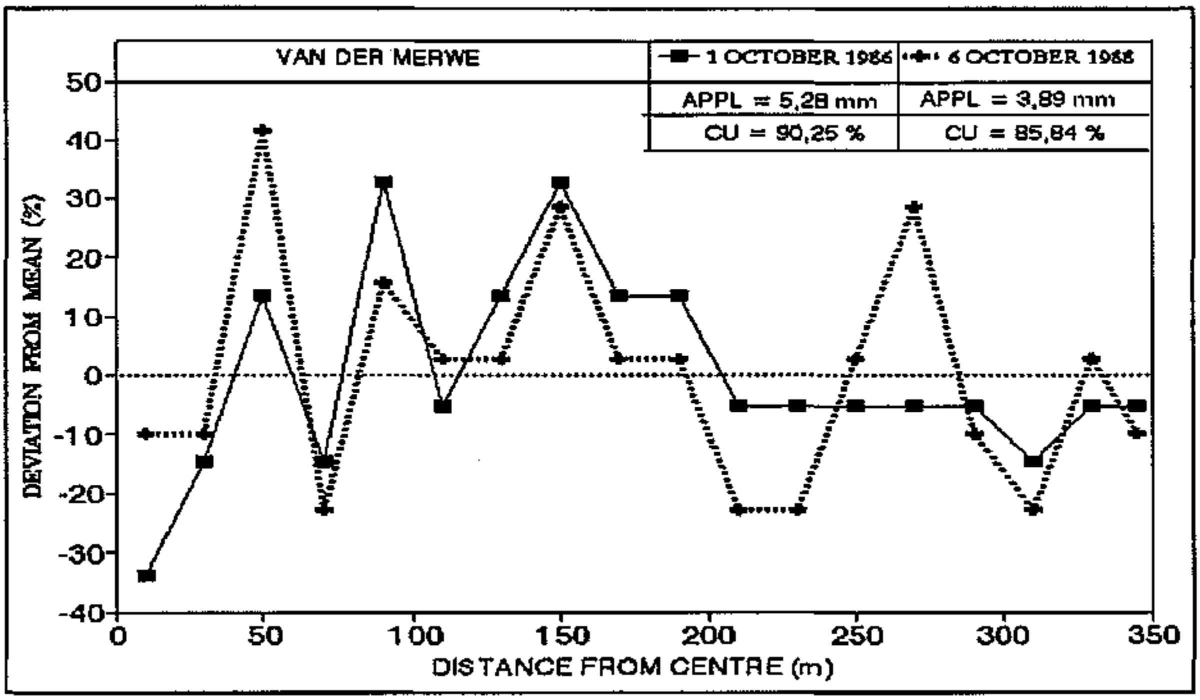

Figure 2.1 Application distribution and CU-index of centre pivot system on Mr van der Merwe's farm

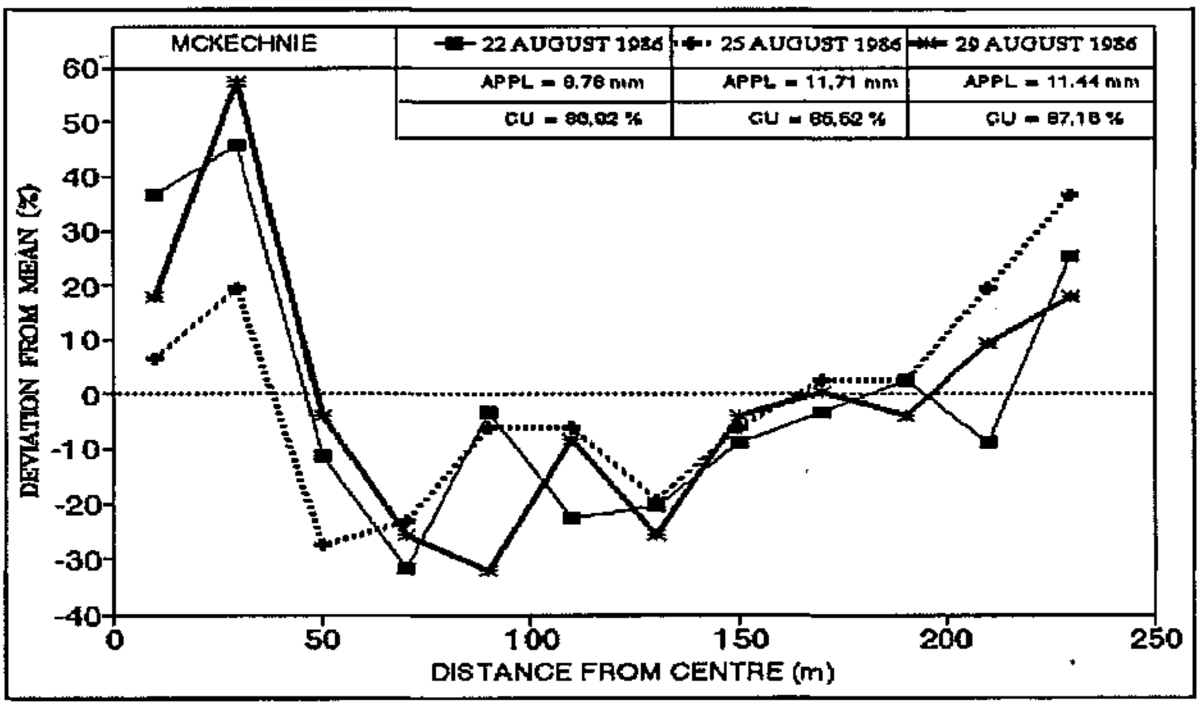

Figure 2.2 Application distribution and CU-index of centre pivot system on Mr McKechnie's farm

2.1.4 Impact survey

At the end of the project the impact which the project had on the farmers, was assessed through a questionnaire (Appendix B) which was completed with each individual farmer.

A summary of farmer responses to the questionnaire is given in Chapter 3 while the responses of individual farmers are presented in Appendix B.

2.2 SYFERKUIL

An automated linear irrigation system was installed on Syferkuil, experimental farm of the University of the North in 1985. The system covered an irrigation area of 77 ha of which 63 ha was devoted to wheat in winter and maize or soyabeans in summer. These three crops were consequently included in this study (See Fig. 2.3). The linear system consists of a seven tower Valley Model 500, 350 m long with an under-ground guiding system, covering a field, 2 200 m in length with a centrally placed control carriage. The system has a total of 36 booms, 15 m long, each carrying 3 ultra-low pressure nozzles mounted at an angle of 63° at a height of 3 m above ground level. The operating pressure in the overhead supply pipe is 120 kPa but the pressure on each nozzle was regulated to maintain a pressure of 42 kPa, by a Nelson PR 15 pressure regulator. At the operating pressure, the main pump delivers 240 $m^3.h^{-1}$, providing a constant application rate of 45 $mm.h^{-1}$ and speed settings ranging from 100% to 7%, allow applications ranging from 3,4 mm to 51,4 mm at a time. Travelling time for covering the 2,2 km field, ranged from 11 hours (at 100% speed setting) to 165 hours (at 7% speed setting) to which approximately 20 minutes must be added for each of the 11 hydrants where the drag-hose and power cable must be disconnected and reconnected to the next one.

However, due to an altitude difference of 40 m between the bottom and top sections of the field, the operating pressure of 120 kPa could not be maintained at the top section and corresponding adjustments had to be made in speed settings to achieve required application depths.

The main pump situated at the reservoir at the bottom of the field, supplied water through a main pipe line starting with a diameter of 250 mm and ending with 150 mm. Eleven hydrants and electrical power points were situated every 200 m along the length of the field. A 100 m long electrical cable and a 100 m long (150 mm diameter) drag pipe, supplied electricity and water respectively to the linear.

Particulars about Cu-index determinations carried out on the linear system appear in Table 2.1 while examples of some of the application distribution patterns are dipicted in Fig 2.3 & 2.4.

2.2.1 Soil survey

The experimental site was divided into 9 blocks (No's 3 to 11) of 7 ha each, i.e. the area covered by each hydrant (200 m by 350 m), and each block was subdivided into two sections (A & B) by the carriage-way running through the centre of the field. Profile descriptions and soil analyses were done on each of these sub-blocks (see Appendix A).

2.2.2 Measuring procedure

The same instruments described under Farmer Collaborators, were installed on both sections A and B of blocks 3 to 11 and readings were taken 3 times a week.

2.3 CALIBRATION OF NEUTRON MOISTURE PROBE

A Campbell Pacific Nuclear 503 DR Hydroprobe was bought in 1984. This instrument gave excellent service and consistency of readings was remarkable. All readings were taken as a count ratio (CR) which minimised the effects of any drift which might have occurred in the instrument provided that the standard count was adjusted regularly.

Attempts were made to carry out both field and drum calibrations of the NMP. Consistent results were obtained from the drum calibration, which was carried out in a 200 *l* oil drum, cut in half, with a crop growing in it to facilitate fast and even extraction of water (see Fig 2.4).

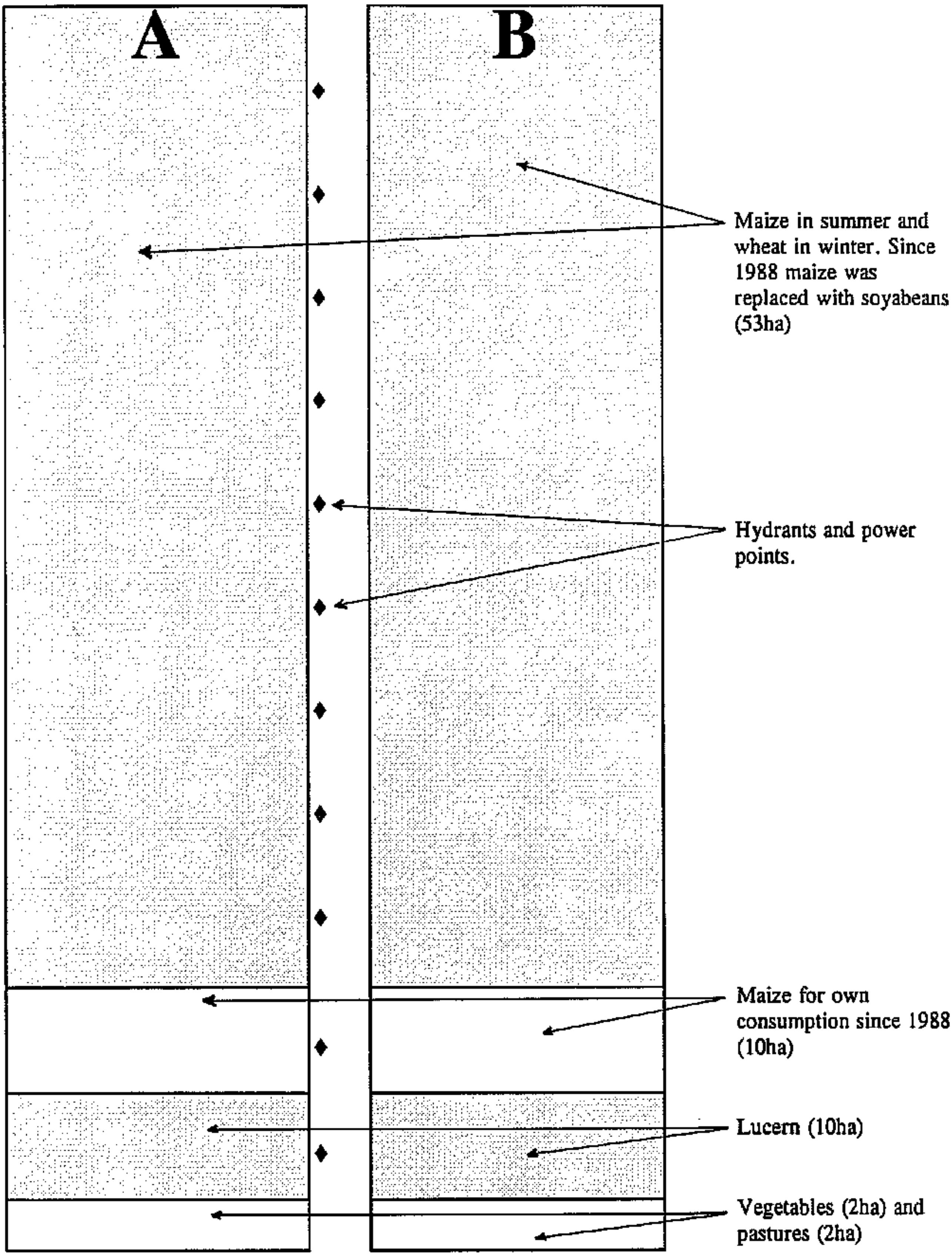

Fig. 2.3 **Sketch of field under the autonomated linear irrigation system on Syferkuil, experimental farm of the University of the Norh.**

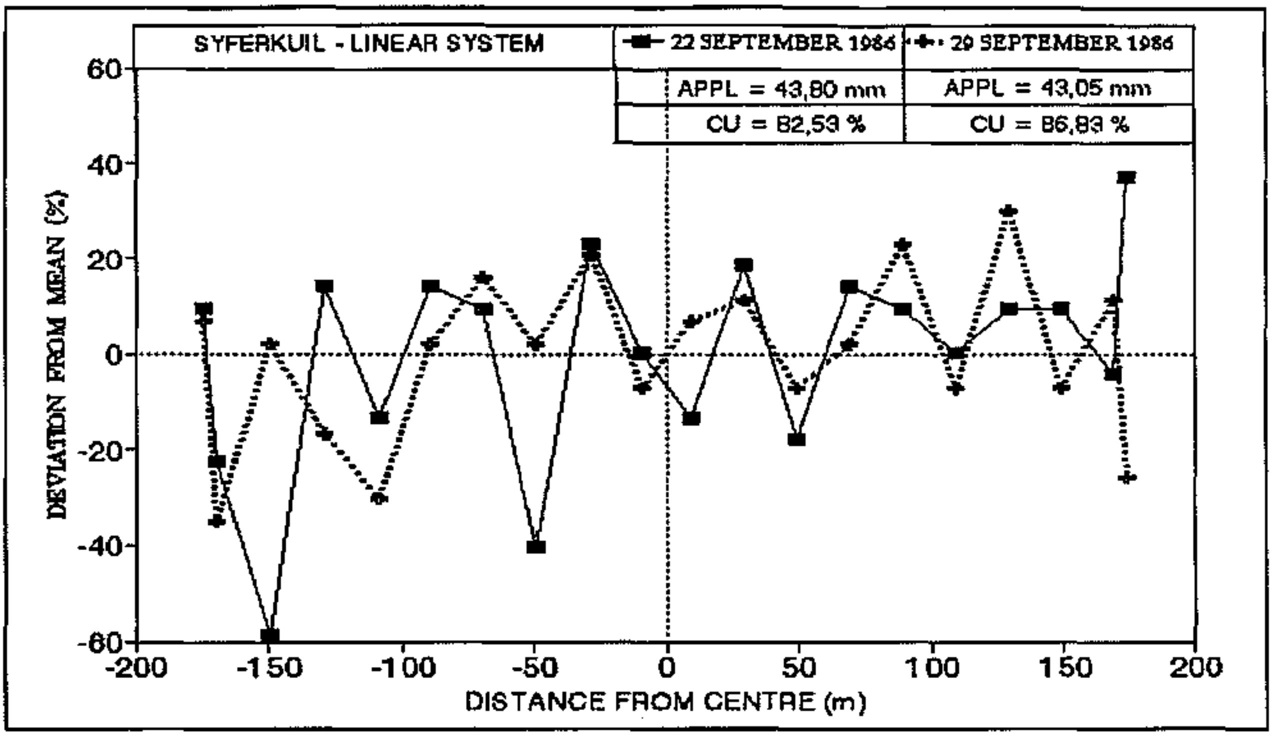

Figure 2.4 CU-indices and application distribution patterns for the linear system (Syferkuil-1986)

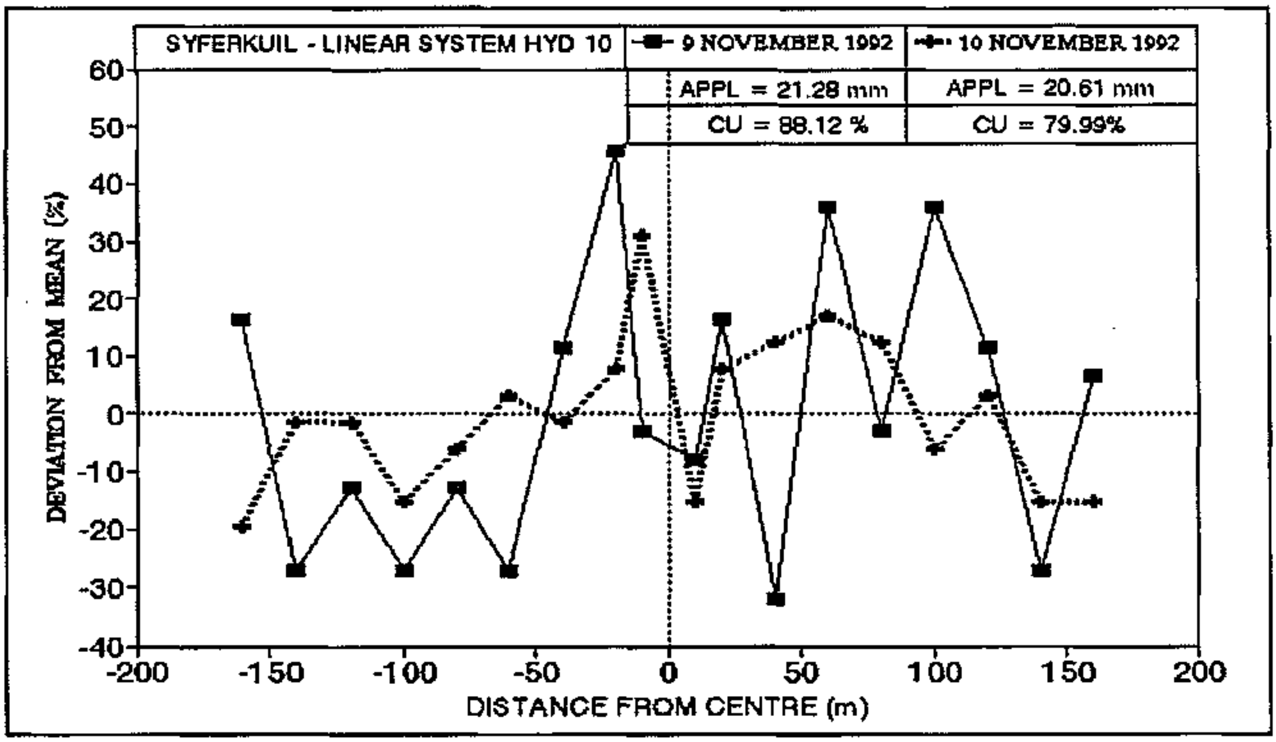

Figure 2.5 CU-indices and application distribution patterns for the linear system (Syferkuil-1992)

However, these results did not correspond with results obtained from the field calibration, both with respect to the range of CR values and the slope of the curve (compare Figure 2.5).

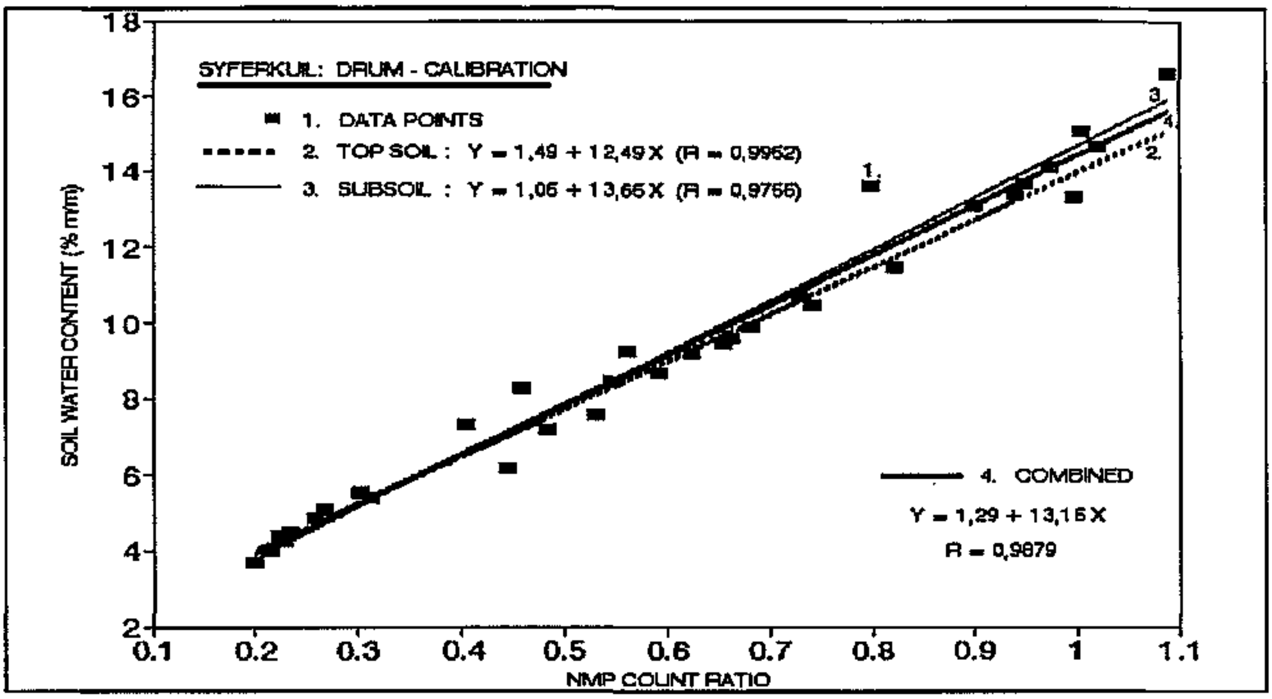

Figure 2.6 Neutron Moisture Probe calibration curves for Syferkuil soil, using the Drum - calibration technique

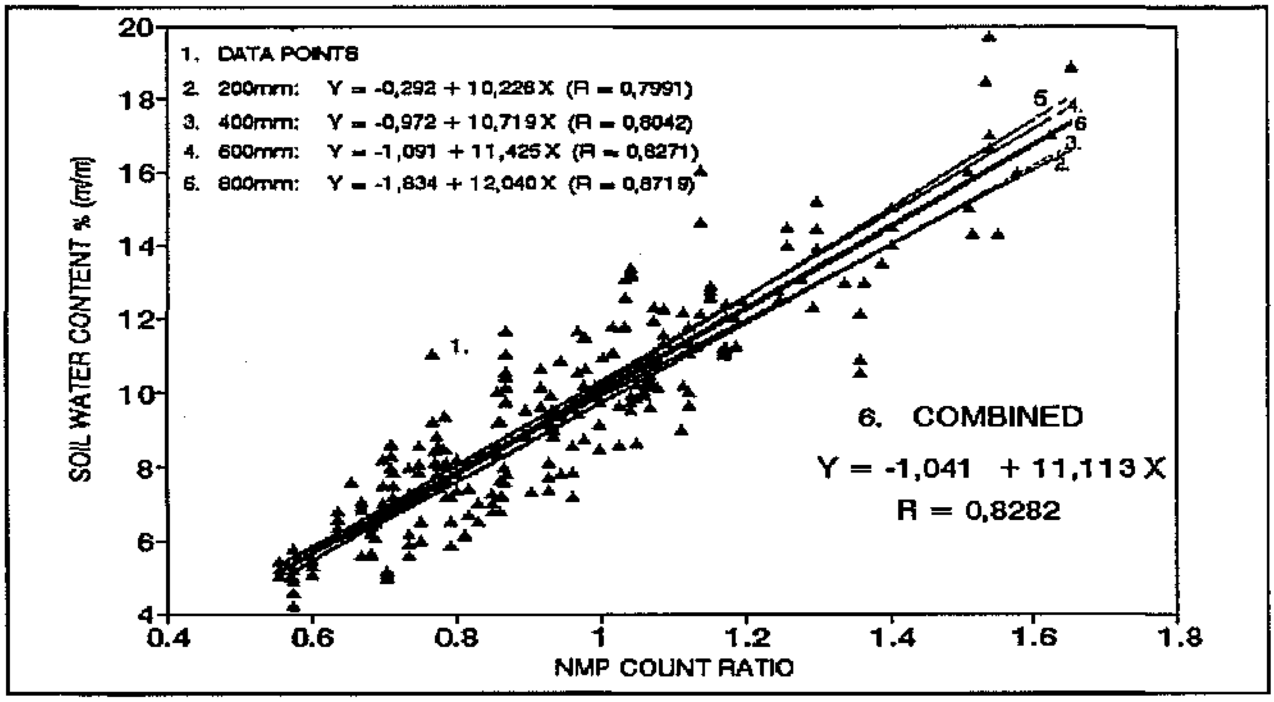

Figure 2.7 Neutron Moisture Probe calibration curves for four soil depths on Syferkuil

It should also be noted that the results of the field calibration were more inconsistent and variable, making the reliability of calibration coefficients less convincing (compare also the calibration curves for individual sites and depths in Figures A1 to A4 in Appendix A). This should be attributed to the unreliability and/or excessive variability of gravimetric soil moisture determinations. However, since all comparisons of soil water in this study were done on a relative basis (comparing only differences in soil water extraction), a coefficient of determination (R^2) of 69% on average, may be regarded as adequate.

2.4 PROCESSING OF FIELD DATA

Vast volumes of field data were gathered during the course of the project and in order to facilitate the processing of the data into a form that would facilitate interpretation and conclusions, Mr J.P. Burgers was contracted to develop an appropriate computer programme for that purpose. Thus WATERCALC came into being.

Watercalc

The programme was specifically designed to facilitate the processing of the kind of data gathered in this project. However, it could easily be adapted to accommodate other situations. The programme allows the user to create any number of measuring stations on a particular field. At this stage all information relevant to the particular station must be entered i.e.:

* Farm name
* Field number
* Position number
* Beginning and end of crop season
* Depths at which readings are to be carried out
* Calibration coefficients
* Dry bulk density of the soil.

Input data consisted of the following:

* duplicate readings of the NMP at depths of 200, 400, 600, 800mm and where soil depth permitted also 1 000 mm at each measuring station of all farm sites, including Syferkuil.
* tensiometer readings
* daily pan evaporation.
* daily precipitation
* irrigation applications.

The programme would then do the necessary calculations and convert NMP count ratios into mm of soil water.

Graphs and Print-outs

Besides viewing or printing individual graphs, the option *Full Report* will give a print-out of the following:

1. Station information
2. Raw data of the NMP count rate readings (Table)
3. Processed data (Table)
4. Profile water content in mm (Graph)
5. Cumulative water extraction in mm (Graph)
6. Soil water balance in mm (Graph)
7. Tensiometer readings (Graph).

Watercalc is a user-friendly programme which facilitates the processing of masses of data tremendously well. The ease with which soil water extraction or soil water status, as indicated by NMP or tensiometer readings, can be monitored and displayed on a daily basis, makes this programme extremely useful to any researcher working in the field of soil water studies or irrigation.

The complete user's manual for Watercalc is provided in Appendix E, Vol II.

CHAPTER 3

RESULTS WITH FARMER COLLABORATORS

3.1 SOIL WATER EXTRACTION - AN OVERVIEW

Amongst the vast amount of data on soil water extraction collected over a period of five years, a selection has been made of typical extraction curves for different crops, measuring stations, and seasons, from the five collaborating farmers. These are presented as an illustration of extraction patterns observed under normal farmer scheduling. It also demonstrates the degree of variation within and between seasons occurring on the same field.

The results revealed some short-comings in the irrigation practices of most of the farmers and it is clear that all of them could have benefitted significantly from more regular feed-back and consultation with the project team. It is a great pity that this did not happen due to the circumstances described in Chapter 5.

However, the results presented in this report and the experience gathered during the collaboration with the farmers were invaluable for the development of the proposed computer based scheduling method presented in this report. Furthermore, it will also provide useful guidelines for more productive cooperative research of the same kind in future.

The farmers followed mostly their own irrigation programmes. However, Dr Scheepers had some of his own tensiometers installed, and took a keen interest in the readings, which did influence his decisions on when to irrigate to some extent. Mr McKechnie used the project A-pan and crop factors for onions to calculate crop water use for his garlic crop with the aid of a spread sheet program on his own computer. He complained, however, about the lack of appropriate crop factors for garlic, maintaining that the crop factors for onions were not applicable for garlic.

The soil water extraction curves presented in this report were all computed by the Watercalc computer programme developed for this project and described in Chapter 2. In most cases only the soil water balance (with *field water capacity* taken as reference point) is depicted. However, where additional explanation was required, the actual neutron probe readings are also presented.

The graphs for each farmer were grouped together and are presented and discussed consecutively.

3.1.1 Dr H J Scheepers (Papkuil)

The wheat crop of 1985 started off with a profile water deficit of 20 mm (Fig 3.1) and although the irrigation programme managed to maintain that level for the rest of the growing period, the probe readings (Fig 3.2) at a depth of 800 mm show a progressive depletion of water from deeper the layers.

The progressive depletion of profile water was much more pronounced in 1986 (Fig 3.4). Comparing Fig's 3.3 and 3.4, demonstrates the in-field variation that may occur between measuring stations. It is obvious that station 2 was on a much drier spot in the field and apparently received less water than station 1. Consequently, it ended the season with a profile water deficit of 80 mm, 37 mm more than station 1. Similar depletion of profile water occurred during 1988 (Fig 3.5) but a good down-pour near the end of the season brought the profile back almost to field capacity.

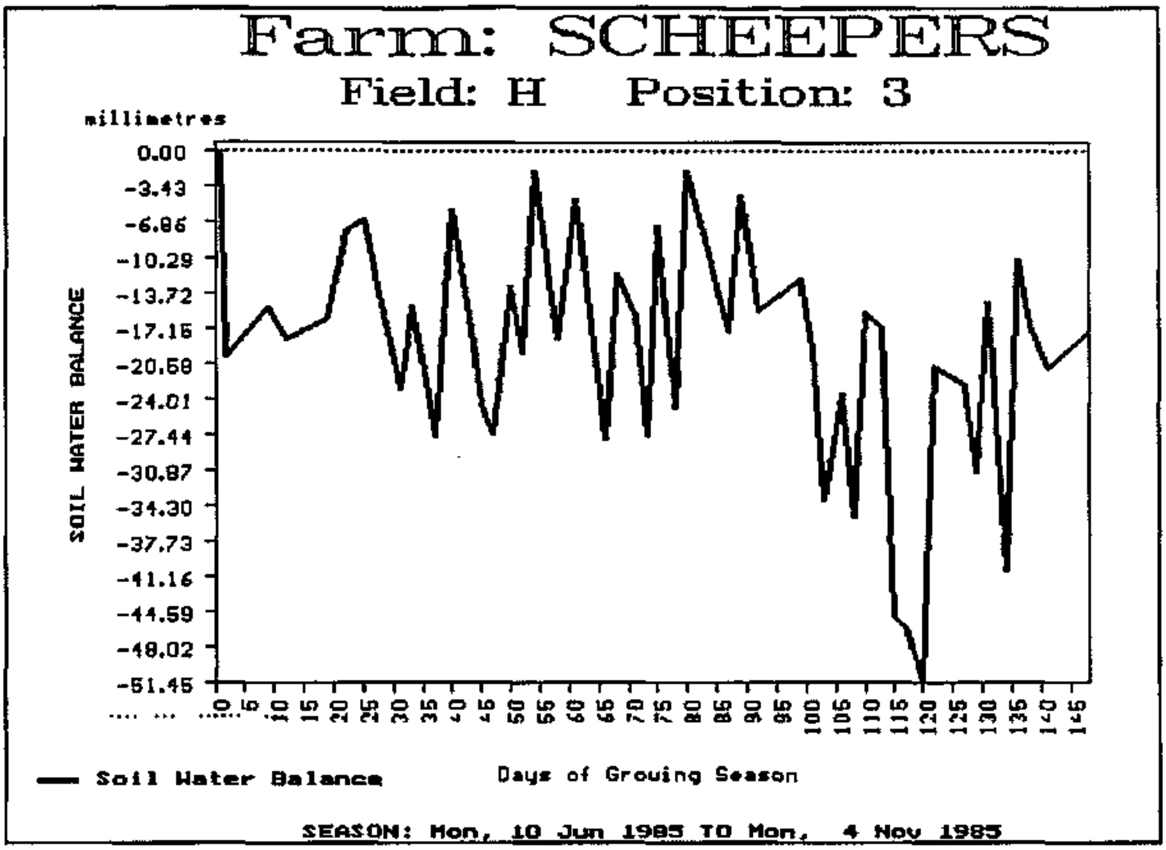

Figure 3.1 Soil water extraction curve for wheat - 1985

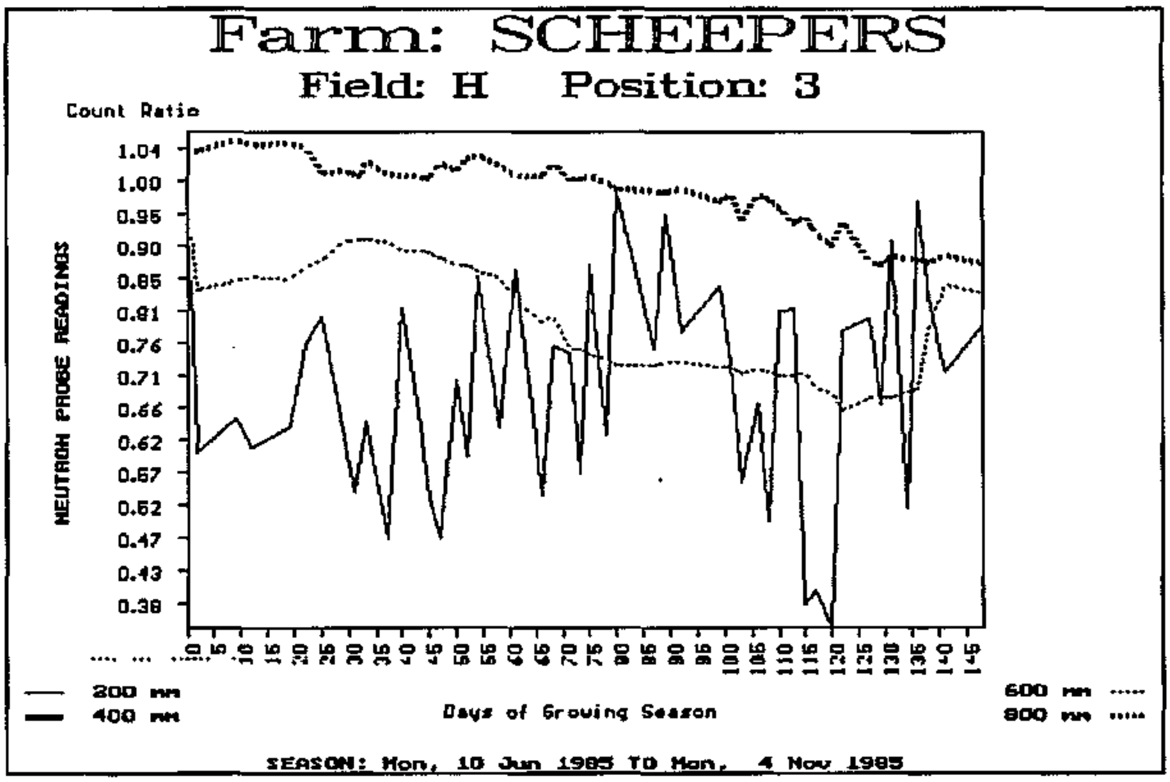

Figure 3.2 Neutron probe readings for wheat - 1985

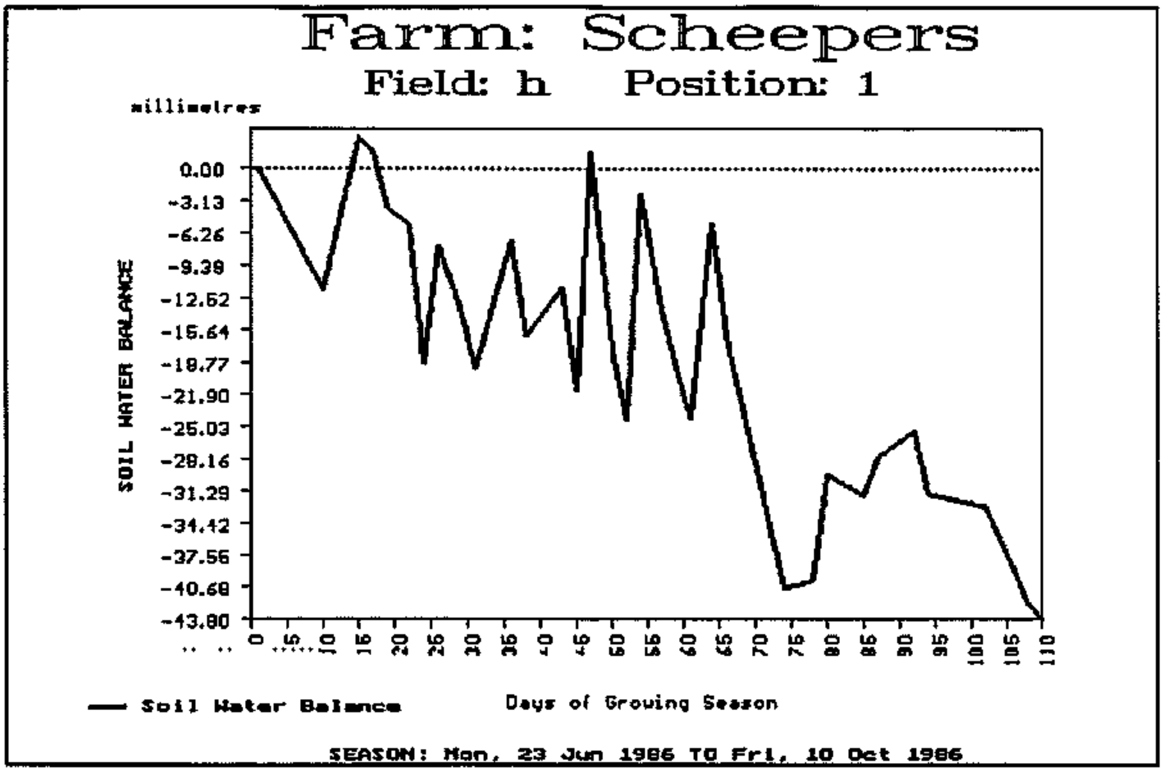

Figure 3.3 Soil water extraction curve for wheat - 1986

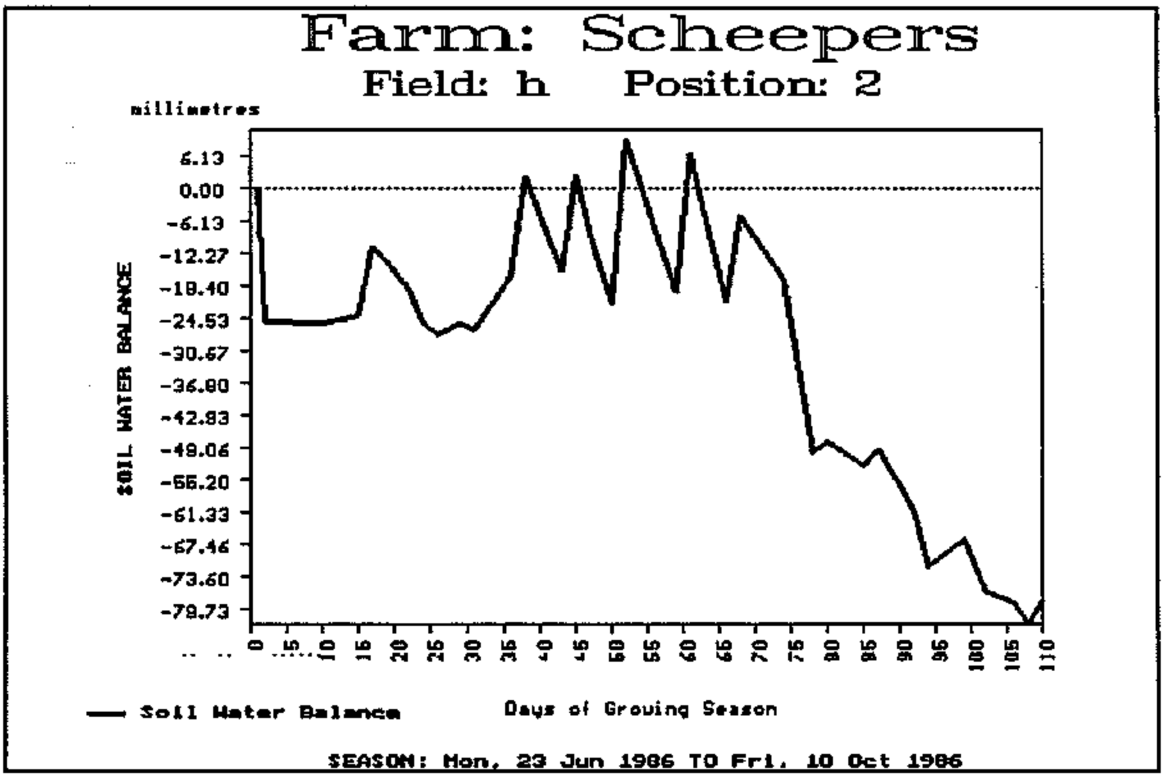

Figure 3.4 Soil water extraction curve for wheat - 1986

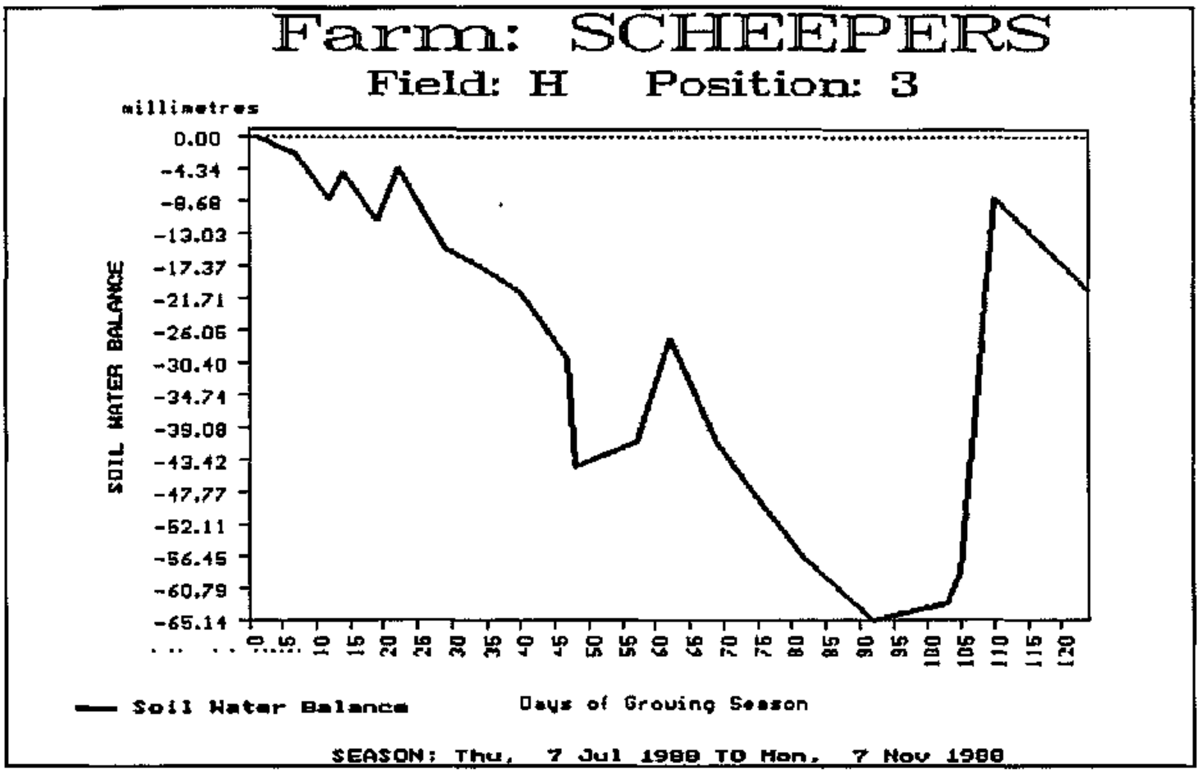

Figure 3.5 Soil water extraction curve for wheat - 1988

Dr Scheepers also produced some hybrid maize seed and the results of soil water studies under this crop for the 1985/6 season are depicted in Fig 3.6.

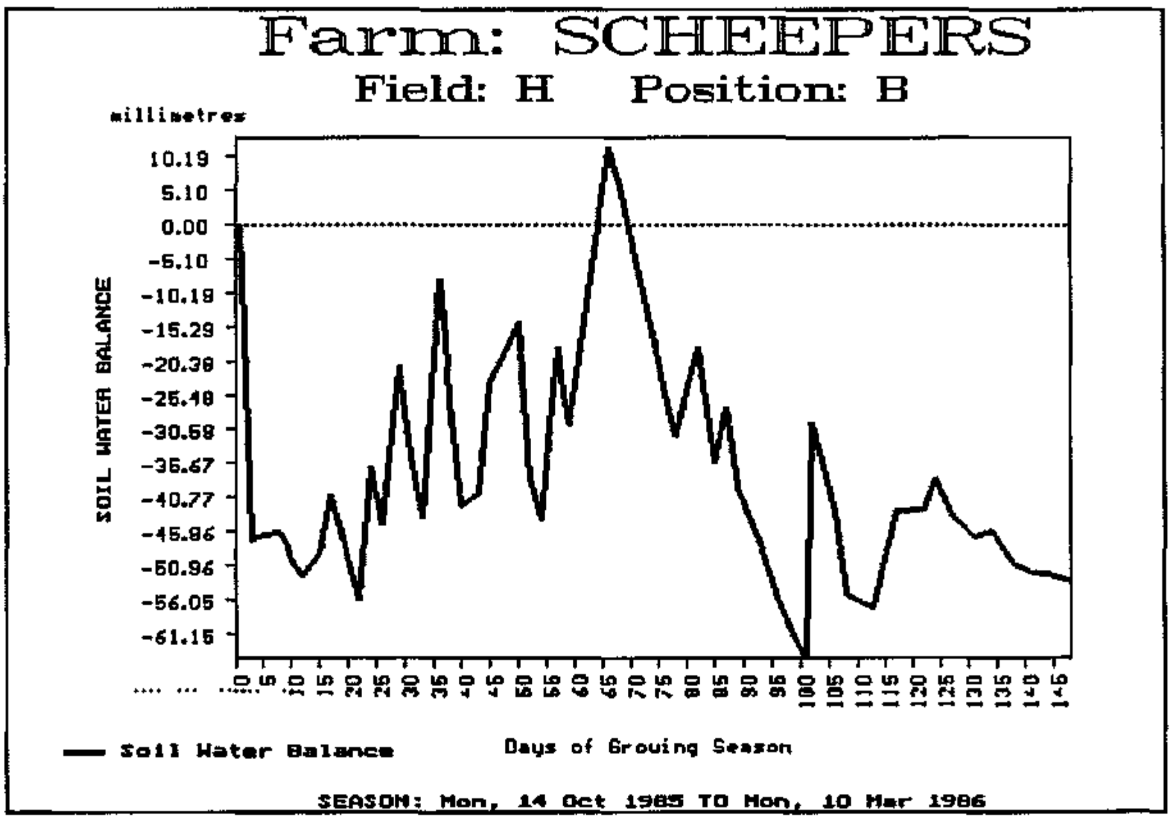

Figure 3.6 Soil water extraction curve for maize - 1985/86

The 1985/86 maize crop started of with a very large soil water deficit and although the irrigation programme and rainfall managed to erase the deficit towards the middle of the growing period, the progressive depletion of soil water continued after that, resulting in a deficit of 51 mm at the end of the season.

3.1.2. Mr A F McKechnie (Balhambra Grove)

Mr McKechnie produces garlic on the field included in this study, under a centre pivot system. Soil water extraction curves for garlic are presented in Fig 3.7 to 3.11.

It is clear that Mr McKechnie managed to a large extent to maintain the profile soil water near field capacity, provided the season started off with a full profile.

The depletion of profile water at station 1 in both 1986 and 1987 may possibly be ascribed to the poor application distribution of the system as depicted in Fig 3.12. It was later discovered that this particular measuring station was situated within an area which received consistently less than the mean application.

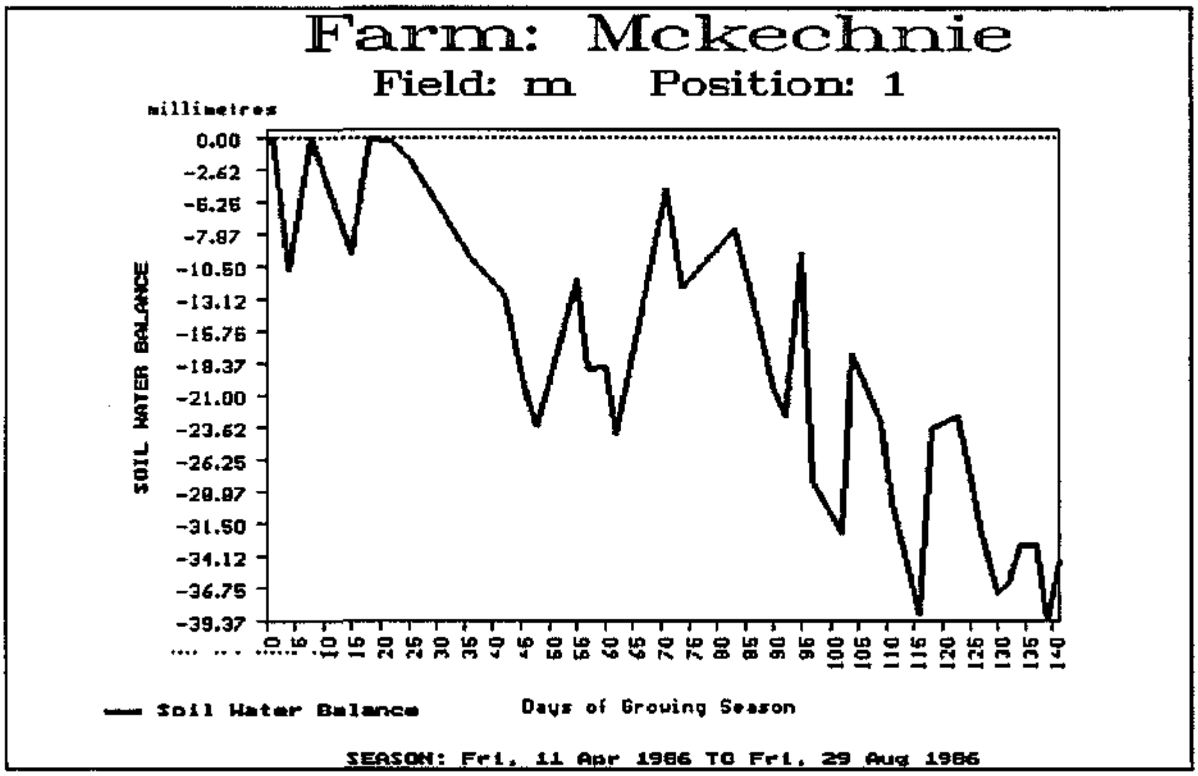

Figure 3.7 Soil water extraction curve for garlic - 1986

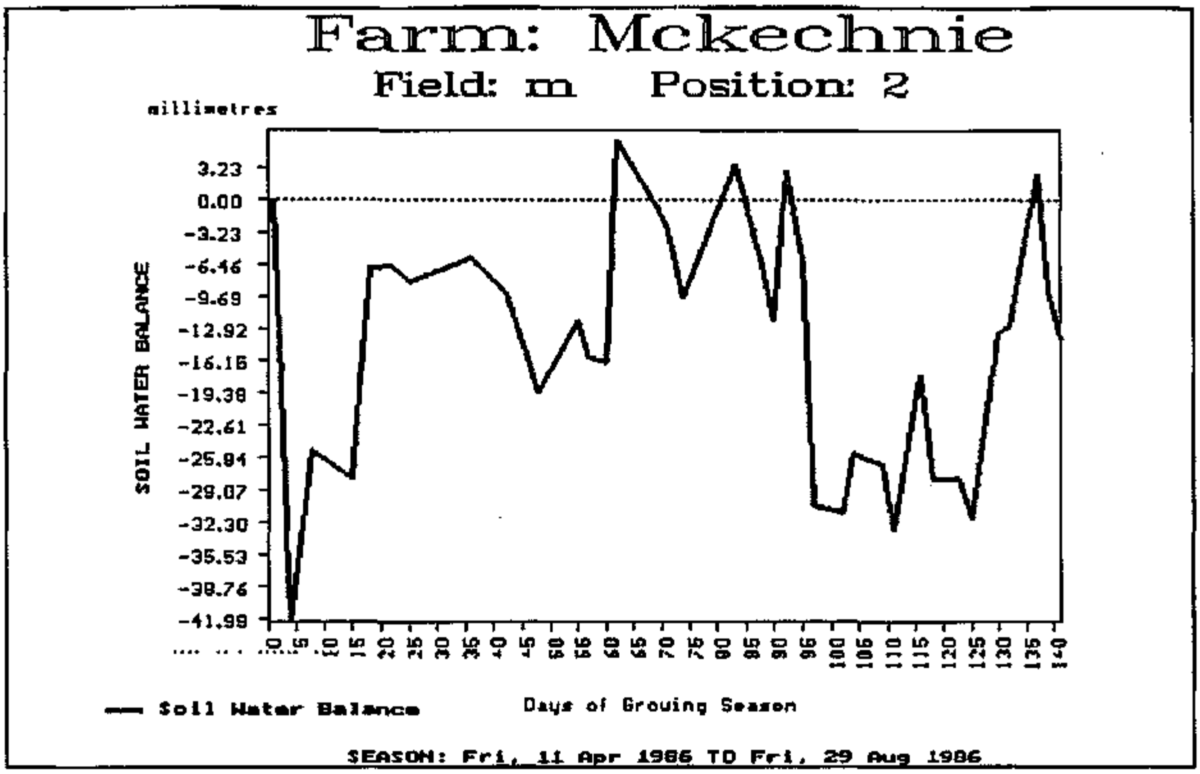

Figure 3.8 Soil water extraction curve for garlic - 1986

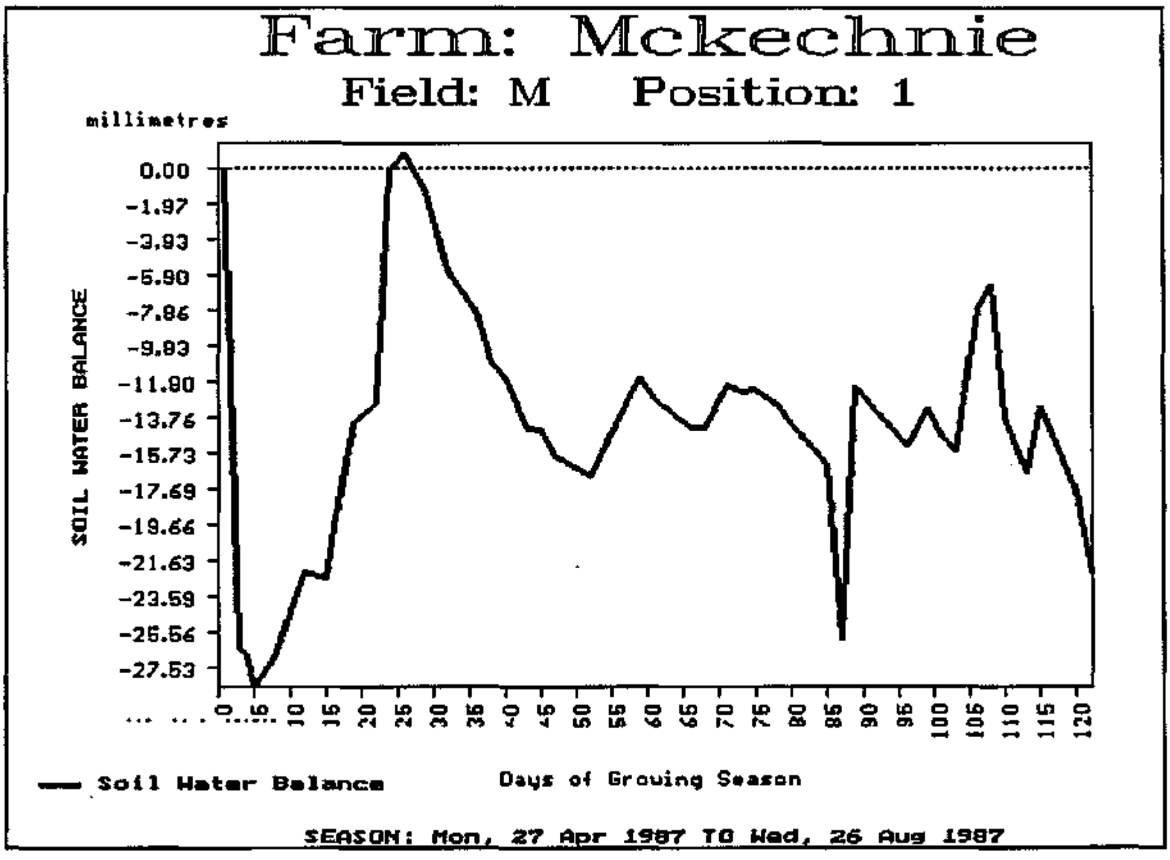

Figure 3.9 Soil water extraction curve for garlic - 1987

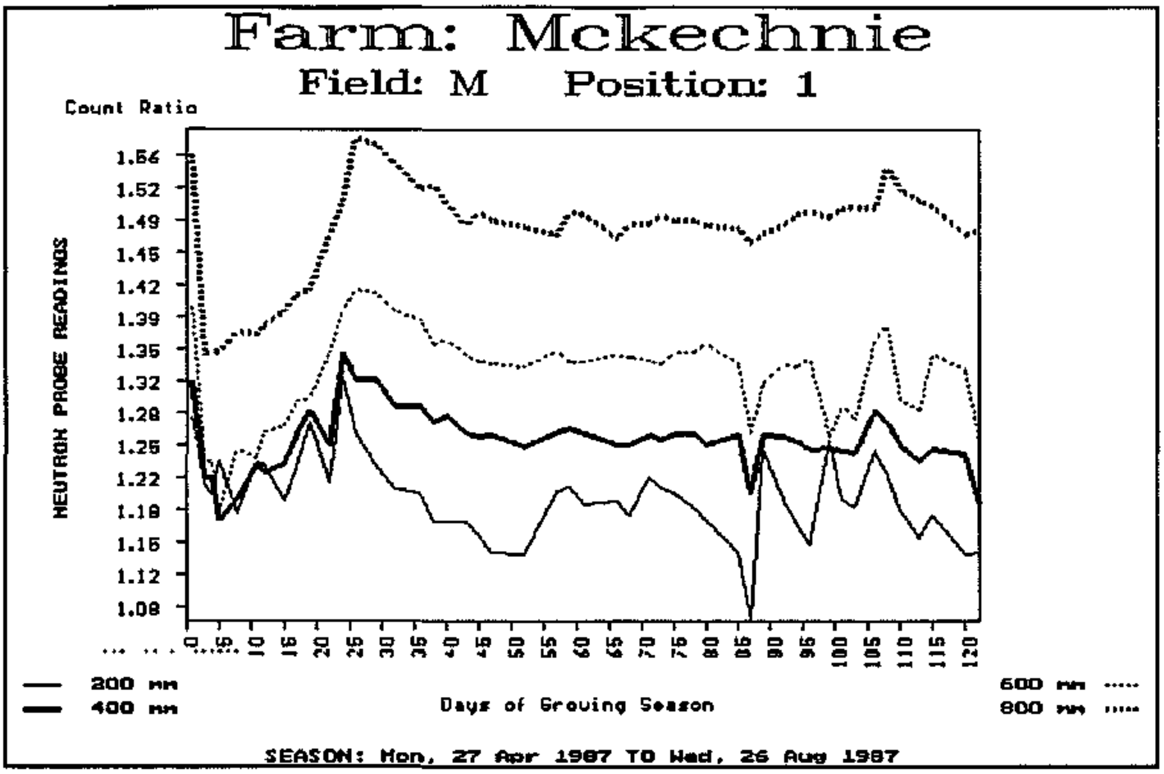

Figure 3.10 Neutron probe readings for garlic - 1987

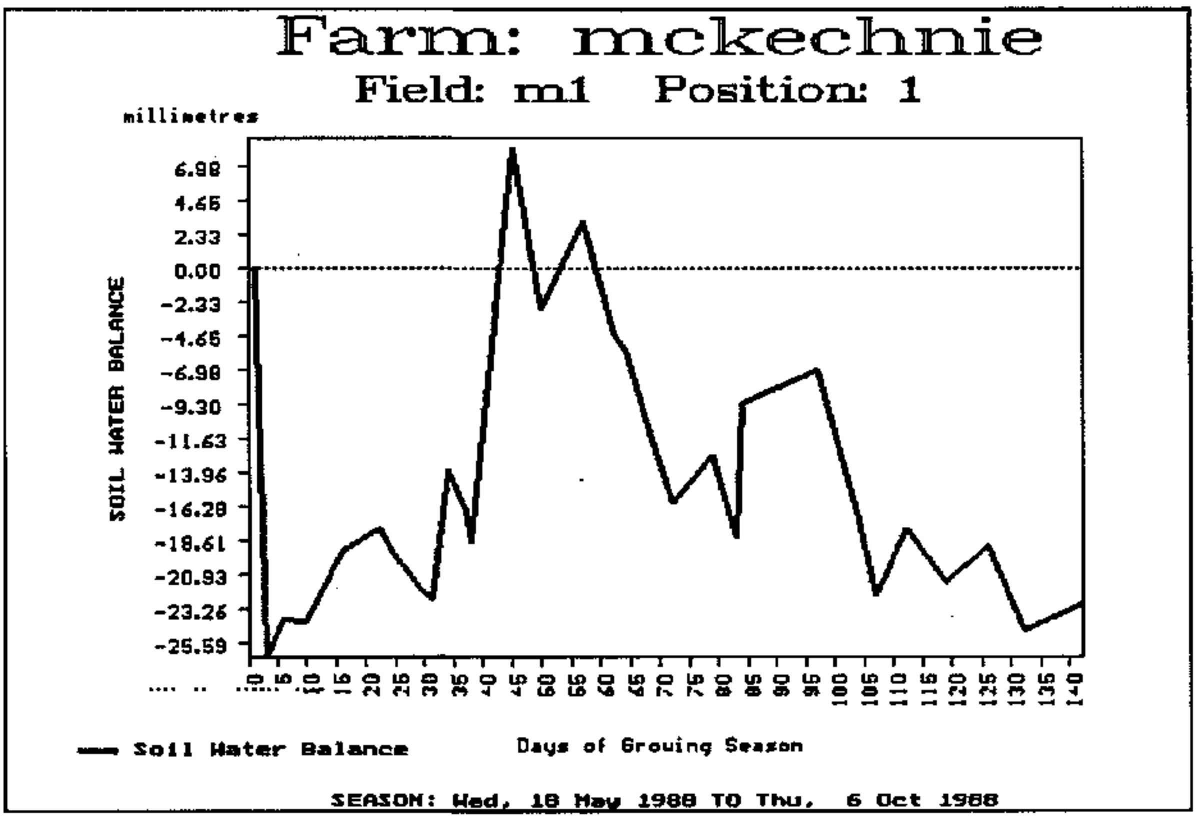

Figure 3.11 Soil water extraction curve for garlic - 1988

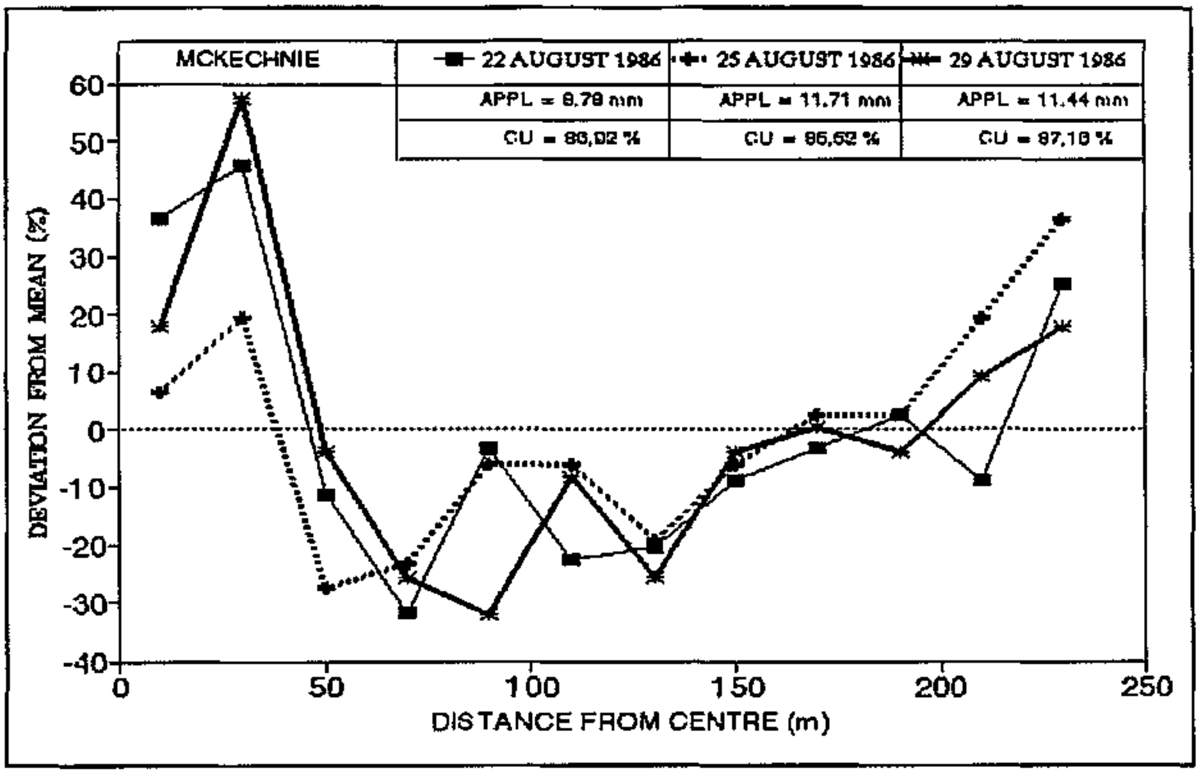

Figure 3.12 **Application distribution and Cu-index of centre pivot system on Mr McKechnie's farm**

3.1.3 Mr G JANSEN

A typical pattern of soil water extraction for maize, on the farm of Mr Jansen, is depicted in Fig 3.13. The progressive depletion of profile soil water demonstrated in Fig 3.13 is confirmed by the neutron probe curves for the different depths depicted in Fig 3.14.

The picture for wheat (Fig's 3.15 & 3.16) is somewhat different in that profile water was not depleted to the same low levels as for maize and that it recovered to almost full capacity in both 1986 and 1988 due to good rains towards the end of the season.

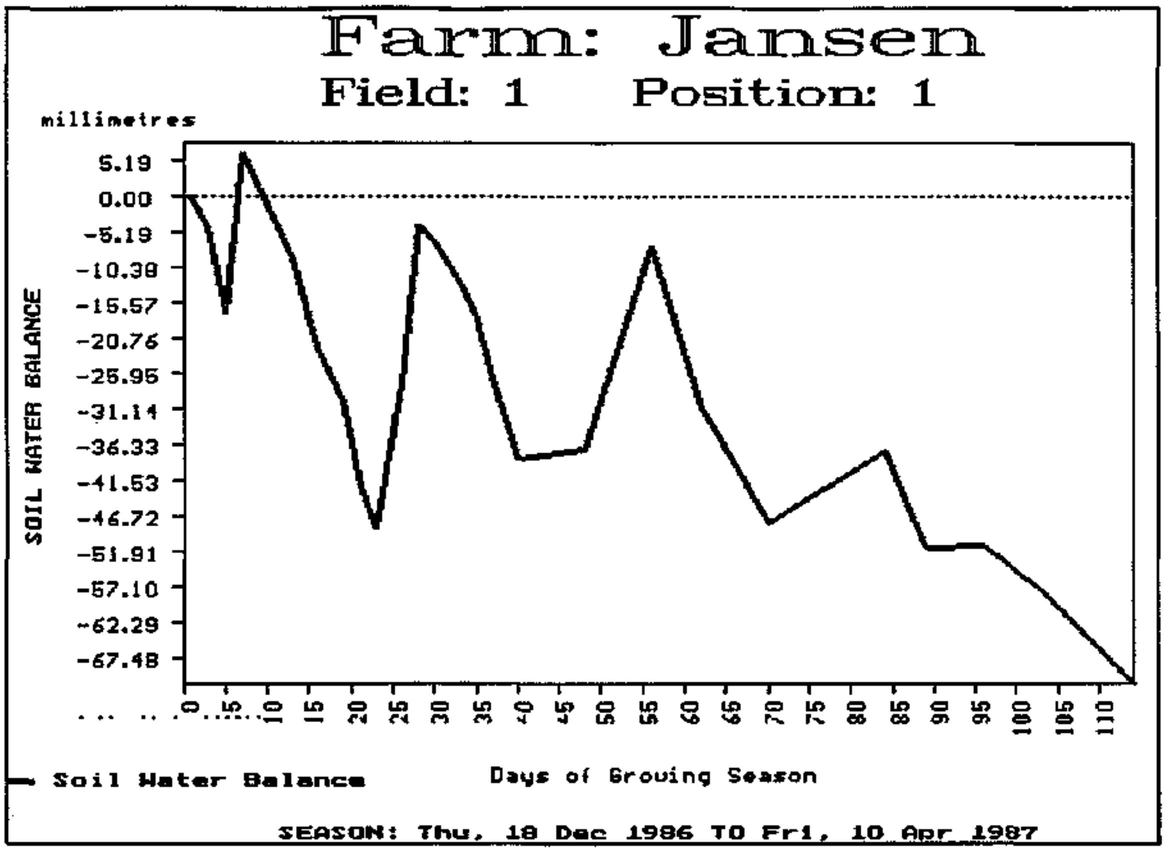

Figure 3.13 Soil water extraction curve for maize - 1986

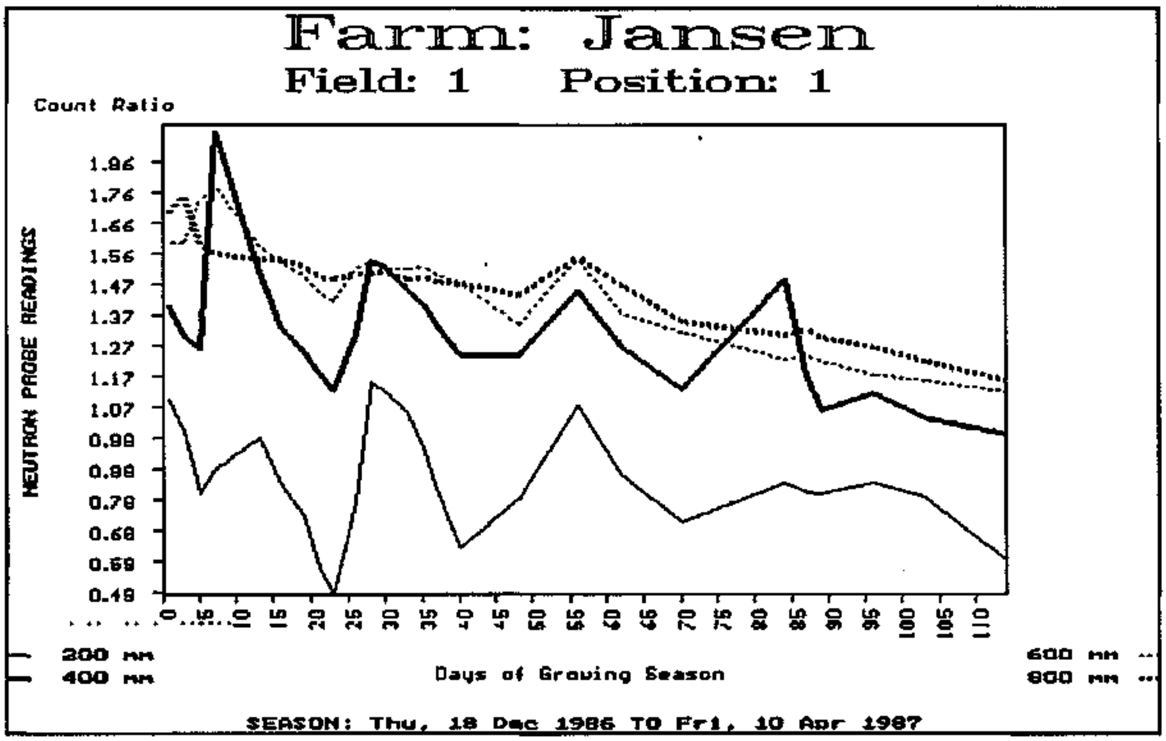

Figure 3.14 Neutron probe readings for maize - 1986

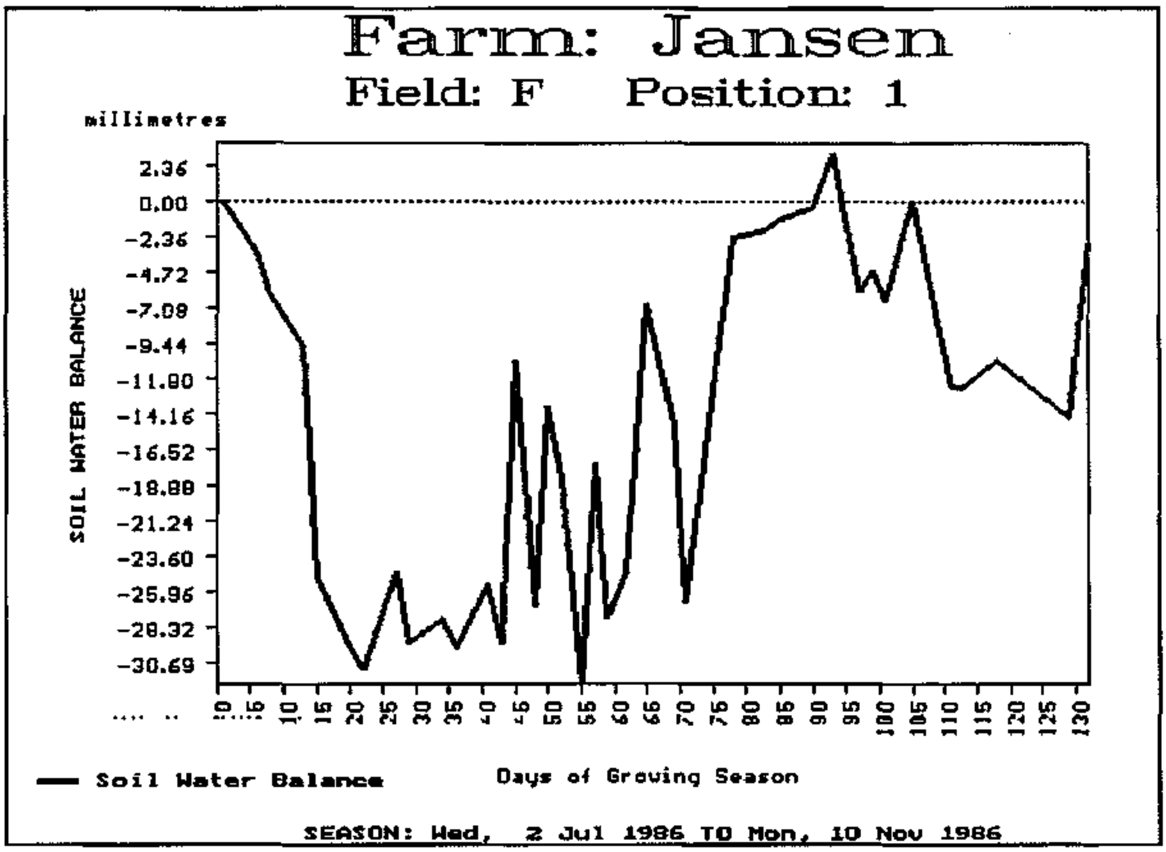

Figure 3.15 Soil water extraction curve for wheat - 1986

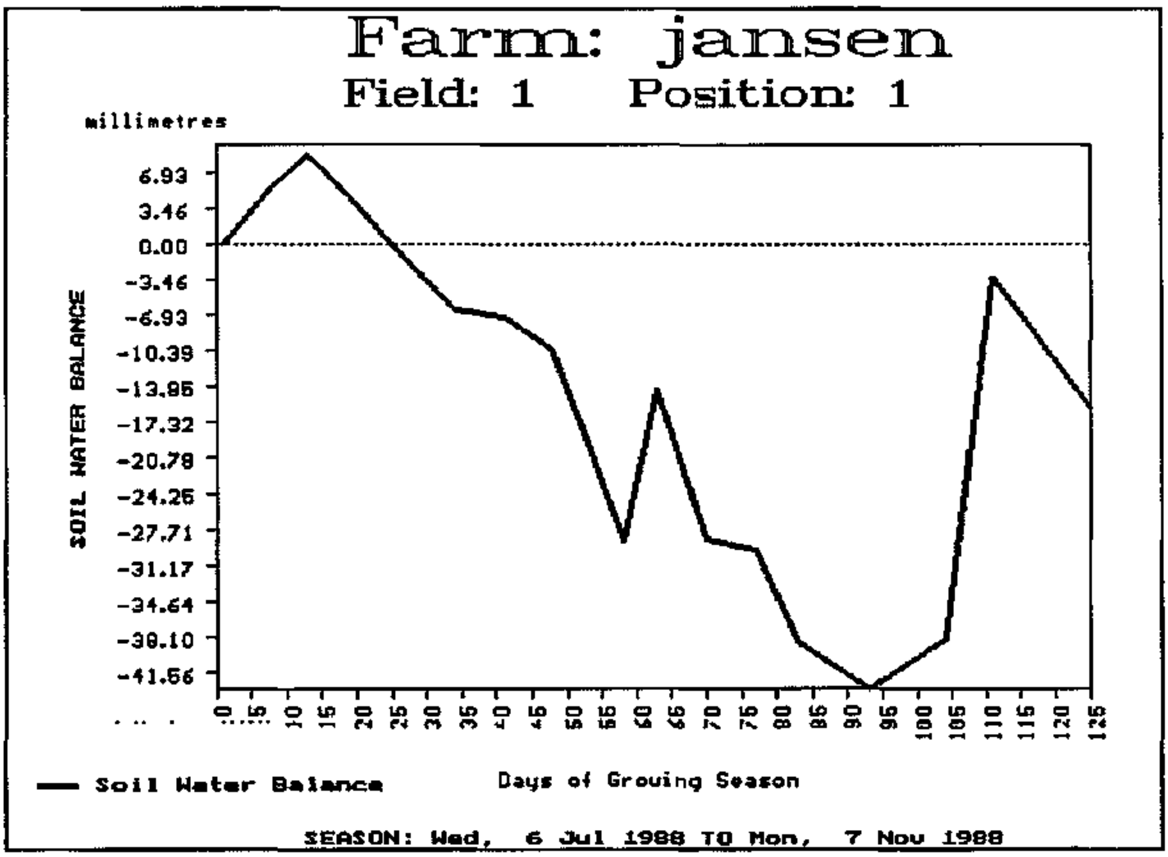

Figure 3.16 Soil water extraction curve for wheat - 1988

3.1 Mr J V D MERWE

The soil water extraction curve for wheat on Mr v d Merwe's farm in 1985, depicted in Fig 3.17, again show a deficit at the start of the season, some recovery there-after followed by a steady decline in profile water and a recovery towards the end of the season thanks to good rains.

Very much the same pattern was observed in the case of the maize crop of 1986/87 (Fig's 3.18 & 3.20). It should be noted that the water extraction curves in Fig's 3.18 & 3.20 stretch over a period of 180 days. This can be explained by the fact that a cultivar with a long growing period was planted very early (15 Sept) and neutron probe readings (Fig's 3.19 & 3.21) proceded until harvest time (16 March).

Although there was some variation between measuring stations 3 & 4, the similarity in the profile water extraction paterns (Fig's 3.18 & 3.20) is rather striking, considering that station 4 was on an area with a soil depth of only 800 mm, compared to a depth of 600 mm at station 3.

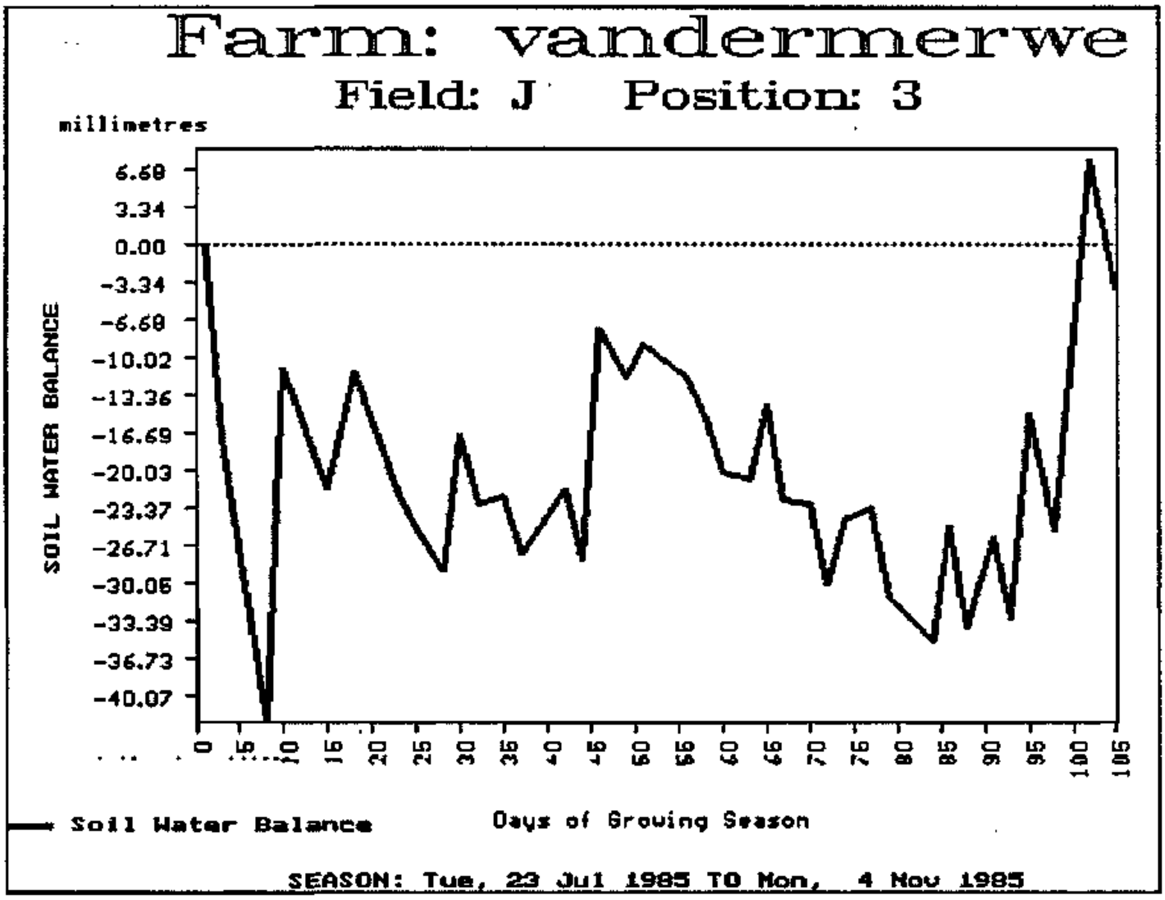

Figure 3.17 Soil water extraction curve for wheat - 1985

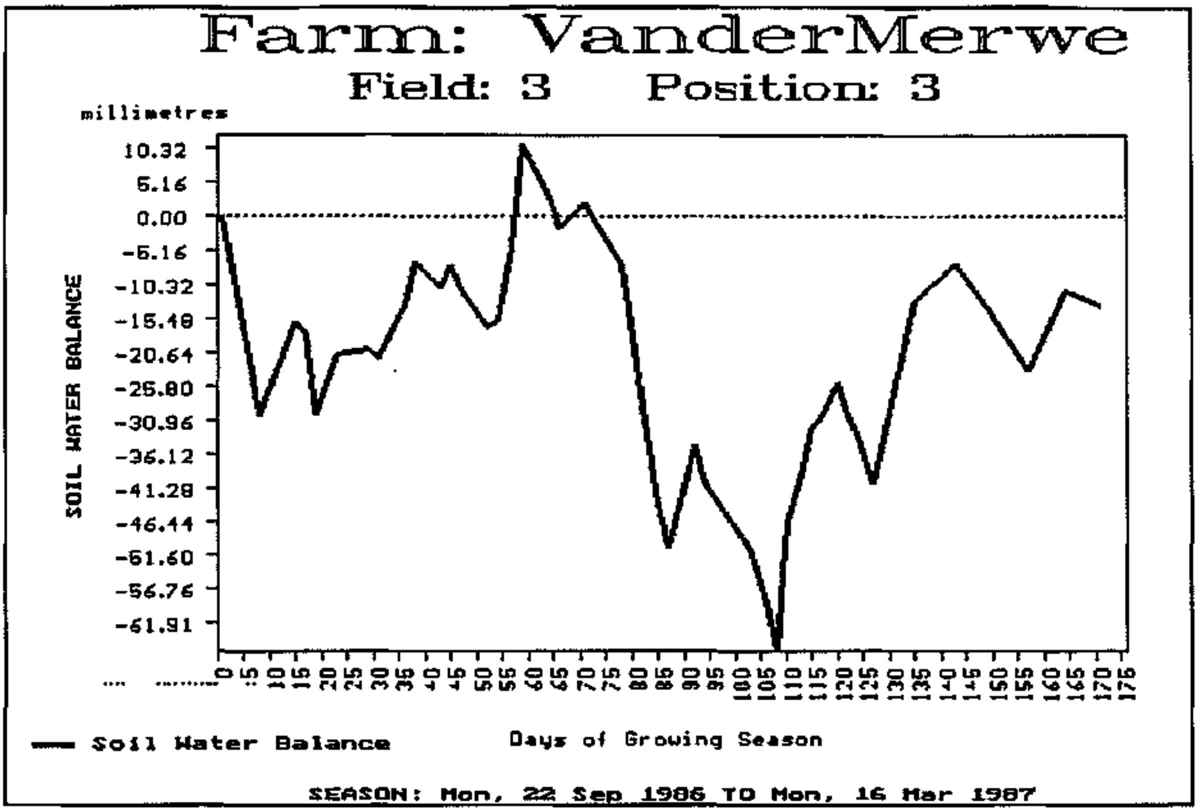

Figure 3.18 Soil water extraction curve for maize - 1986/87

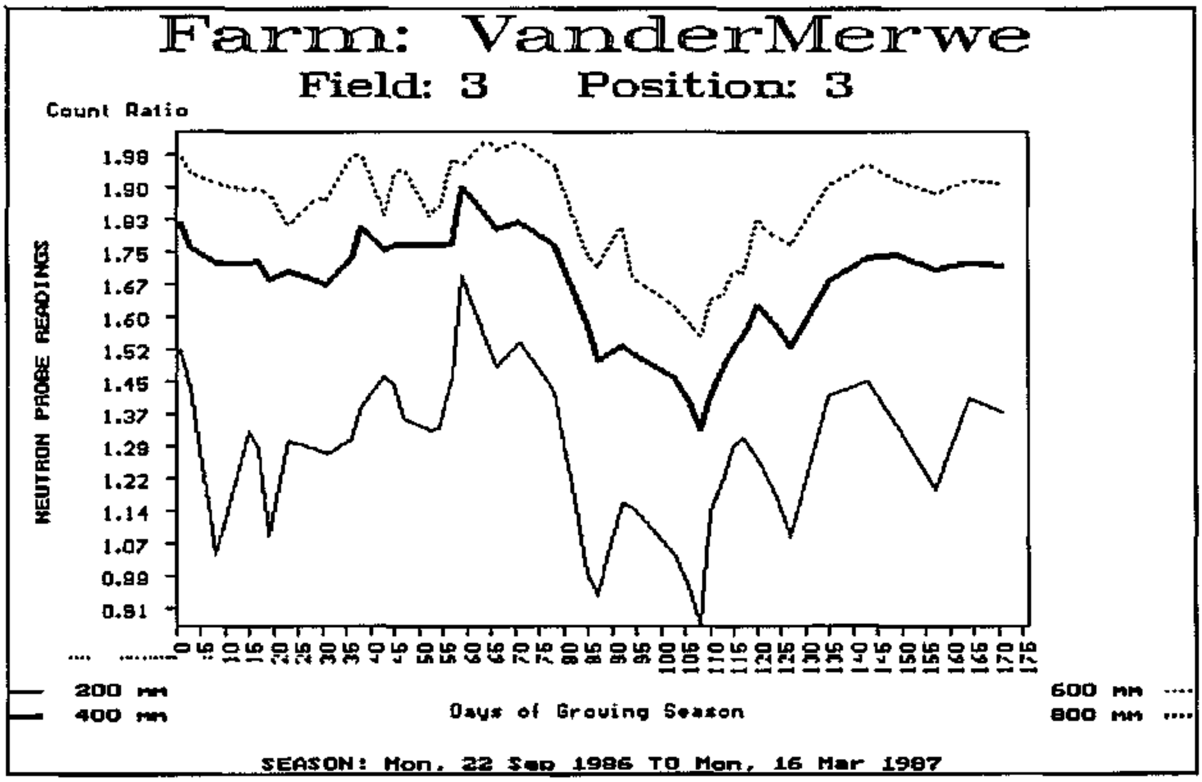

Figure 3.19 Neutron probe readings for maize - 1986/87

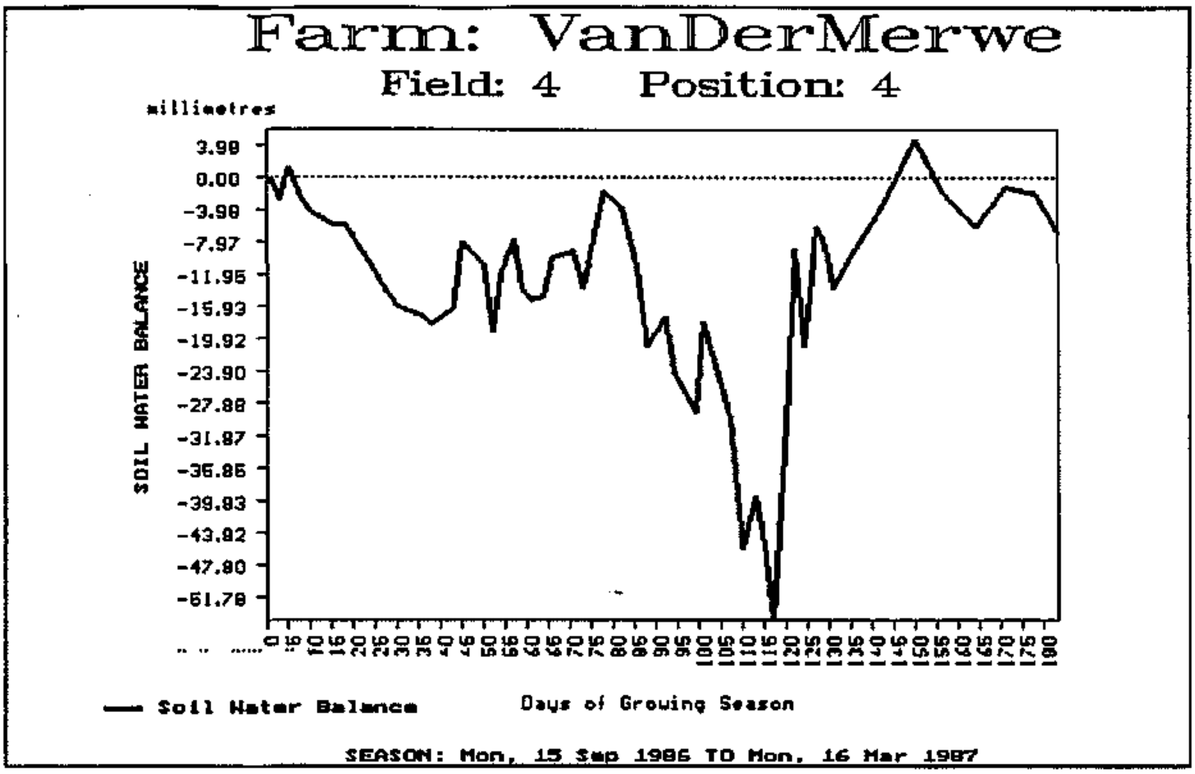

Figure 3.20 Soil water extraction curve for maize - 1986/87

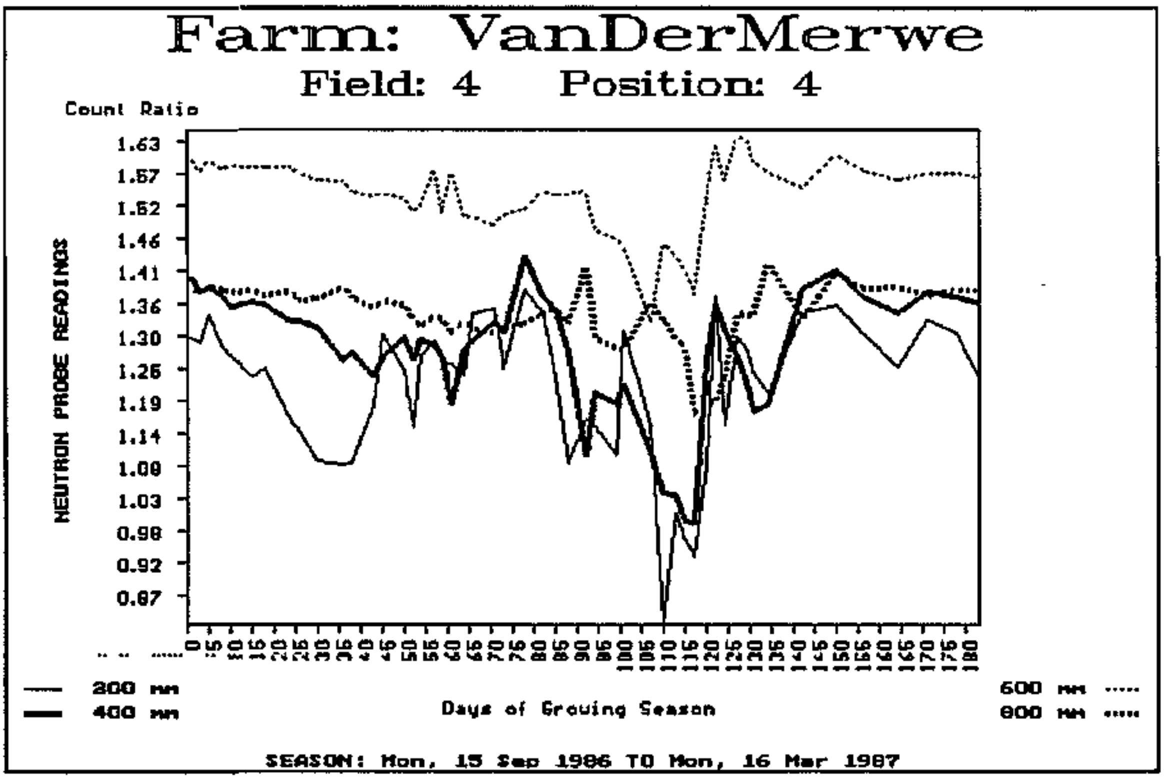

Figure 3.21 Neutron probe readings for maize - 1986/87

3.1.5 Mr P Bezuidenhout

Mr Bezuidenhout was the only collaborator who produced potatoes. Soil water extraction as well as neutron probe readings for the 1985/86 potato crop are depicted in Fig 3.22 & 3.23. Measurements started only after the crop was well established and the *days of growing season* should be interpreted as the *days after measurements commenced.* It should be noted that a fair amount of root activity took place at all depths of measurement.

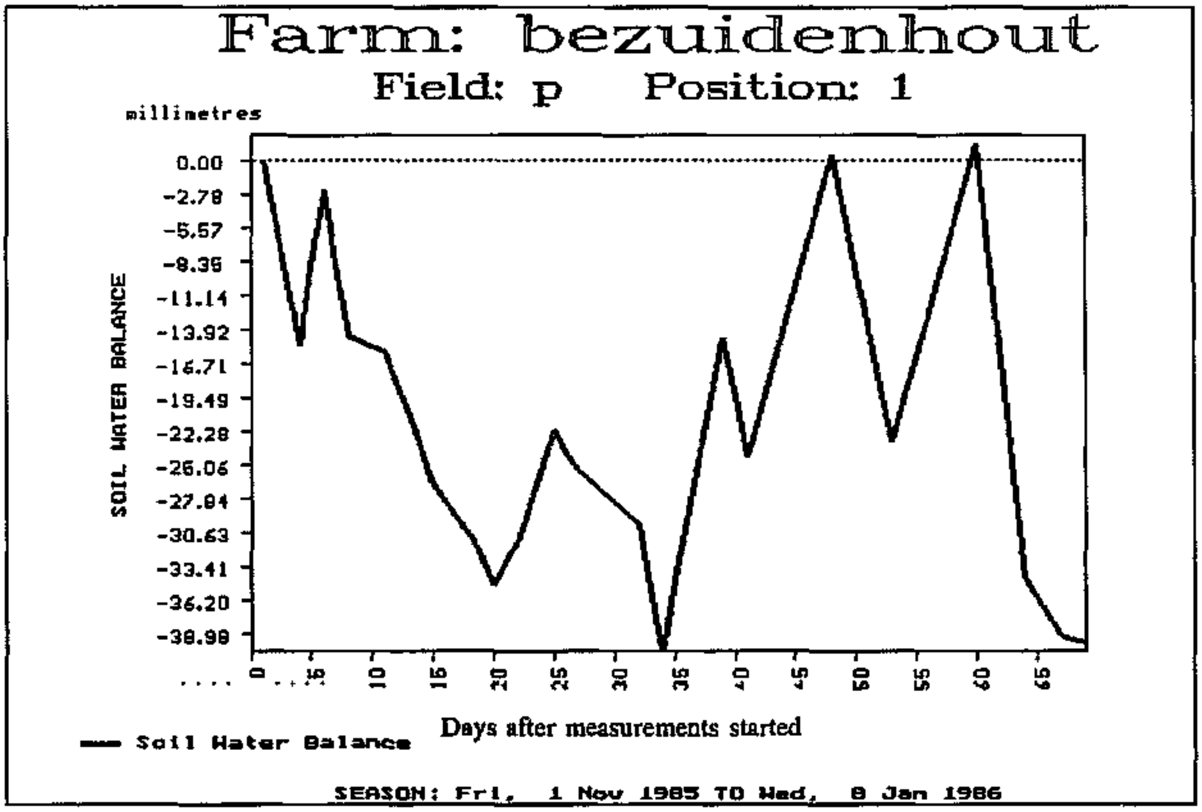

Figure 3.22 Soil water extraction curve for potatoes - 1985/86

The same could be said about the 1986-crop at station 2 (Fig 3.24 & 3.25), although to a lesser extent. However, at station 4, neutron probe readings at the 400, 600, and 800mm depths (Fig 3.26) remained virtually constant through-out the measuring period and the profile water extraction curve (Fig 3.27) is almost a mirror image of neutron probe readings at the 200mm depth.

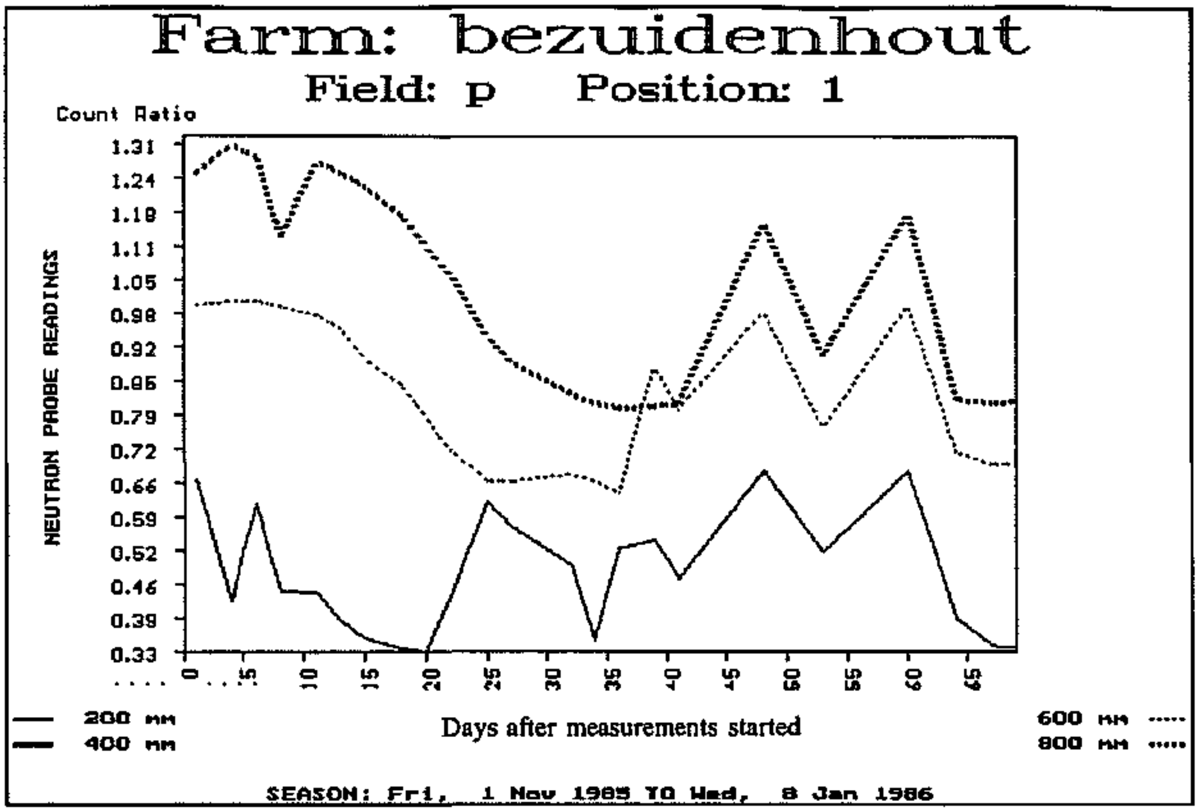

Figure 3.23 Neutron probe readings for potatoes - 1985/86

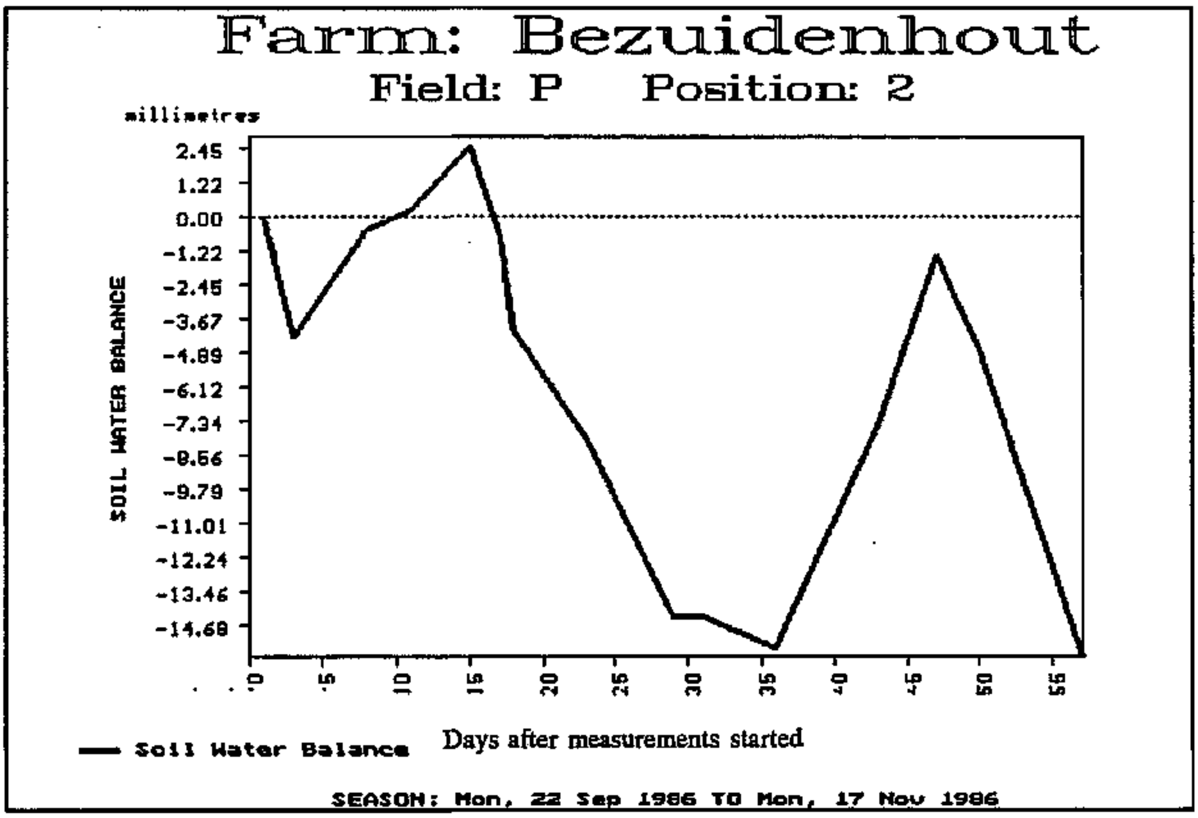

Figure 3.24 Soil water extraction curve for potatoes - 1986

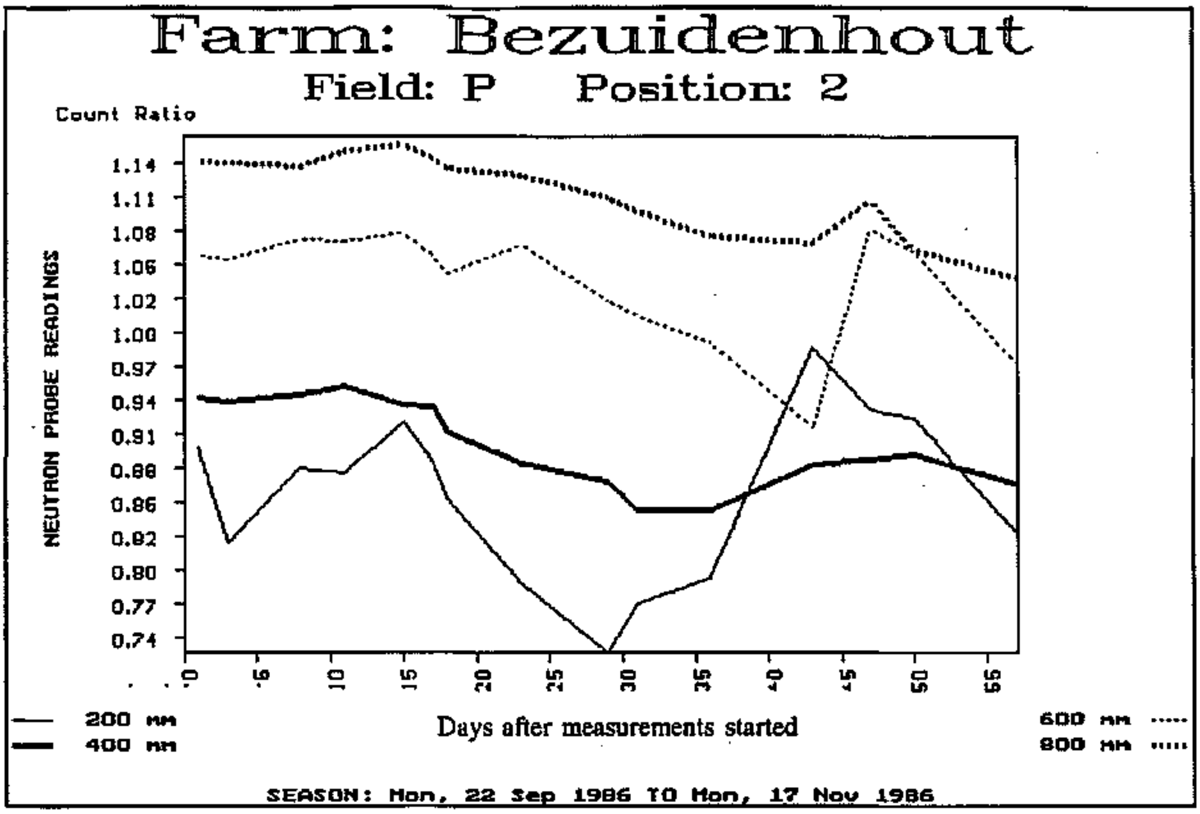

Figure 3.25 Neutron probe readings for potatoes - 1986

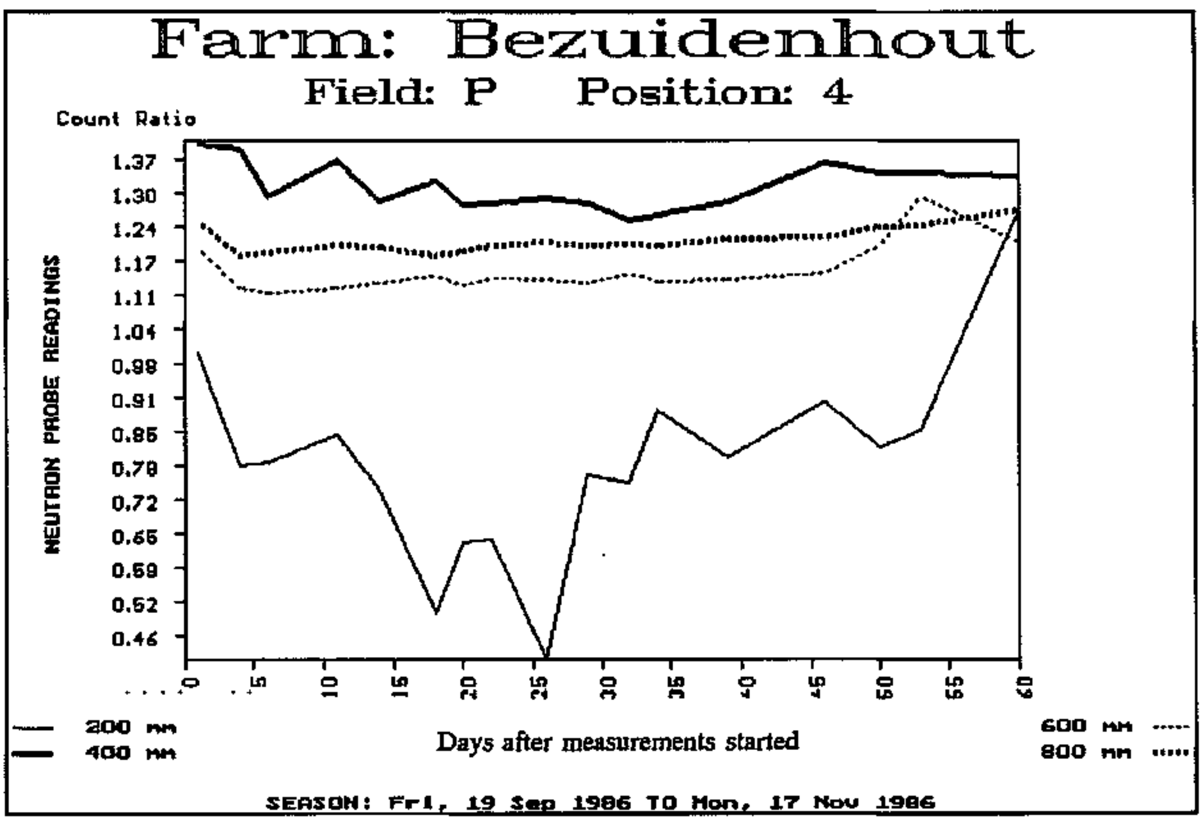

Figure 3.26 Neutron probe readings for potatoes - 1986

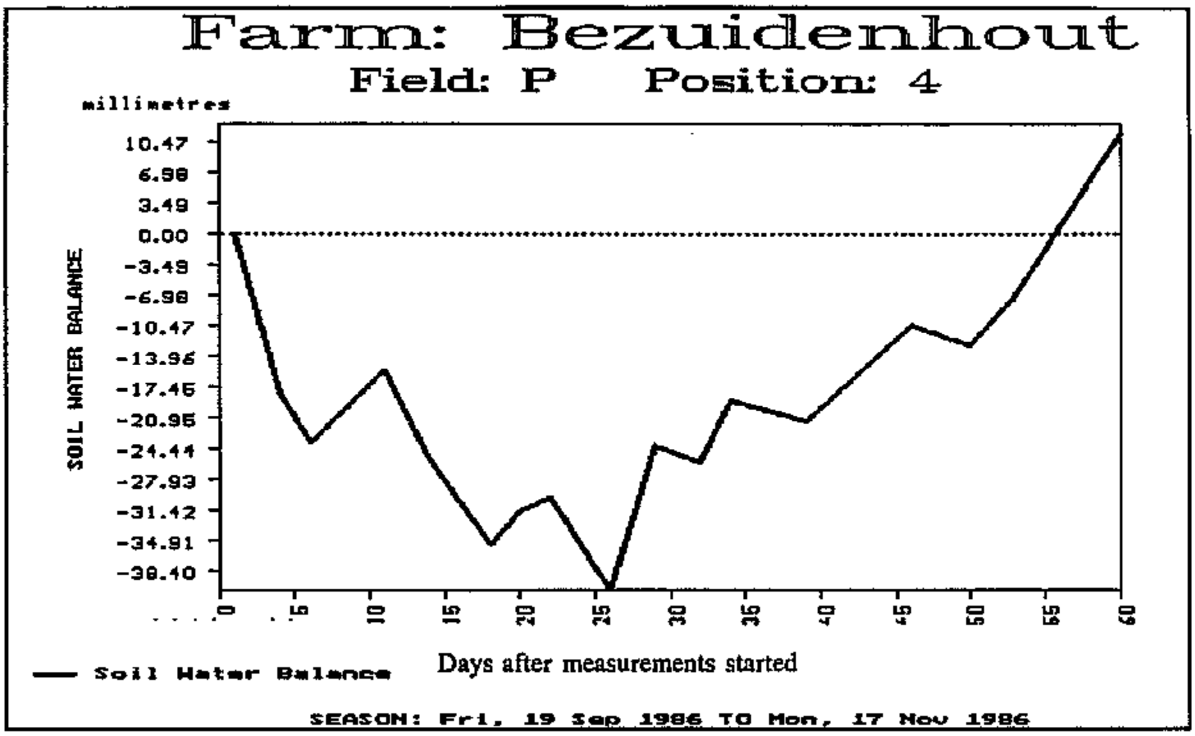

Figure 3.27 Soil water extraction curve for potatoes - 1986

Mr Bezuidenhout also planted the occasional wheat crop and the results of the 1986 crop are depicted in Fig's 3.28 & 3.29. Unfortunately there was a break in the regular measurements on this crop and readings between day 71 and day 110 had to be interpolated.

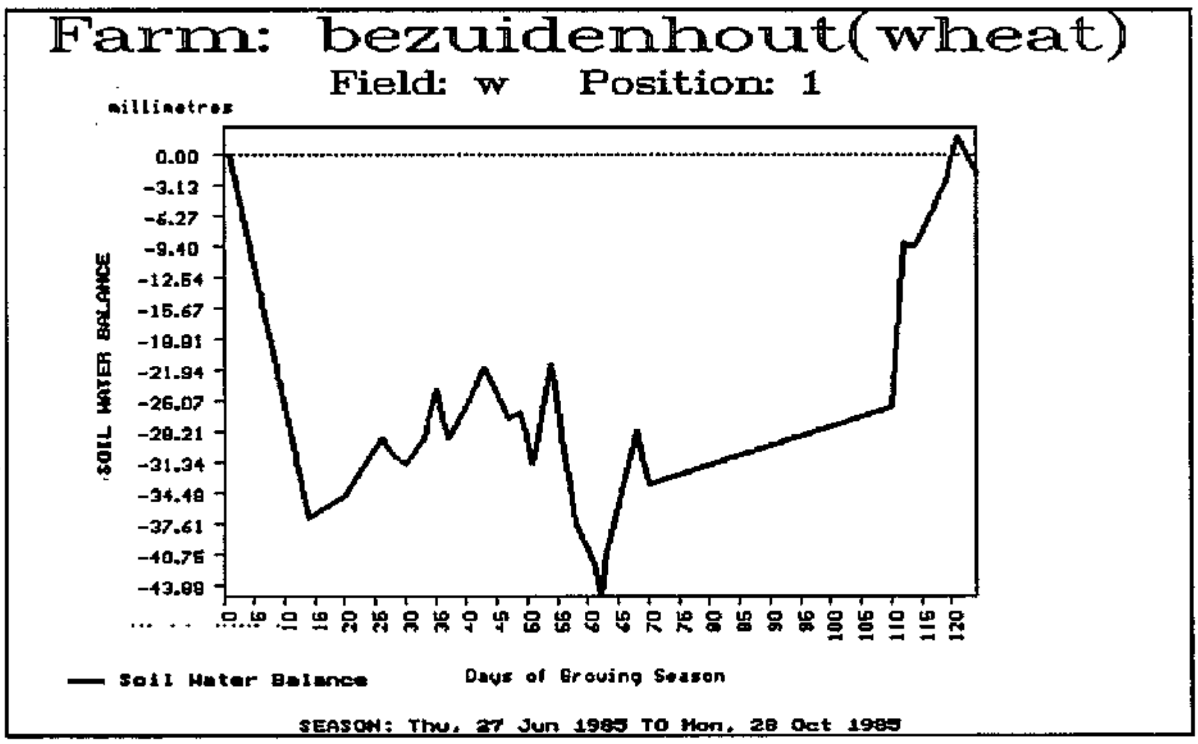

Figure 3.28 Soil water extraction curve for wheat - 1986

Although the wheat crop started the season with a profile water deficit, this was recovered and the season ended with a full profile.

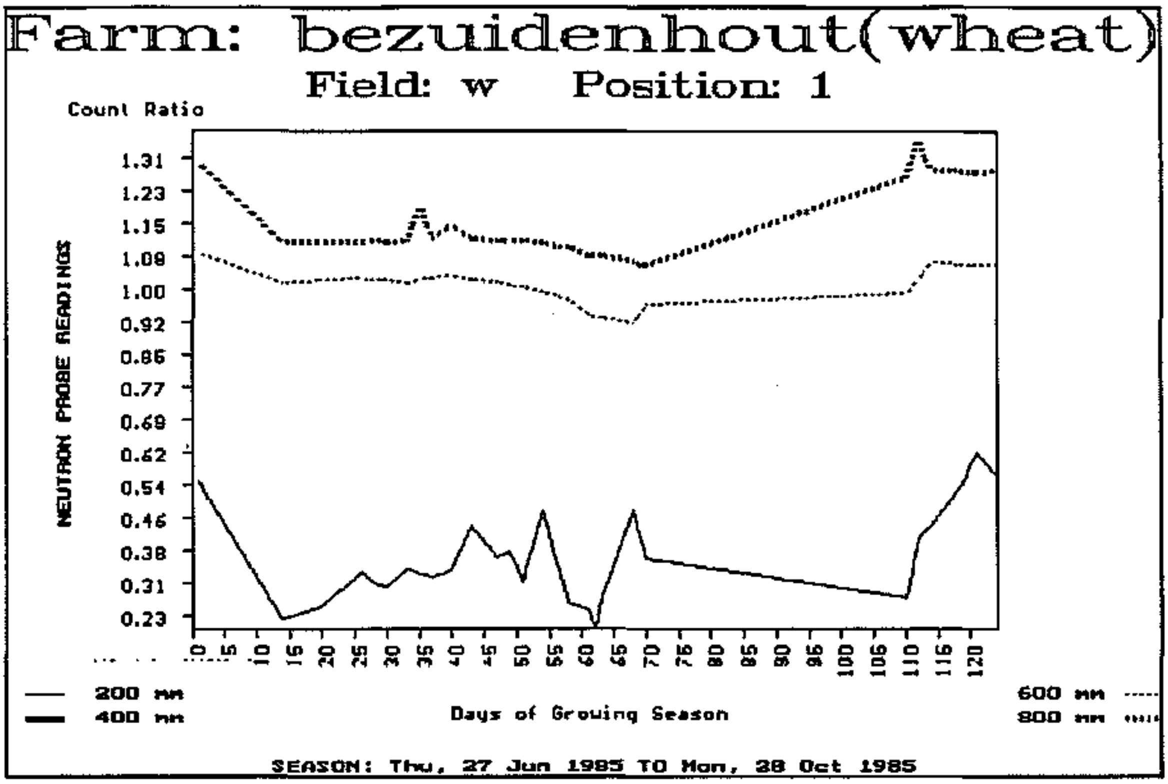

Figure 3.29 Neutron probe readings for wheat - 1985

3.2 IMPACT OF PROJECT

Generally speaking, the collaborating farmers had gained considerable knowledge about irrigation scheduling from this project.

The equipment provided had been adequately utilized to aid them in scheduling. The farmers didn't always agree with the crop factors provided but with one exception they were satisfied with results achieved.The project got off to a good start with much enthusiasm from all concerned. However, when contact was lost due to staff shortages, their enthusiasm waned and farmers became disillusioned with the project. This fact was indeed unfortunate because in their opinion they could have derived much benefit from regular visits, crop monitoring, discussions and groups meetings. Two out of the four collaborators would be eager to cooperate again in a similar project, if they were approached.

Individual responses to the questionnaire referred to in Chapter 2, are presented in Appendix B.

CHAPTER 4

RESULTS ON SYFERKUIL

4.1 SOIL WATER EXTRACTION

The research work on Syferkuil was conducted on an area of 63 ha (blocks 3 to 11), which formed part of a field of 77 ha, irrigated with the automated linear system described in chapter 2. Measuring stations were installed on blocks 3, 4, 6, 7, 8, 10 and 11 on both sides of the central carriage way (A & B). However only the most typical examples of soil water extraction curves were chosen to be presented in this chapter.

4.1.1 Wheat

Once again it should be noted that, although measurements were taken on a regular basis throughout the duration of the project, the data could not be processed before the completion of the Watercalc computer program. Immediate follow-ups on results obtained, as well as on possible reading errors could thus not be effected. Because of this, unfortunately, a great deal of the value of the project was lost.

For instance, the sudden drop in NMP readings at the 400, 600, and 800mm levels, on day 92 of the 1986 wheat crop at Block #6 (Fig 4.1), which resulted in a decrease in the soil water balance of 55mm in only two days (Fig 4.2) in spite of an application of 28mm since the last reading of two days previously is inexplicable at this stage since no such phenomenon occurred at Block #10 (Fig 4.3 & 4.4) or any of the other measuring stations. An immediate follow-up on the same or the next day, may have provided an explanation.

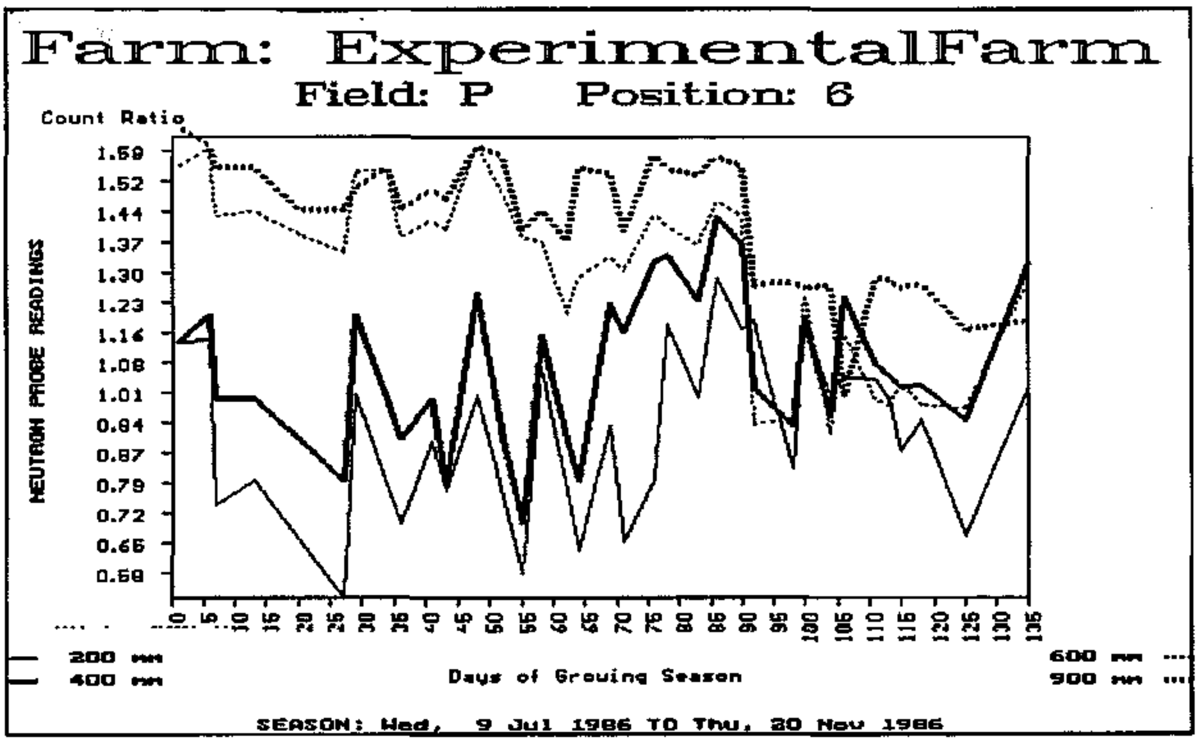

Figure 4.1 Neutron probe readings for wheat - 1986

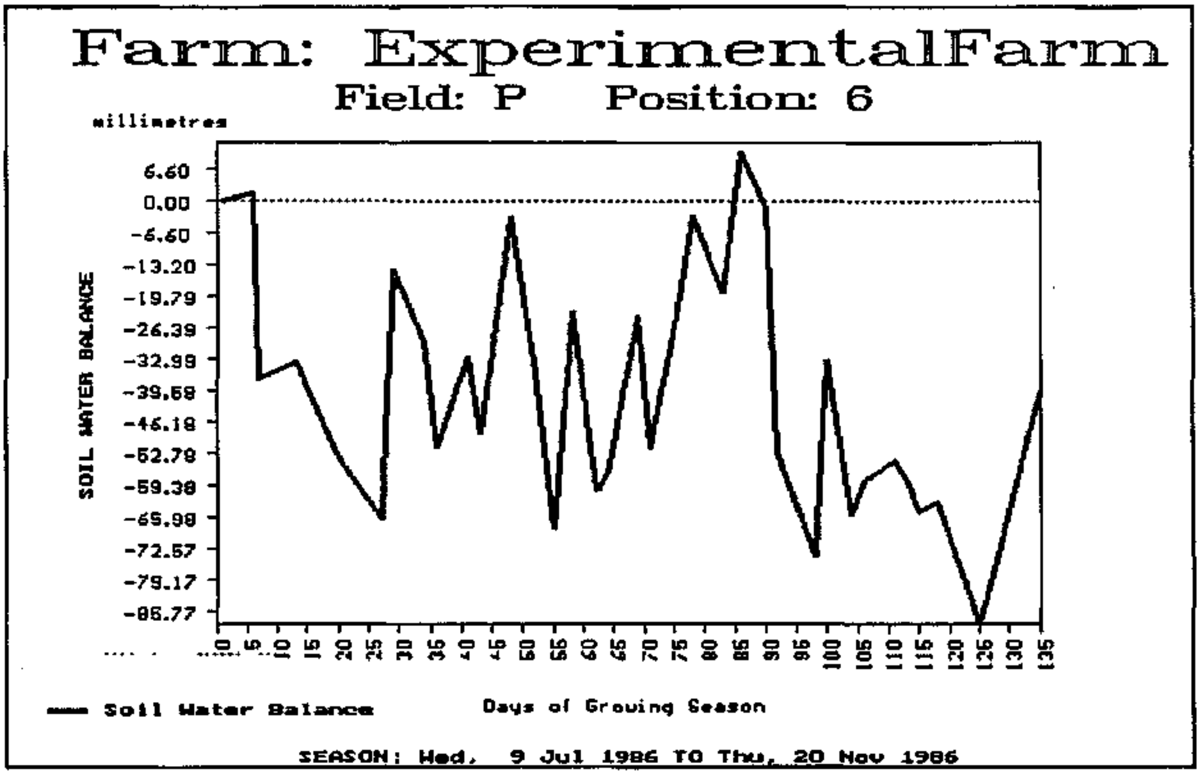

Figure 4.2 Soil water extraction curve for wheat - 1986

If Fig 4.2 is ignored, it would appear that the irrigation programme managed to maintain the profile soil water at or near field capacity for the greatest part of the irrigation period of the wheat crop in both seasons reported here (Fig 4.3 to 4.6).

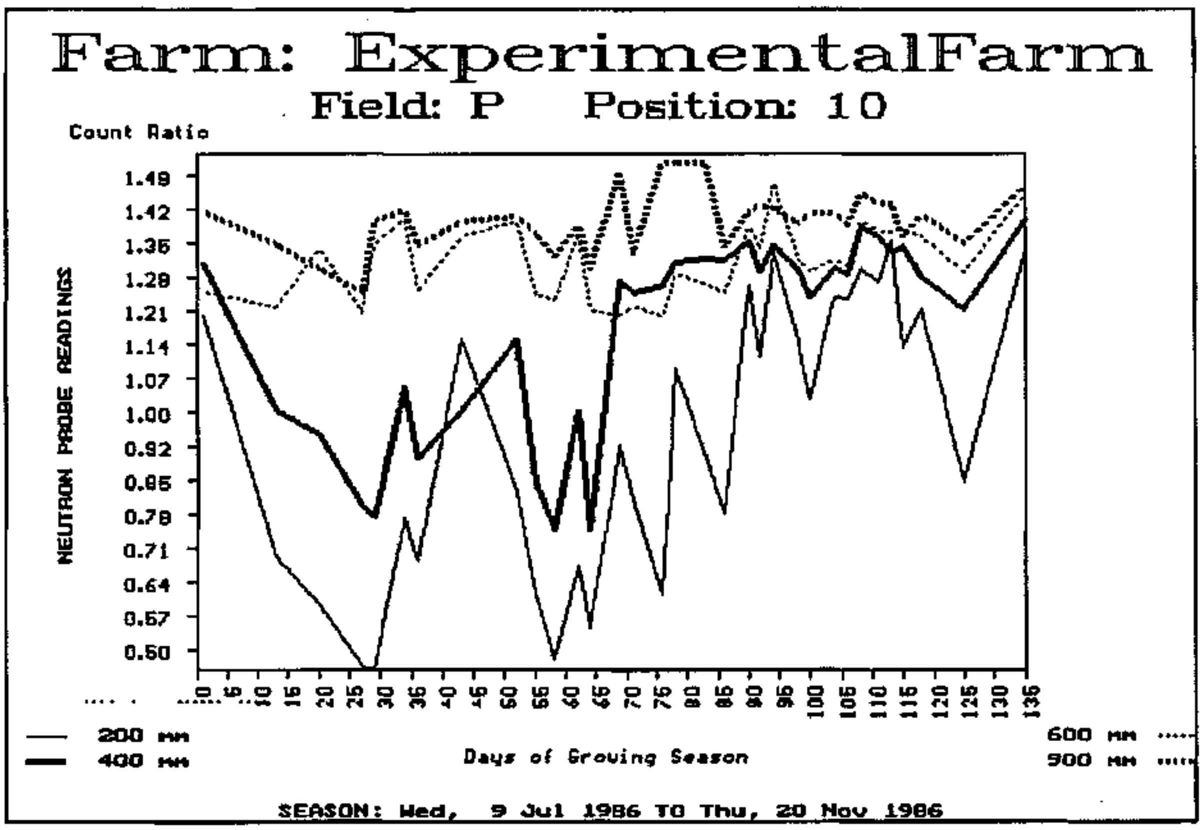

Figure 4.3 Neutron probe readings for wheat - 1986

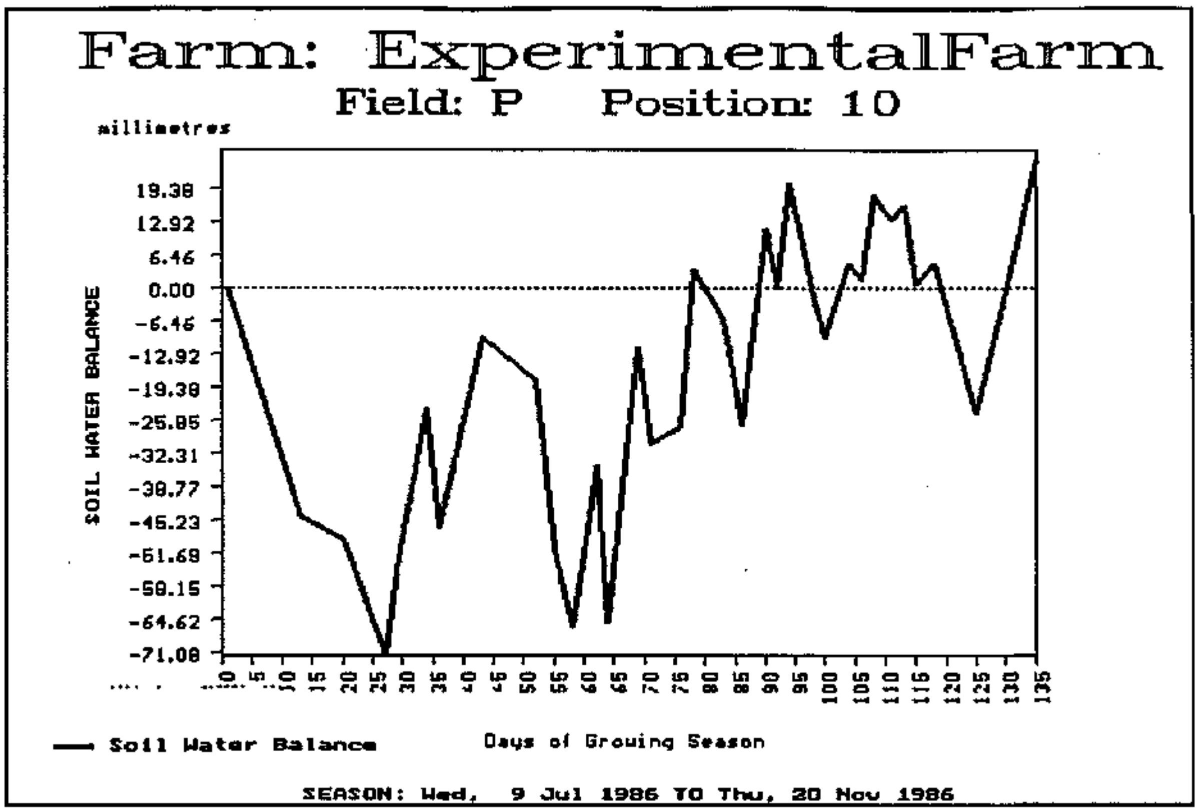

Figure 4.4 Soil water extraction curve for wheat - 1986

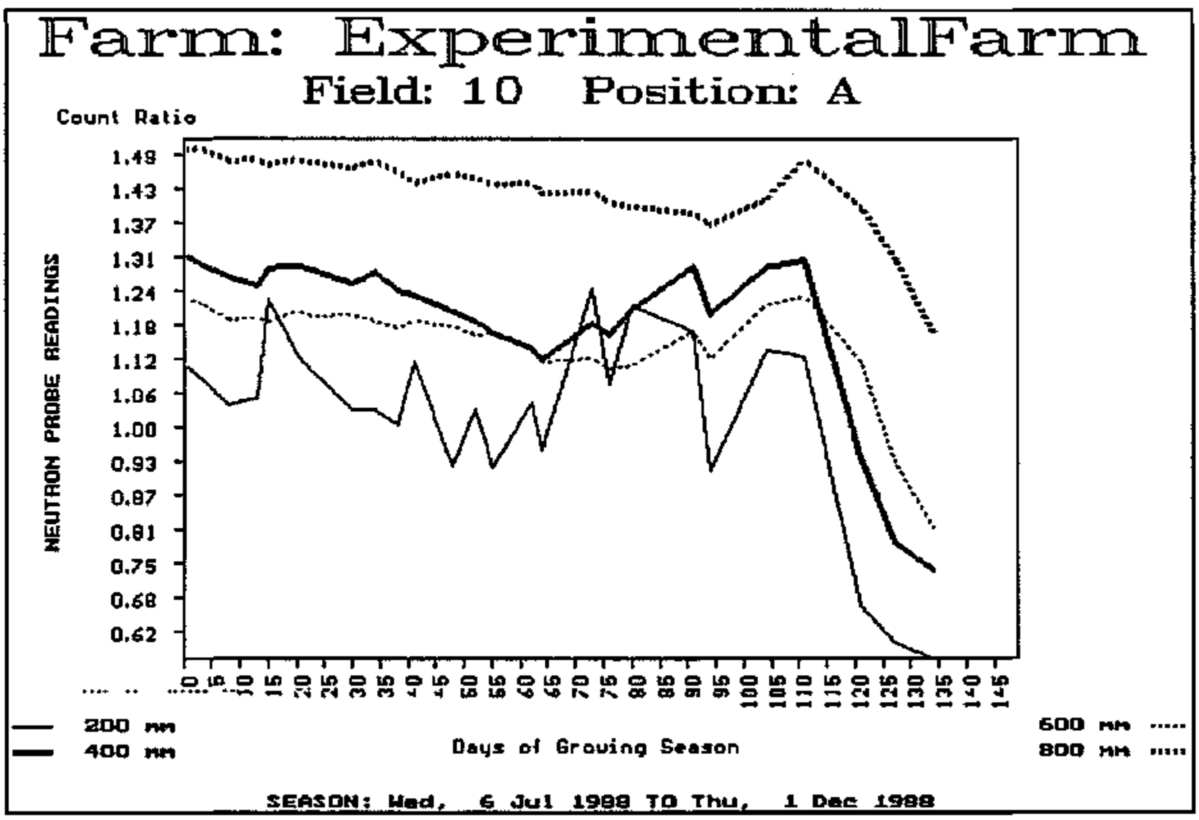

Figure 4.5 Neutron probe readings for wheat - 1988

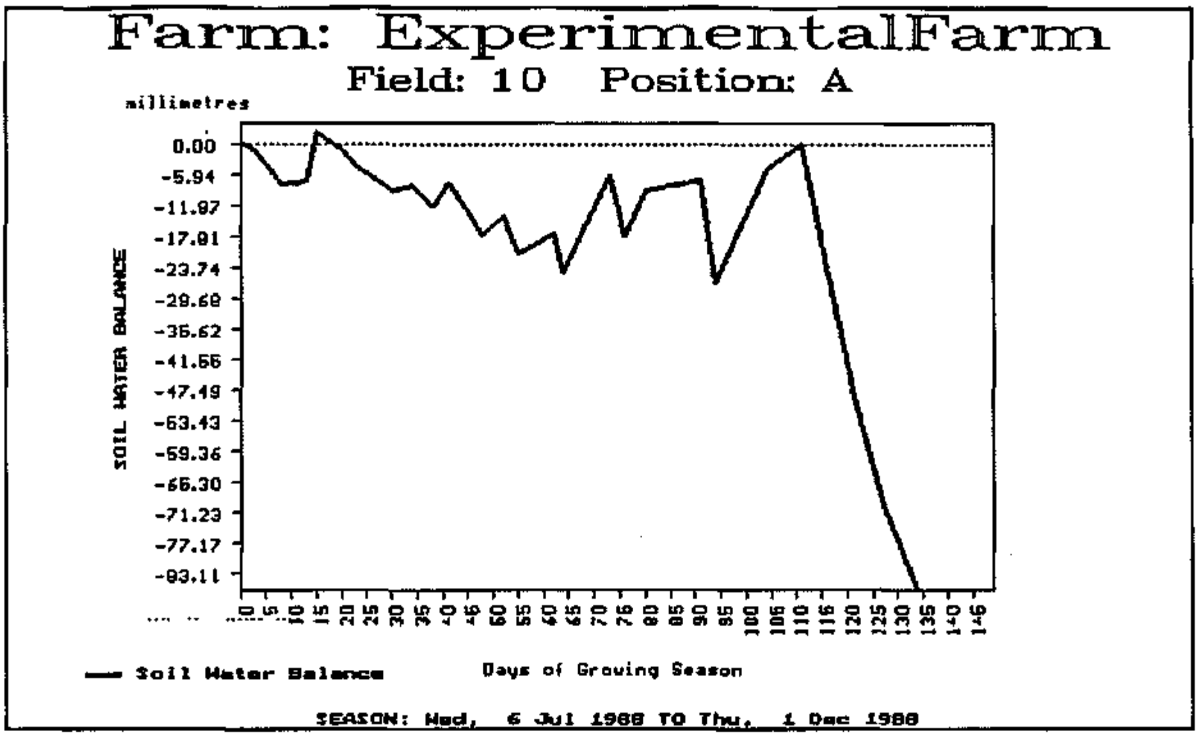

Figure 4.6 Soil water extraction curve for wheat - 1988

Block # 6, however, again responded differently and showed a progressive decline in profile water throughout the season (Fig 4.7 & 4.8), particularly from the upper soil horizons, while the soil water in the part of the profile covered by the NMP-reading at a depth of 800mm remained almost constant until the end of the irrigation period (Fig 4.7).

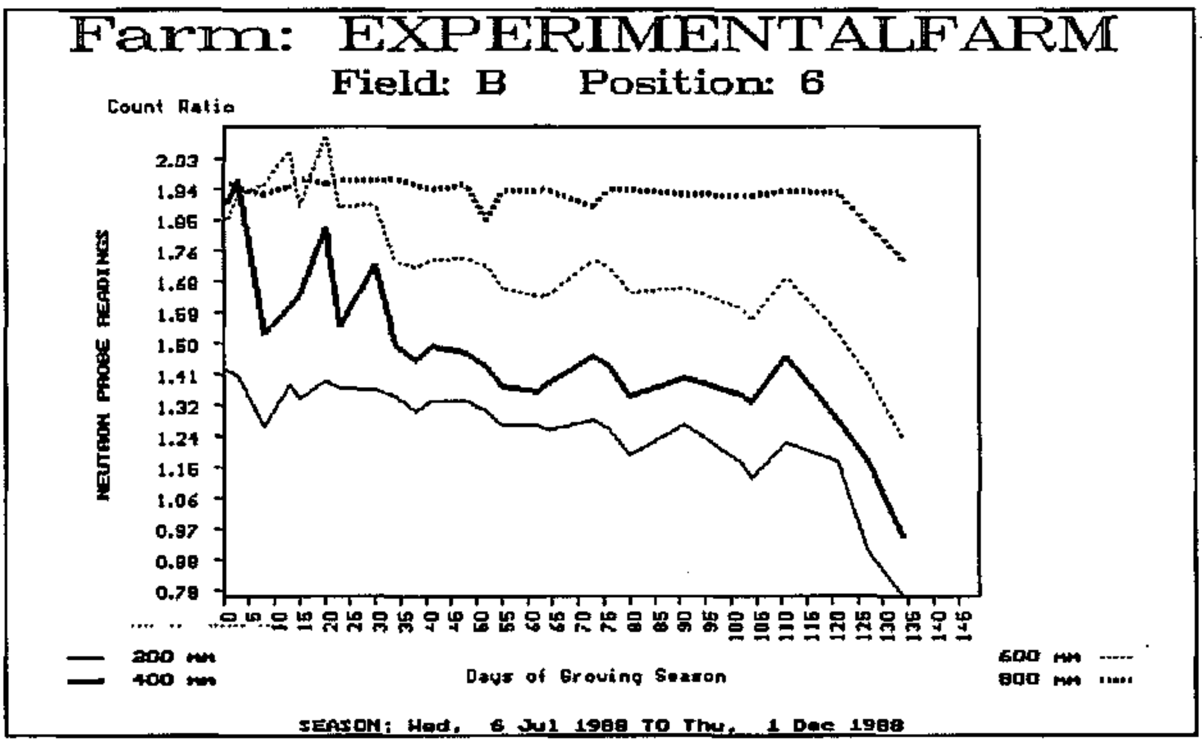

Figure 4.7 Neutron probe readings for wheat - 1988

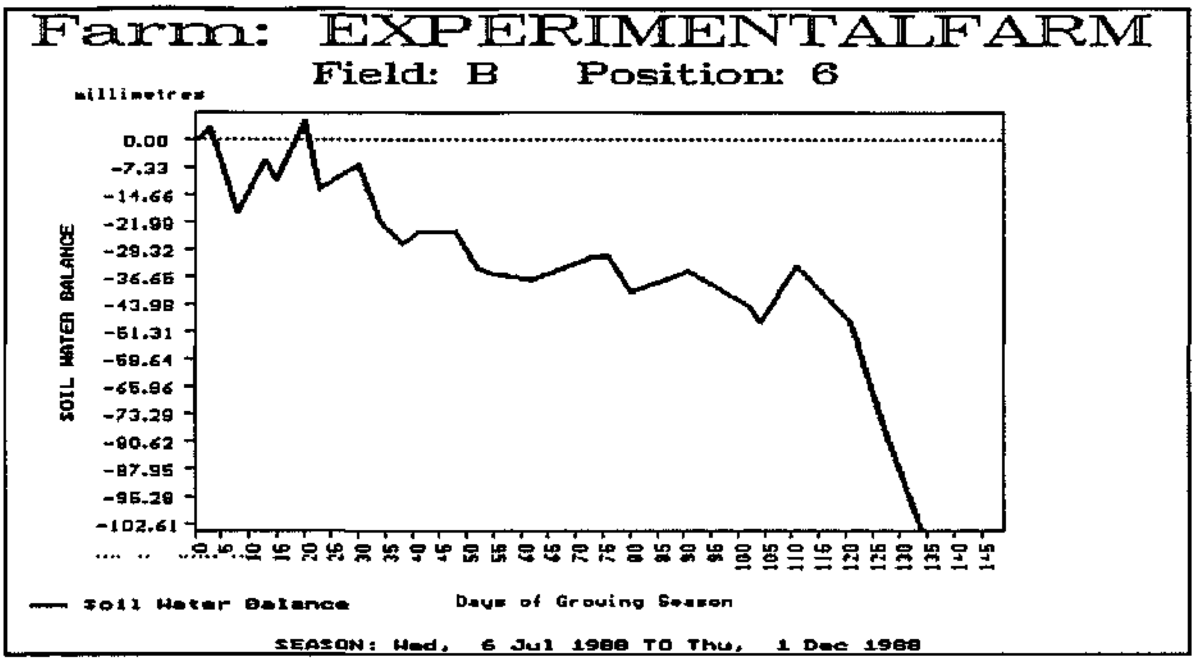

Figure 4.8 Soil water extraction curve for wheat - 1988

Due to frequent rain showers during harvest time, harvesting of the 1986 wheat crop was delayed, the subsequent maize crop could be planted only during the second half of January. The maize was then harvested only during August which made it too late to plant a wheat crop during 1987.

4.1.2 Maize

At first glance it appears that severe depletion of profile water occurred during the growing period of the 1987 maize crop (Fig 4.9 & 4.10). However, closer inspection reveals that by the end of the irrigation period, the soil water deficit stood at only 28mm and at harvest time, two months later, it had lost only a further 13mm.

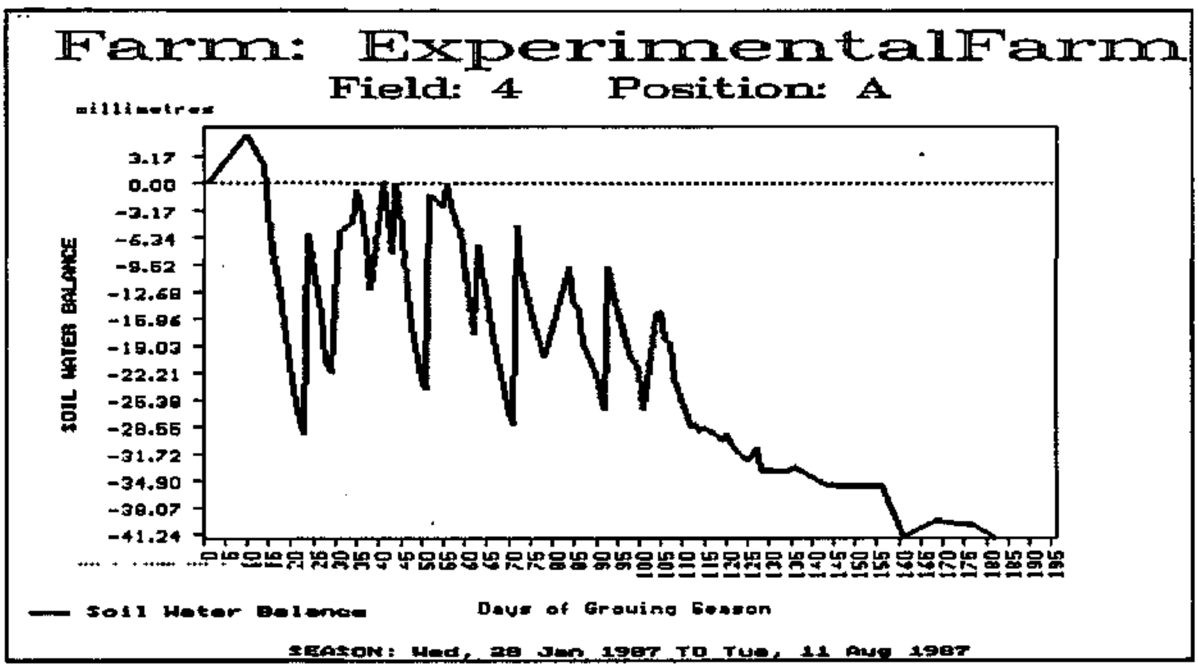

Figure 4.9 Soil water extraction curve for maize - 1987

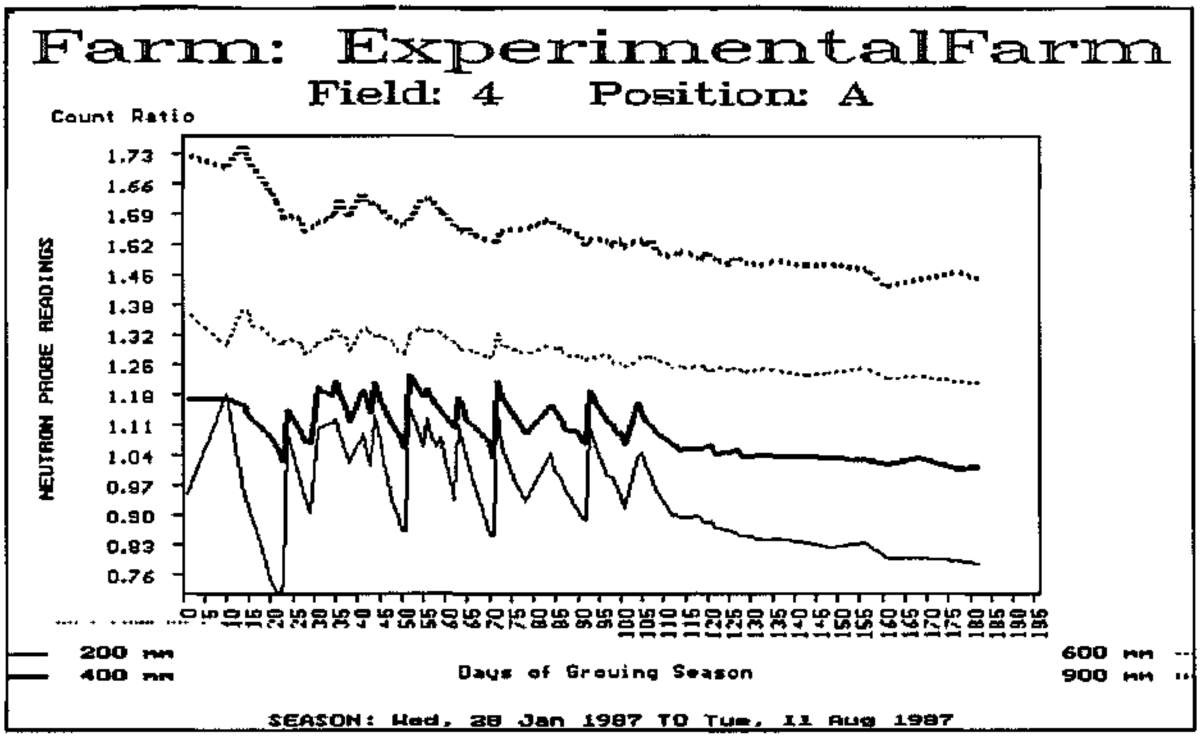

Figure 4.10 Neutron probe readings for maize - 1987

The latter observation is confirmed by the tensiometer readings for the period up to the end of the irrigation period, depicted in Fig 4.11.

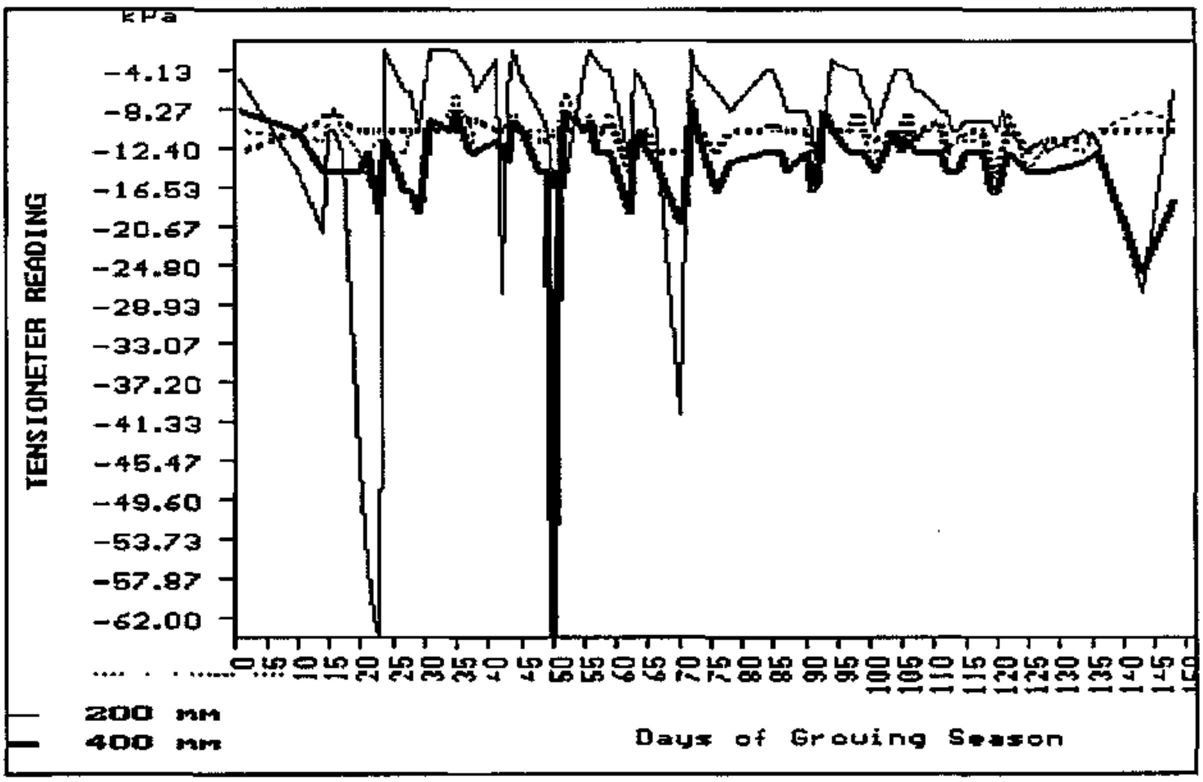

Figure 4.11 Tensiometer readings for maize at station 4A - 1987

Block # 7 which is, like Block # 6, located in the middle of the field, also responded differently (Fig's 4.12 & 4.13). The season started with a profile soil water deficit, followed by a steady increase in soil water which eliminated the deficit completely, shortly after anthesis. Then a sharp decline in profile soil water took place, ending with a deficit of 45mm by physiological maturity.

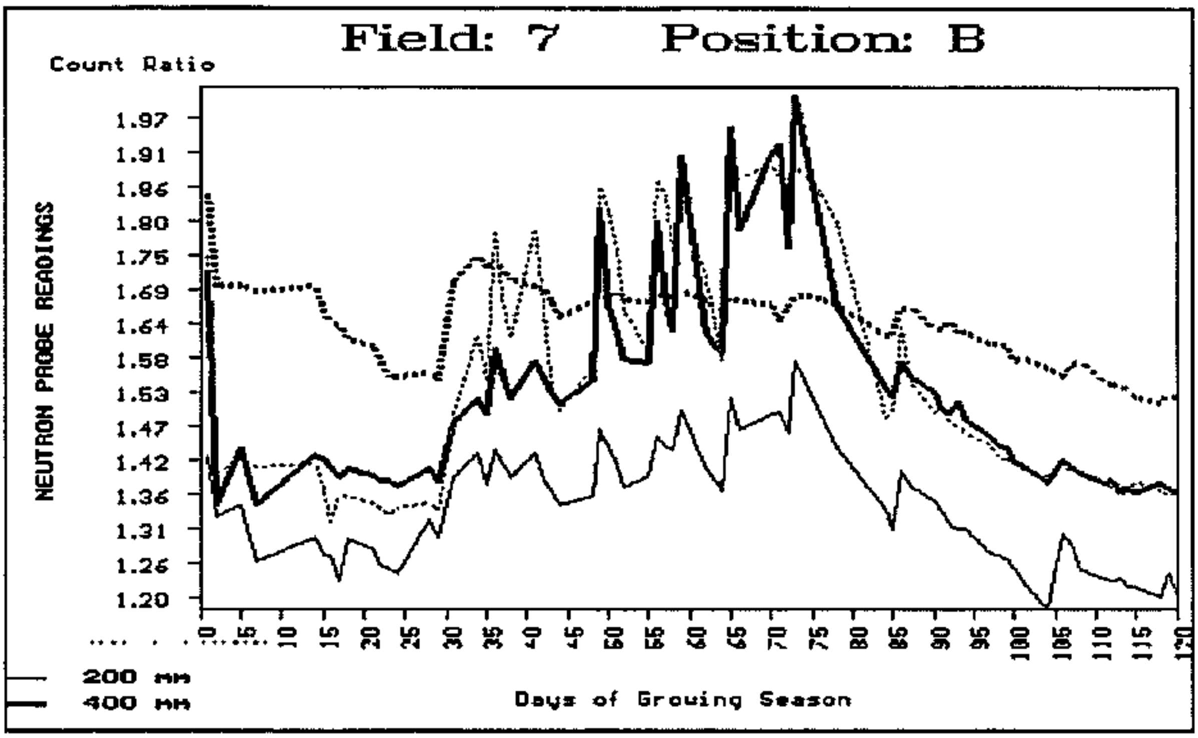

Figure 4.12 Neutron probe readings for maize - 1987

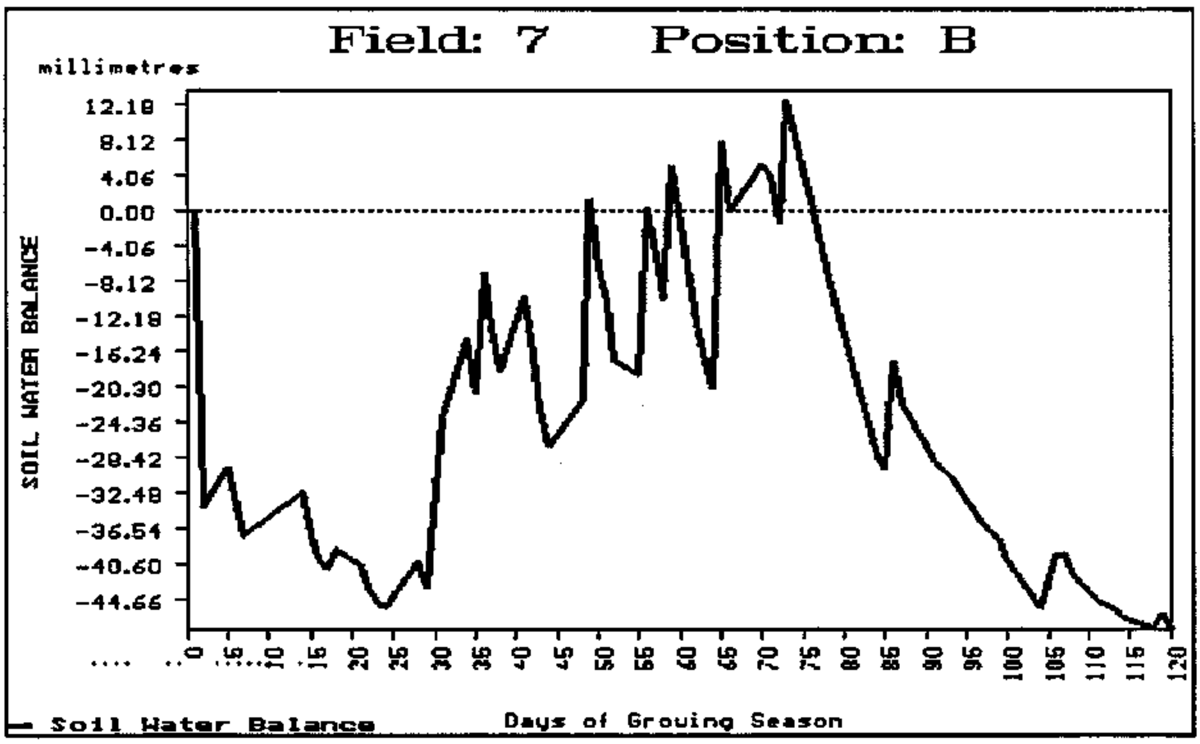

Figure 4.13 Soil water extraction curve for maize- 1987

The seasonal march of profile soil water under Block # 10 (Fig 4.15 & 4.17) followed almost an identical pattern as that under Block # 4 (Fig 4.10).

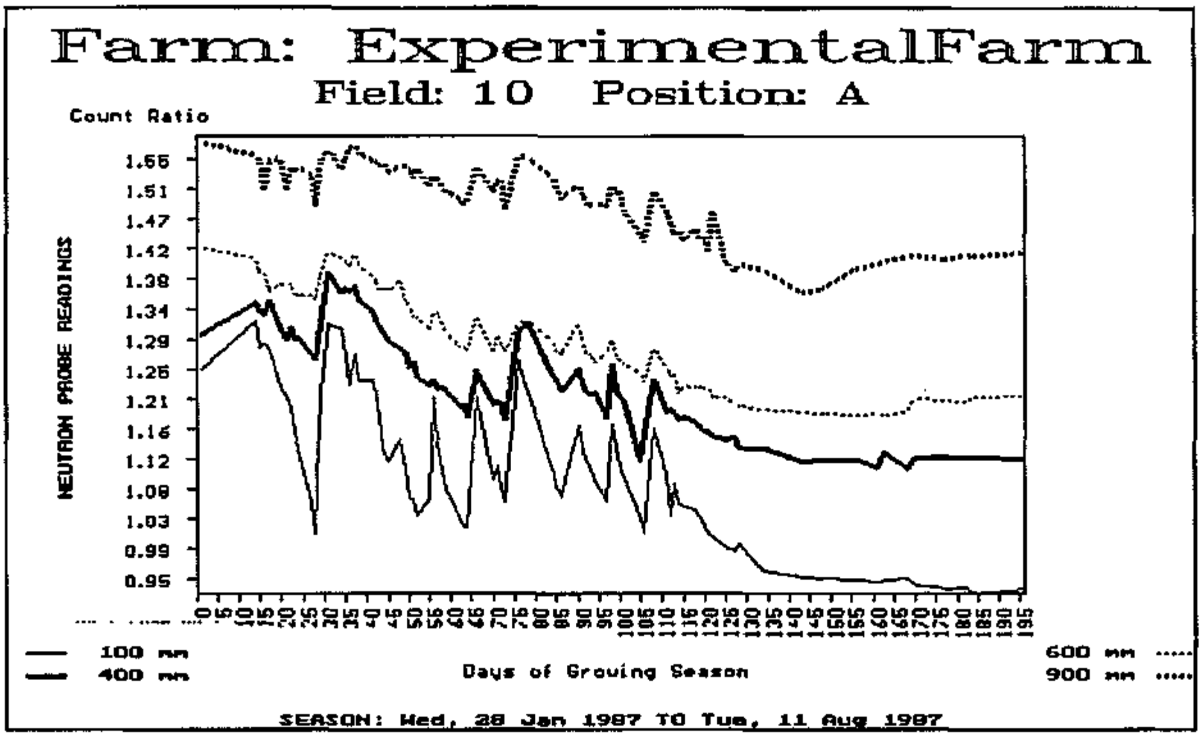

Figure 4.14 Neutron probe readings for wheat - 1987

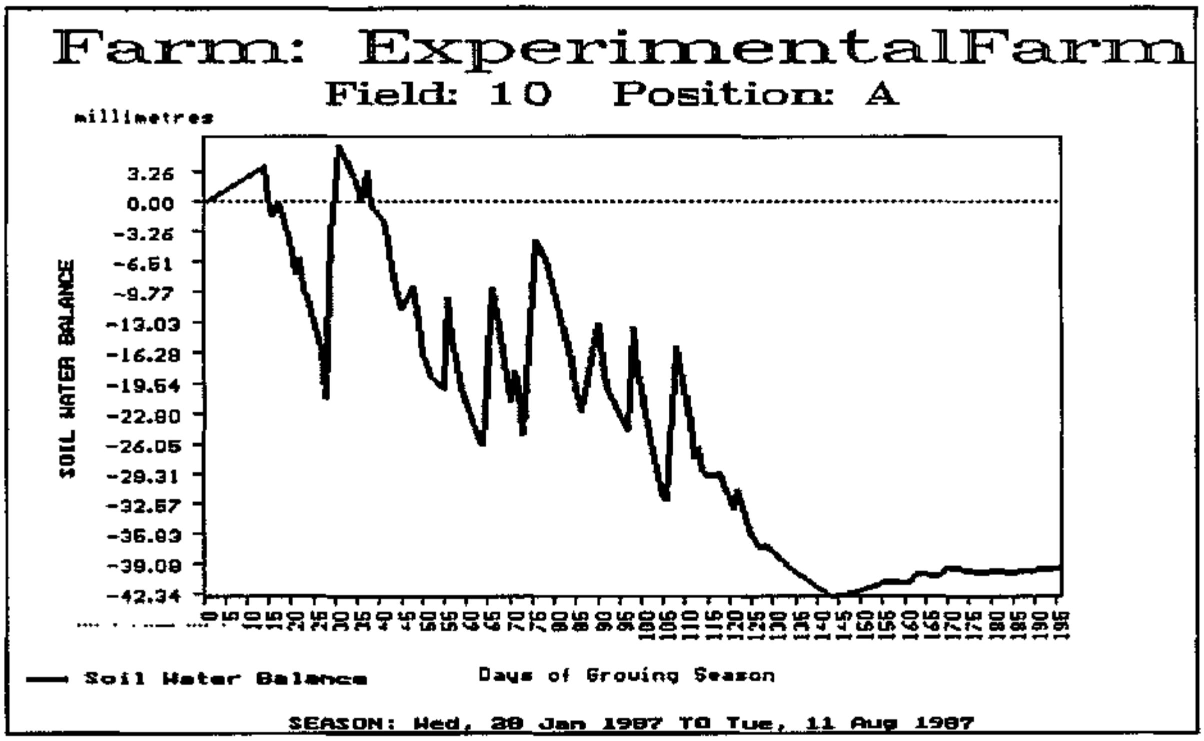

Figure 4.15 Soil water extraction curve for wheat - 1987

Again, the pattern indicated by the neutron probe readings were confirmed by the tensiometer readings depicted in Fig 4.17. The sudden peaks in the tensiometer readings at depths 200, 400, and 600mm after the end of the irrigation period, can be ascribed to malfunctioning of the tensiometers when the soil became too dry.

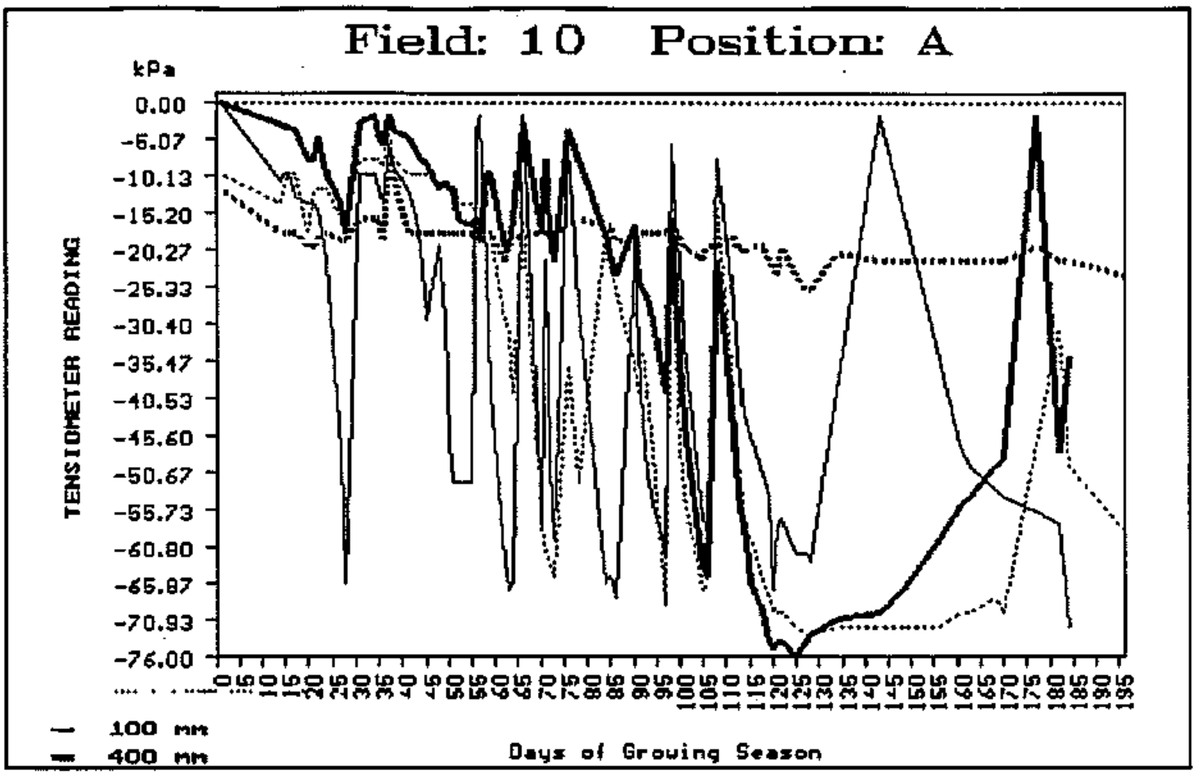

Figure 4.16 Tensiometer readings for maize at station 10A - 1987

4.2 CONSERVATION TILLAGE

During times when it was possible to stick to the schedule, it was clear that recommended crop factors from the *Green Book* were too high for the zero tillage system, which left a thick mulch of crop residue on the soil surface.

The situation did not allow for accurate comparisons with conventional tillage, but it was estimated that water applications could be reduced by as much as 30% during the early stages of the growing period.

The most remarkable feature of the zero tillage practice was, however, the dramatic improvement in infiltration rate. The linear system was designed to apply water at a constant rate of 45 mm.h^{-1} and during the first maize crop, which was tilled and planted conventionally, it was estimated that run-off amounted to at least 50% of applied water. As soon as zero tillage commenced and the soil surface was mulched, however, **run-off was completely eliminated.**

4.3 IRRIGATION SCHEDULING

The implementation of the **Irrograph** as proposed by Burgers(1982) was a disaster. Even under strict control and supervision, it was soon evident that this scheduling tool, as most other scheduling tools, works well in the on-farm situation only when the farmer/manager has to deal with only one irrigated field which can be irrigated in one day. The dire need for an improved scheduling tool which will be able to deal with all the peculiar problems in the on-farm situation, as well as the particular requirements of the farmer, and at the same time remains simple and easy to use, became increasingly evident.

4.4 COMPUTER BASED IRRIGATION SCHEDULING

It appears that most farmers would prefer to schedule irrigation applications conveniently according to routine farm activities and in a more or less fixed time schedule. At the same time, however, they would like to have the assurance that they are meeting the water requirements of their crops.

A **fixed schedule** which is well planned according to:

* the average atmospheric evaporative demand for the time of the year.
* the soil profile water retention characteristics; and
* the design features of the irrigation system,

could work well, provided the correct amount of water is applied at each of the scheduled dates.

An accurate estimate of soil water extraction since the previous scheduled application, taking into account any effective rain during the same period, would be essential to such a scheduling procedure. Any such estimates would necessarily involve fairly complicated calculations, which may not be acceptable to most farmers. However, computers are fast becoming an essential facility on farms, and a user-friendly program which computes the amount of water to be applied on each of the scheduled dates, may well be the answer to the farmer's scheduling problems.

Mr J.P. Burgers was contracted to develop a computer program which would facilitate the day to day management of Centre Pivot and Linear irrigation systems on a predetermined time schedule, which resulted in the program called, **IRRISCHED**.

Irrisched

Irrisched is a practical irrigation scheduling tool which is the culmination of 25 years of research on irrigation scheduling methods and is believed to eliminate most of the practical problems encountered with other on-farm methods such as the Irrograph, the Balance Sheet, the Scheepers-pan etc.

The main purpose of the program is to estimate **crop evaporation** (E) on a continuous basis, provide for effective rain and indicate the estimated **soil water deficit** (SWD) when the irrigation system arrives at the starting point of a section of the field to be irrigated. The farmer may then decide on an **application amount** (d) equal to, or smaller than the SWD (as in deficit irrigation as described by Vanassche & Laker, 1989) or larger than the SWD (in order to meet the leaching requirements of the soil).

The program would then indicate the corresponding **speed setting** for the control panel of the irrigation system which would allow the chosen d-value to be applied. Finally the program would display a graph indicating the daily march of the **soil water balance** as influenced by application amounts and effective rain.

The main features of the program can be summarised as follows:

* **On-board Data files** - The program contains the following on-board data files:

  I Long term average pan evaporation data for the region for every week of the year.

  II Average crop factors for as many crops as required as per irrigation/drying cycle for the whole growing season - growth stages being identified by the percentage of growing season that has lapsed since planting.

  III Daily crop factors within each drying cycle - the specific stage within a particular drying cycle is identified by the cumulative pan evaporation since the previous wetting by irrigation or rain (Burgers & Nel, 1984)

  IV Speed setting values (%) for the control panel of the irrigation system which would allow the application of any amount from a minimum of say 3 mm to a maximum of say 70 mm, depending on the capacity of the system.

  All these on-board data files may be edited or adjusted to suit different situations.

* **Master schedule**

  Using on-board data files I, II & III, the program simulates a complete irrigation schedule for the whole growing season of the crop as soon as the **planting date** and the **design application amount** are entered by the operator. This schedule can now be adjusted manually to suit the on-farm situation with respect to the number of hours per day available for irrigation, week-end irrigation, application of chemicals etc., as well as design features of the irrigation system and peak crop water requirements during different growth stages of the crop.

* **Easy day-to-day Operation**

  The only action required from the farmer/manager is to enter daily A-pan readings (before and after regulation) as well as any rain that may have occurred. The program then:

  - calculates the day's crop evaporation by selecting the appropriate *daily crop factor* from the column under the particular growth stage's average crop factor corresponding with the value of accumulated pan-evaporation since the previous wetting, which is then multiplied with the day's pan evaporation.
  - subtracts the day's crop evaporation from the soil water balance.
  - when rain occurs: first checks how much room there is for rain water storage in the profile and then adds the *effective rain*♣ to the soil water balance and then
  - gives a print-out of all blocks in the field that should be irrigated that day, the amounts to be applied and the **speed settings** which would allow these amounts to be applied

    ♣ It is assumed that no run-off occurs and when the *effective rain* exeeds 10mm, the program regards it as a *wetting*-event and the *cummulative evaporation*-vallue returns to 0mm, however when the *effective rain* is appreciably less than the *profile water deficit*, the program first allows the added rain to be depleted and then returns again to the *cummulative evaporation*-vallue before the *wetting*-event.

* **Graphic display**

Finally a graph is displayed of the daily march of the soil water balance, showing also all effective precipitation and applications of irrigation water (see Fig 4.17).

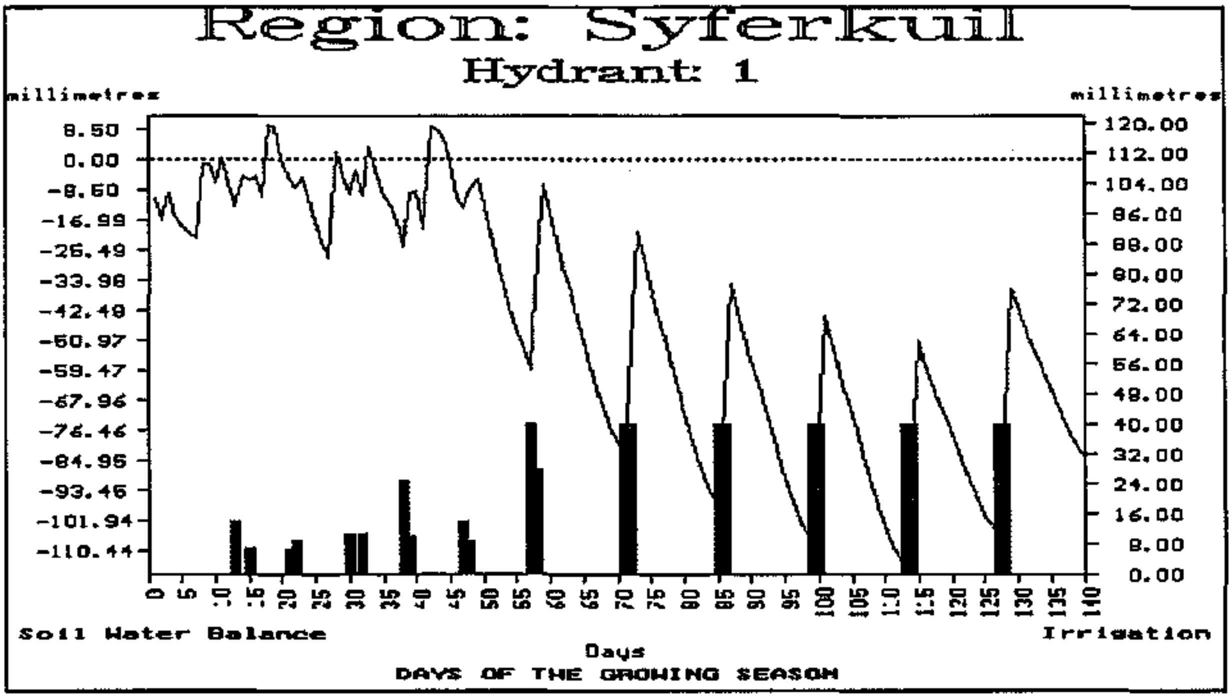

Figure 4.17 Actual and projected irrigation schedule for soyabeans - 1990/91

The display in Fig 4.17 depicts a situation where actual data has been entered up to day 50 of the growing season. From day 51 onwards the graph displays the projected schedule if no rain should occur, resulting in a deficit of 84 mm in the soil profile at the end of the season. This may be supplemented by rain, or be rectified by increasing the application amount.

A more detailed description of the program is presented in Appendix C, which represents a copy of the poster paper presented at the Southern African Irrigation Symposium (June 1991).

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

It is obvious that the project suffered a great deal because of the difficulties experienced in recruiting properly qualified research fellows as well as the limited time that the Project Leader could spend on the project due to increased administrative duties in the executive management of the University of the North. All these problems led to lack of continuity in the management of the project and eventually also the loss of opportunities to take important actions due to the fact that data could not be processed and interpreted on a day to day basis.

Initial progress, enthusiastic farmer co-operation and study group involvement were promising. However, the resignation of the Research Assistant, imported from Belgium, and the subsequent difficulties in recruiting a replacement, resulted in a setback from which the project never really recovered. As a last resort and after extensive but unsuccessful recruitment locally and abroad, the services of an Engineering Consultants firm, Murray Biesenbach and Badenhorst (MBB), was employed to take over the practical management of the project. A detailed agreement was drawn up and duly signed by the University and MBB. Two agricultural engineers (Messrs J Badenhorst and G Bloem), were assigned to the project by MBB.

Meanwhile the Project Leader was elected Dean of the Faculty of Agriculture and his administrative commitments steadily increased throughout the duration of the project, resulting in less and less time available to supervise the management of the project.

Immediately after MBB got involved in the project, progress was encouraging. Regular and fruitful work sessions between the MBB engineers and the Project Leader, resulted in more reliable field measurements and accelerated computer processing of data. However, after approximately one year, changes in the structure of MBB and subsequent transfer of Mr Bloem from Tzaneen to Pietermaritzburg, resulted in the loss of some processed data and a decline in MBB's involvement.

Although field observations went on throughout all of these difficult periods, with the assistance of the technician and student assistants, the processing and interpretation of accumulated data never really received attention before the completion of the contract period, which resulted in a complete lack of feedback to the farmers and inevitably also a decline in their interest in the project. Likewise, their interest in taking regular readings of pan evaporation from the class A pans, which were provided to them, waned because we never progressed to a stage where they could be introduced to managing their own scheduling system. The negative response of these farmer collaborators to some of the questions put to them in a questionnaire at the end of the project, was thus to be expected (See Appendix B)

The mass of data accumulated over 5 years from the farmer collaborators can at the most serve as a record of what happens under normal, unscientific farmer-scheduling of irrigation applications. However, valuable information and first hand experience was obtained regarding the problems that farmers may encounter, should scientific methods of scheduling be introduced on their farms. All this information and experiences were very useful during the design of the proposal for practical on-farm scheduling, presented in this report.

The work on Unin's experimental farm, Syferkuil, was done much more intensively and the farm manager Mr Van As was guided in the use of the Irrograph. However, even here, practical problems, specific to the linear system and cropping programme, led to the abandonment of the Irrograph in favour of the IRRISCHED-method, proposed in this report. While the data obtained from the farmer collaborators have been presented to illustrate the extent to which the farmers managed or failed to maintain the soil water balance, the development of the **IRRISCHED** programme, should be regarded as the most important contribution of this report.

5.2 CONCLUSIONS

The objectives of this project, as formulated in the contract between the Water Research Commission and the University of the North, were as follows:

* *To investigate the applicability of irrigation scheduling methods in the on-farm situation*
* *To promote the use of scientific scheduling methods by involving farmer study groups in the research programme*
* *To establish scheduling criteria for automated linear and centre pivot irrigation systems*

The first objective was achieved to some extent in that it was clearly demonstrated that existing popular scheduling methods will have to be modified or adapted a great deal before it will be adopted and applied by the average farmer with any degree of consistency. It is also true that important criteria to which scheduling methods for automated systems must conform have been established. However, it is doubtful whether any progress has been made with the promotion of scientifically based scheduling methods. It should thus be stated that, due to the difficulties explained above, the project never really satisfied the initial high expectations held by everybody concerned.

Nevertheless, the project did produce some worthwhile results and valuable lessons were learnt with regards to on-farm research and technology transfer in the field of irrigation management. The most important findings and conclusions may be summarised as follows:

5.2.1 The importance of on-farm research

The experience gathered during this project clearly showed that recommendations with respect to **practical irrigation scheduling** will have no value unless it has been extensively tested in the on-farm situation with various farmer collaborators. Problems which may be experienced with the day to day running of the recommended programme, can only be identified in the real farm situation. However, it is important to emphasize that such on-farm research will capture and retain the interest and co-operation of the farmer only for as long as the researcher maintains intimate contact with, and provides regular feedback about progress to, the farmer.

The results obtained from farmer collaborators emphasised the tremendous need for proper information about, and efficient but simple tools for, irrigation management. Although the farmers seemed to be coping well and obtained reasonable results under the circumstances, it was clear that they had no idea of how close to, or how far off, the mark they were with their irrigation programmes.

In general there was a tendency to under-irrigate with most farmers that were monitored, which led to a progressive decline in soil water status and it should be regarded as a great pity that this could not be followed up with constructive recommendations and guidance towards more efficient programmes.

5.2.2 Conservation tillage under irrigation

Much of the work for this project was done with an automated linear irrigation system under which maize, wheat and soyabeans have been grown under a system of zero tillage for the past 8 years (15 crops). The results pertaining to yields and economic aspects of the conservation tillage practices were reported in the following ways:

* Video film broadcasted on TV1 on September 12th and December 4th, 1988 in the programmes 50/50 and Agriforum.
* Paper presented at the Annual Conference of the Crop Science Society of South Africa held at the Wild Coast Sun from 23-25 January 1989.
* Paper presented at a Farmer's Day on Conservation Tillage, held at the University of the North Experimental Farm on April 20, 1989, which was attended by close to 200 farmers and officials from all over Transvaal.
* The principles and practices of conservation tillage with specific reference to these results form an integral part of several courses offered at the University of the North in the Faculty of Agriculture.

Besides the obvious advantages with respect to cost savings and timeliness of conservation tillage, it was emphasized in all reports that the system resulted in tremendous savings in irrigation water due to a remarkable improvement in infiltration and reduction in run-off and evaporation. Irrigation schedules had to be adjusted - in some instances by as much as 30% - in order to prevent severe over-irrigation and waterlogging.

5.2.3 Development of Computer Software

Two computer programs **Watercalc** and **Irrisched**, were developed during the course of this project, both having the potential for wide-spread marketing amongst irrigation researchers and practitioners.

* **Watercalc** is a program which facilitates the processing of results obtained from a neutron moisture probe. After having entered appropriate calibration constants and daily or weekly probe readings, the program would automatically calculate soil water extraction and soil water balance which are then displayed in a graph and when tensiometer readings are available these are also displayed as a graph.
* **Irrisched** is a practical scheduling tool which is the culmination of 25 years of research on scheduling methods and is believed to eliminate most of the practical problems encountered with other on-farm methods such as the Irrograph, the Balance Sheet, the Scheepers-pan etc. Although **Irrisched** was designed to work with pan evaporation data, only minor adjustments would be required to make use of other methods of estimating crop evaporation.

Irrisched was reported in a poster paper, presented at the Southern African Irrigation Symposium held at the Elangeni Hotel in Durban from 4-6 June 1991, as well as at a Wheat Farmer's day held at the University's experimental farm on 11 September 1991.

Ever since these presentations, we were inundated with enquiries regarding the availability of Irrisched on the market and **TSB Sugar and Citrus** estates have requested the development of a program which would facilitate irrigation scheduling on all their farms.

Both programs, **Watercalc** and **Irrisched** have been incorporated in the course PLNP 300 at the University of the North, Faculty of Agriculture, which deals with Agrometeorology and Irrigation Principles and Practices. Students are taught the principles on which the programs are based and given opportunities of operating the programs in a real on-farm situation.

5.3 RECOMMENDATIONS

5.3.1 Based on the experiences gathered during the course of this project it is recommended that all projects involving cooperative research with collaborating farmers, should be well planned with due attention to resources, continuity, regular feedback and active involvement of the farmers in the project. It may even be considered to have a representative from the farmers on the steering committee of the project

5.3.2 The **Watercalc** computer program, developed during this project has proved to be very useful in the processing of large volumes of soil water data obtained with the Neutron probe and it is recommended that the program be disseminated amongst researchers involved in soil water studies. A paper, describing the program and its functions, will be prepared by the project leader for publication in **S A WATER**

5.3.3 The most important achievement of the project was the development of **IRRISCHED**, a computer based scheduling method for automated irrigation systems. It is recommended that this program be further developed and tested in the on-farm situation. It has already been adopted on the University experimental farm where it will be subjected to rigorous testing and adjustments. Any further developments and progress in this regard will be submitted to the WRC for dissemination of the results

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UNIVERSITY OF THE NORTH

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APPENDIX

A, B, C, D & E

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APPENDICES A, B, C, D & E

APPENDIX A

A1 SOIL CHARACTERISTICS

A1.1 FARMERS' SOILS

In order to determine the characteristics of the farmer collaborator's soils under consideration, profiles were examined and described in detail. The number of profiles for each farm was determined by the size of the irrigation project concerned.

Samples were taken for chemical analysis and in all cases the pH is expressed in terms of 1 to 1 KCl analysis, the P was analyzed according to the Bray 2 method and CEC is expressed in me/100g soil. Bulk density is expressed in g/cm^3. The profile descriptions and chemical analysis for each collaborator is summarised below.

1. Dr H.J. Scheepers, Papkuil

Summarised profile description

A. Physical analysis

Horizon	Depth	Colour	Sand(%)	Silt(%)	Clay(%)	ρ_b(g.cm^{-3}
Ap	0-300	7,5 Yr ¾ (moist)	80	8	12	1,34
B1	300-600	5 Yr $^4/_8$ (moist)	70	8	16	1,42
B2	600-750	7,5 Yr $^7/_3$ (dry)	76	5	18	-

B. Chemical analysis

Horizon	pH KCl	P ppm	CEC me/100g	Ca ppm	Mg ppm	Na ppm	K ppm
Ap	6,0	55	2520	402	236	111	237
B1	5,0	4	2702	342	185	169	213
B2	5,1	5	3026	423	277	128	233

On this irrigation project, a total of six soil profiles were examined.

The 0-300mm Ap layer of soil consisted of a dark brown sandy loam with a sand content (often very coarse) of approximately 80 percent. The silt and clay content were 8 and 12 percent respectively.

The bulk density of this top layer was 1,34g.cm^{-3} and many fine roots were present. Chemically this layer was neutral with a pH of 6,0. The phosphatic content was high averaging above 50 ppm. and the base saturation also high with a CEC content between 2 000 and 3 000me/100g.

The B1 layer which averaged between 300 to 600 mm deep consisted of yellowish red soil often with layers of small angular stones. Here the sand content dropped to just over 70% with the silt and clay content correspondingly higher. The bulk density was also slightly lower. Fine roots were again present. The pH was very favourable averaging about 5,0, the CEC value more than 2 000me/100g but the most remarkable difference from the previous layer was a very low P content of less than 5 ppm.

The B2 layer varied in depth from 600 to 750 mm to slightly deeper. This level was characterised by many stone layers with spaces filled with dark brown sandy loam. There was also much weathered material, soft plinthite and fine to medium prominent mottles. Chemically there was a slight rise in pH due to a correspondingly higher CEC level and the P content remained very low.

Although chemically favourable, the stony nature of this soil made it physically marginal for irrigation purposes.

2. Mr Jan van der Merwe, Fortklipdam

Summarised profile description

A. Physical analysis

Horizon	Depth(mm)	Colour	Sand %	Silt %	Clay %	ρ_b g.cm^{-3}
Ap	0-350	7,5 Yr $^{2}/_{1}$ (moist)	40	27	35	1,25
A13	350-550	10,0 Yr $_{3}/_{1}$ (moist)	5	25	70	1,2
B2	550-1200	2,5 Y $^{2}/_{1}$	36	21	43	1,1

B. Chemical analysis (ppm)

Horizon	pH (KCl)	P	CEC	Ca	Mg	Na	K
		ppm	*me/100g*	*ppm*	*ppm*	*ppm*	*ppn*
Ap	6.4	45	5520	1964	1752	552	600
A13	7.0	25	8320	2160	3444	3932	204
B2	7.2	20	-	1056	2196	1348	132

The 0-350mm Ap layer consisted of coarse silty clay strongly prismatic cracks up to 15mm when dry, very hard, friable, few very fine (< 1mm) lime concretions.

The sand content was 40 percent with the silt and clay 27 and 37 percent respectively.

The bulk density of the top layer was 1,25g.cm^{-3} and a few roots were observed. Chemically the soil was slightly alkaline with a pH of 6,4. The phosphatic content was high averaging over 40 percent. The CEC was also high, over 5 000me/100g.

The A13 layer which averaged from 350 to 550mm was classified as a silty clay with a very low sand content and a correspondingly high silt and especially high clay content of 70 percent. This layer was strongly prismatic, very hard and cracked when dry. There were a few fine roots present. The bulk density was 1,20g.cm^{-3}.

Chemically this layer was strongly alkaline (pH 7.0) and characterised by a very high CEC (8320me/100g) with all cation readings very high. The P content was medium.

The lower B, layer had a coarse strong angular blocky nature, very hard with deep cracks when dry. Lime concretions were common. However, the clay content was not as high as the previous layer. The pH was again high and the P level had dropped slightly. No CEC figures were available.

3. Mr M.J. Jansen, Dooringkraal.

Summarised profile description

A. Physical analysis

Horizon	Depth(mm)	Colour	Sand %	Silt %	Clay %	ρ_b g.cm^{3}
Ap	0-350	7,5 C/R$^{3}/_{3,5}$ (moist)	90	0	10	1,5
A13	350-600	7,5 Yr $^{3}/_{3,5}$ (moist)	82	3	15	1,7
B2	600-1200	7,5 YR $^{4}/_{1,5}$ (moist)	72	5	23	1,4

B. Chemical analysis (ppm)

Horizon	pH KCl	P ppm	CEC me/100g	Ca ppm	Mg ppm	Na ppm	K ppm
Ap	5,1	30	920	400	210	110	150
A12	4,1	3	920	420	280	120	70
B2	4,4	3	1400	450	290	150	65

Two profile pits were considered.

The 0-350mm Ap layer of soil was classified as a course stony sandy soil, hard friable and not sticky and non-plastic. Many fine roots as well as stones and Fe and Mn oxide concretions were present. This soil had a high bulk density.

Chemically the soil was slightly acid with pH 5,1, P content 30ppm and a relatively low CEC.

The following layer was 350-600mm deep and basically a sone layer filled with sandy loam soil. A few very fine roots were present and again Fe and Mn oxide concretions. The pH and especially the P content had fallen markedly in this layer.

The bottom layer (600-1200mm) was again characterised by many small stones and Fe-Mn concretions. The pH and CEC values were slightly higher but the P content remained low.

Water management on this very stony soil is of utmost importance if a crop is to succeed.

4. Mr A.F. McKechnie, Balhambra Grove

Mr McKechnie was a relatively late comer as a collaborating farmer and no profile descriptions were undertaken on his farm. However, a chemical soil analysis revealed that the pH (KC1) of the topsoil varied from 4,9 - 5,7, the B2 layer from 4,7 - 5,2 and of the subsoil from 5,3 to 5,8.

The P-level of this new land was 10ppm and 35ppm on old land in the topsoil. In all lower levels the phosphate level was very low averaging less than 5ppm.

The potassium content varied from 70 - 130ppm in the topsoil and was generally lower in the lower levels.

Calcium averaged about 750ppm and magnesium 260ppm in the topsoil with higher values in the lower levels; about 1000ppm for calcium and 350ppm for magnesium.

A1.2 SYFERKUIL SOIL

The majority of the 63ha irrigation land has been classified as a Bainsvlei soil farm.

Summarised Profile Description

Horizon	Depth	Colour	Description
Ap	0-400	7,5 YR $^4/_3$ moist; 7,5 YR $^4/_4$ dry	Sandy loam (15% clay)
B21	400-700	5 YR $^4/_3$ moist; 5 YR $^4/_6$ dry	Sandy loan (32% clay)
B22	700-1200+	5 YR $^5/_4$ moist; 5 YR $^3/_4$ dry (with mottling and gley at the bottom)	Sandy loam (33% clay)

Chemical analysis (summary)

Horizon	pH (Kcl)	P ppm	K ppm	Ca ppm	Mg ppm	Na ppm
Ap	6,5	20	200	500	400	150
B21	5,8	2	150	450	350	200

A2 CALIBRATION FUNCTIONS FOR NEUTRON PROBE

All neutron moisture probe drum and field callibration curves appear in Fig A1 - A6.

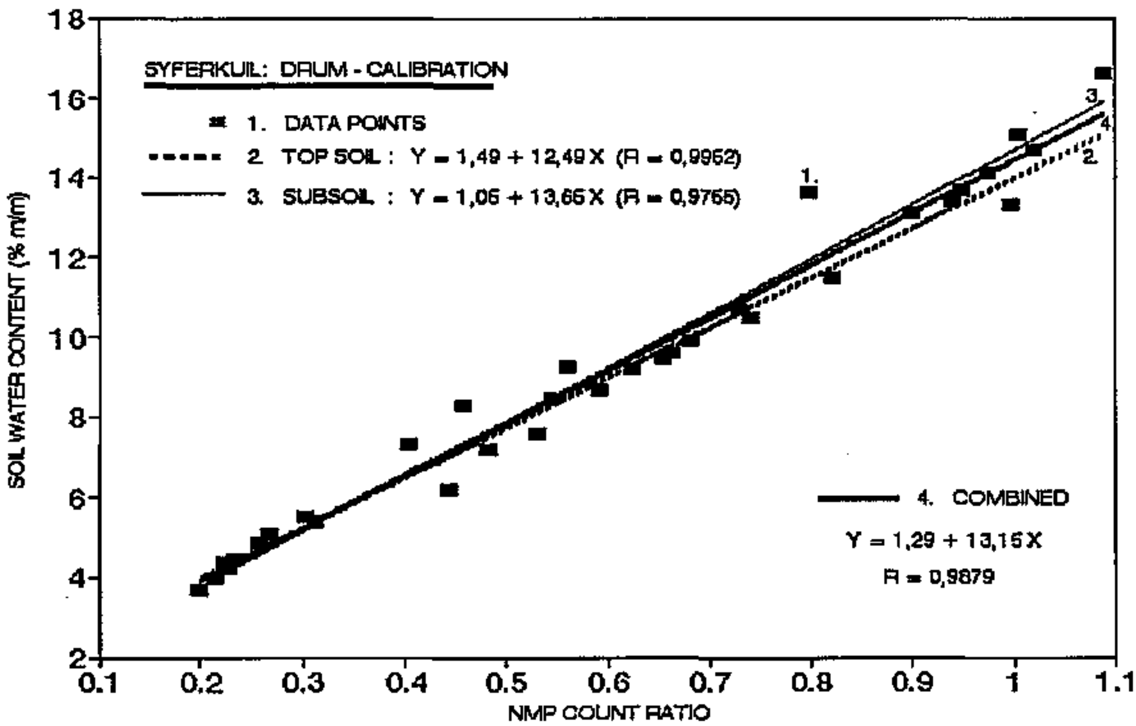

Figure A1 Neutron Moisture Probe calibration functions for Syferkuil soil, using the Drum - calibration technique

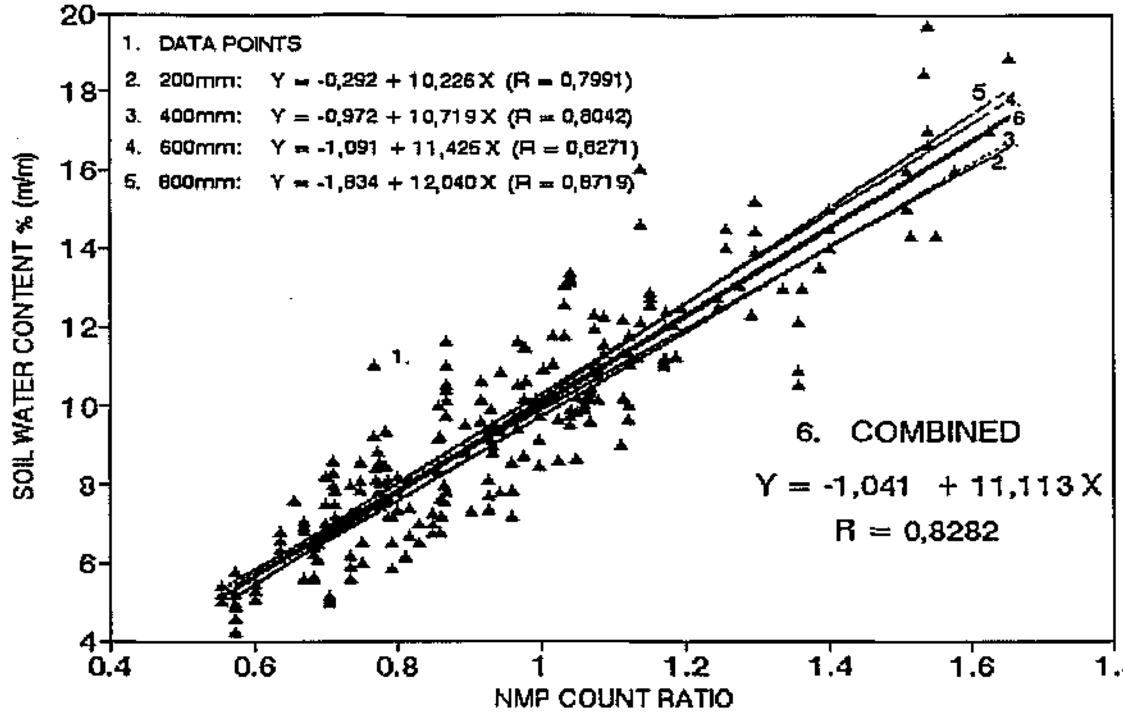

Figure A2 Neutron Moisture Probe calibration functions for four soil depths on Syferkuil obtained during a field calibration

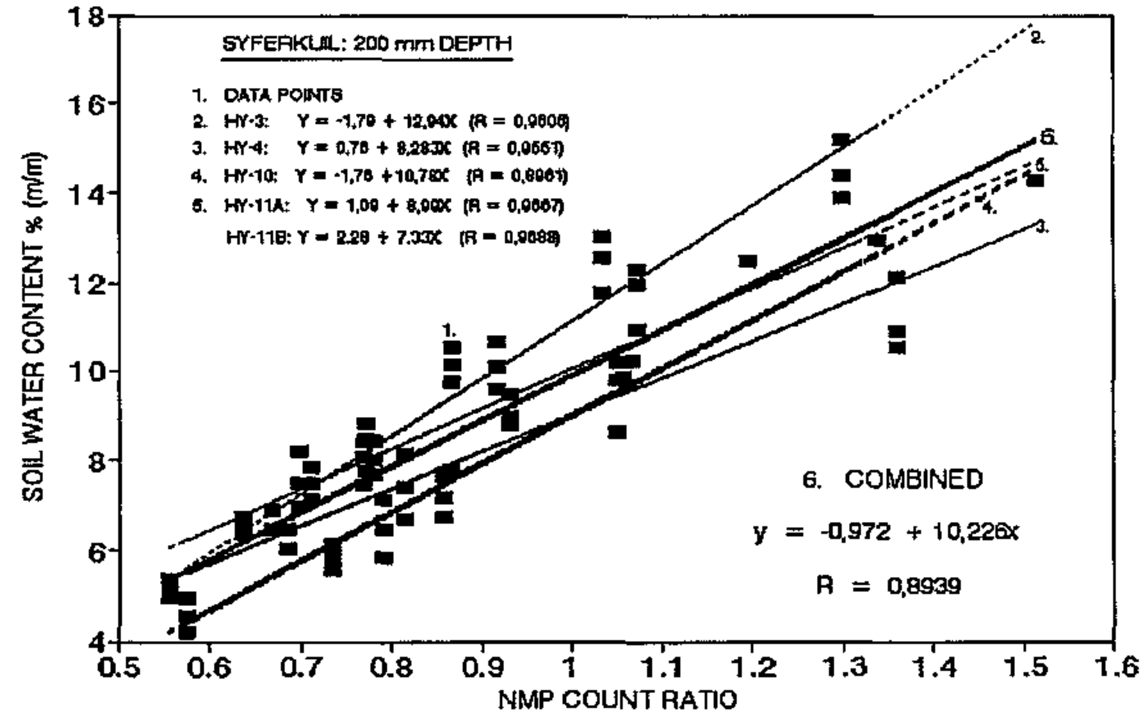

Figure A3 Neutron moisture probe calibration functions

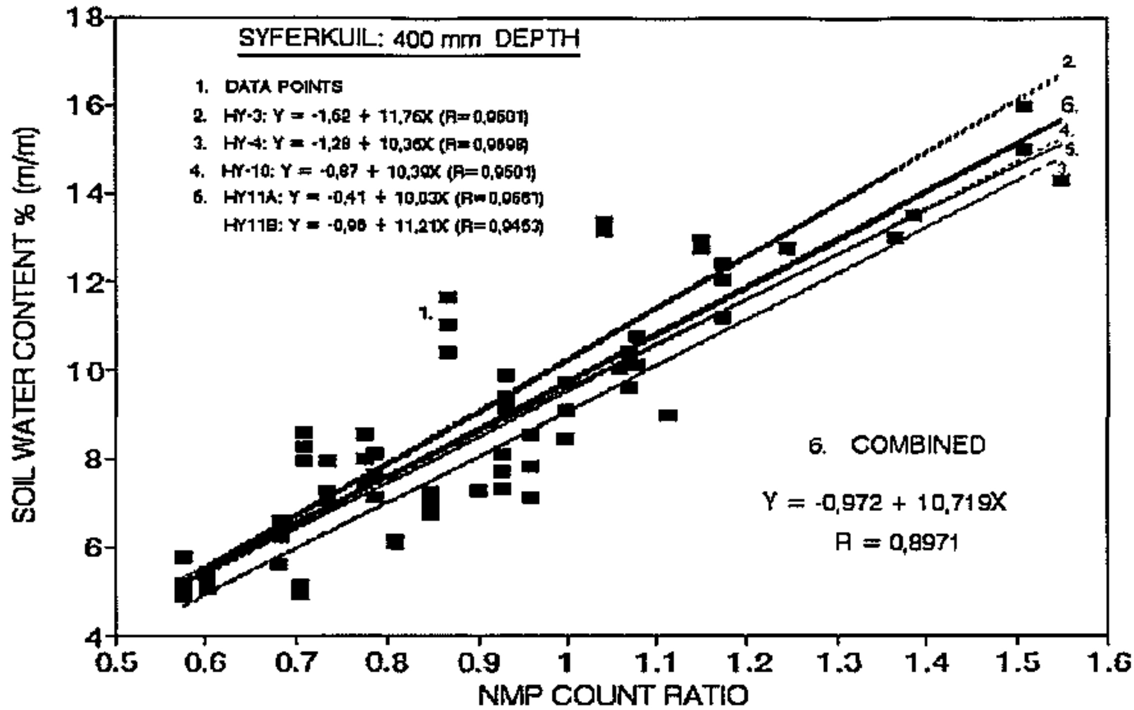

Figure B4 Neutron moisture probe calibration functions

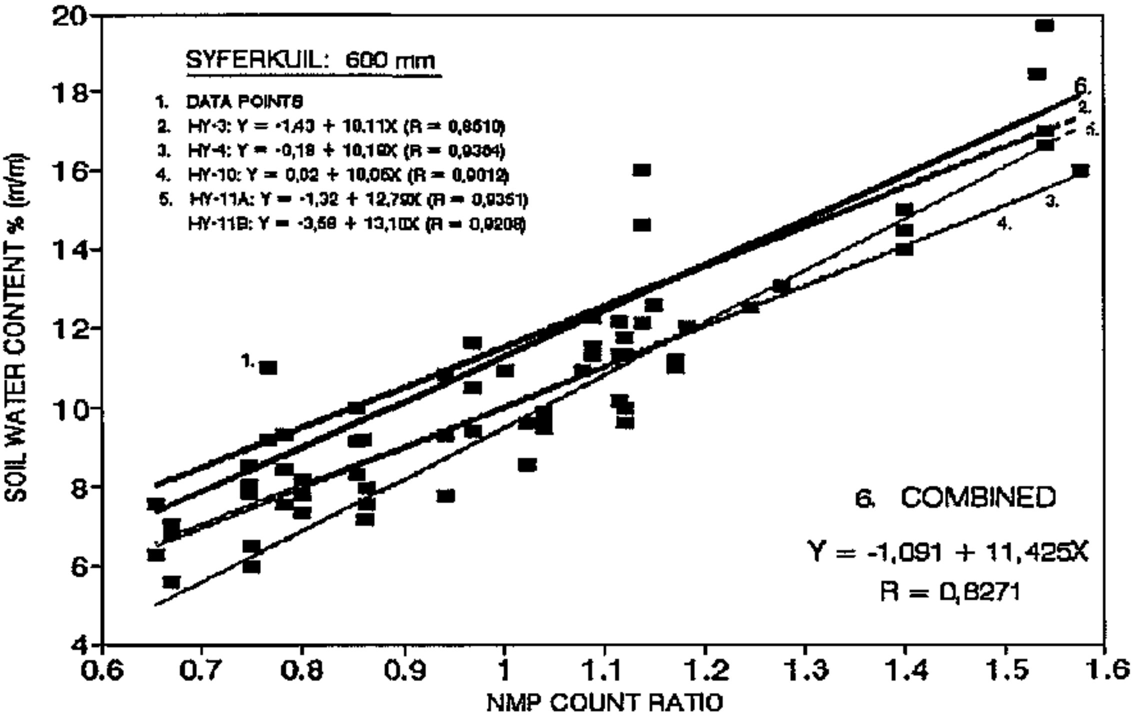

Figure A5 Neutron moisture probe calibration functions

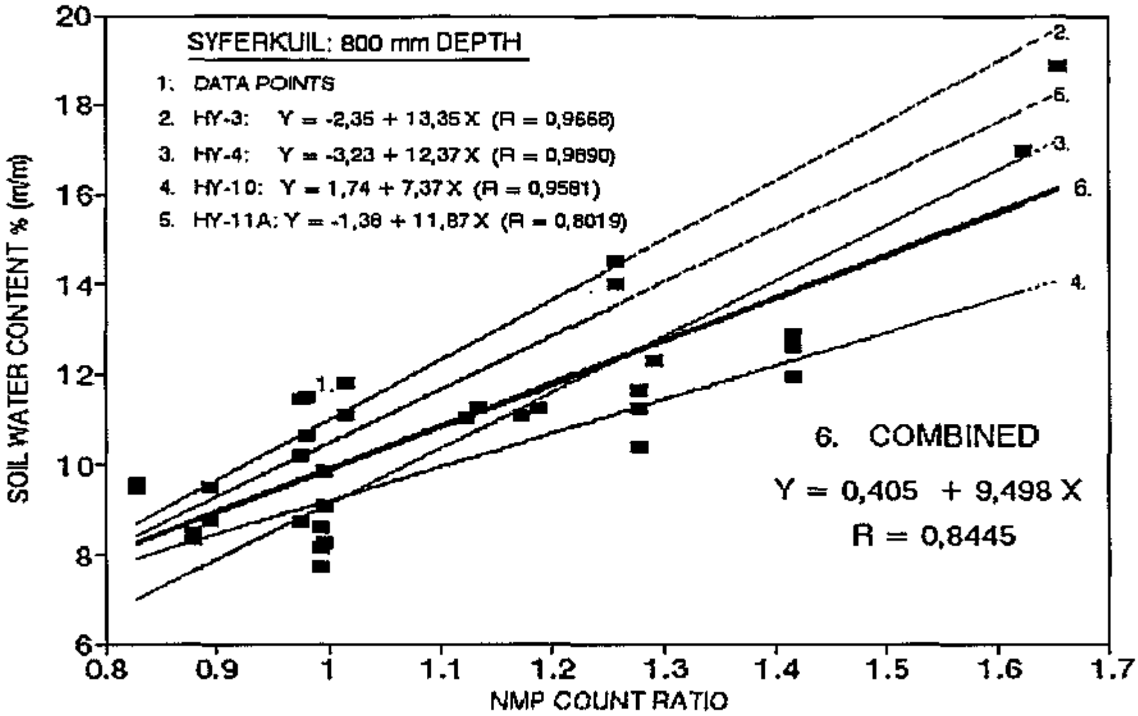

Figure B6 Neutron moisture probe calibration functions

A3 CU - INDICES OF IRRIGATION SYSTEM

1. MR J VAN DER MERWE

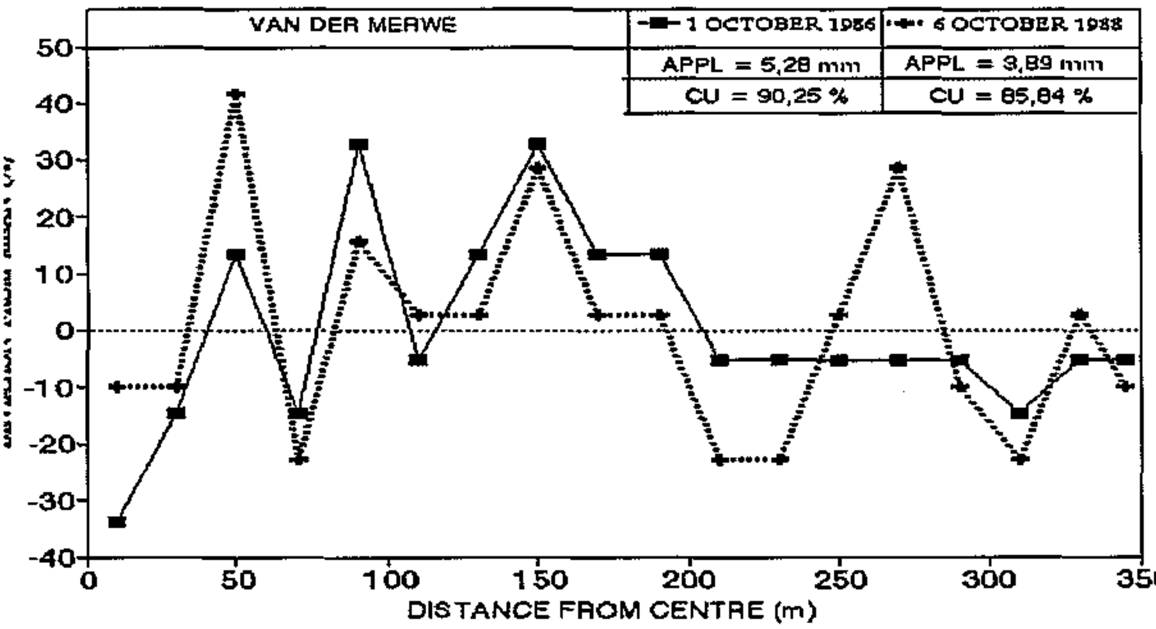

Figure A7 Application distribution and CU-index of centre pivot system on Mr van der Merwe's farm

2. MR G JANSEN

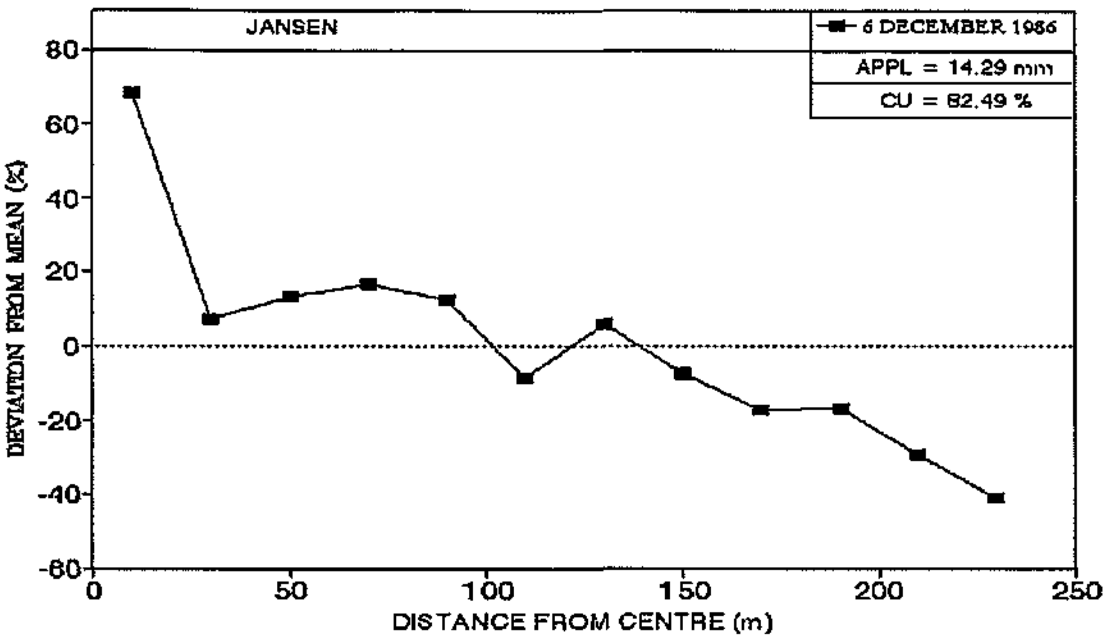

Figure A8 Application distribution and CU-index of centre pivot system on Mr Jansen's farm

3. MR A McKECHNIE

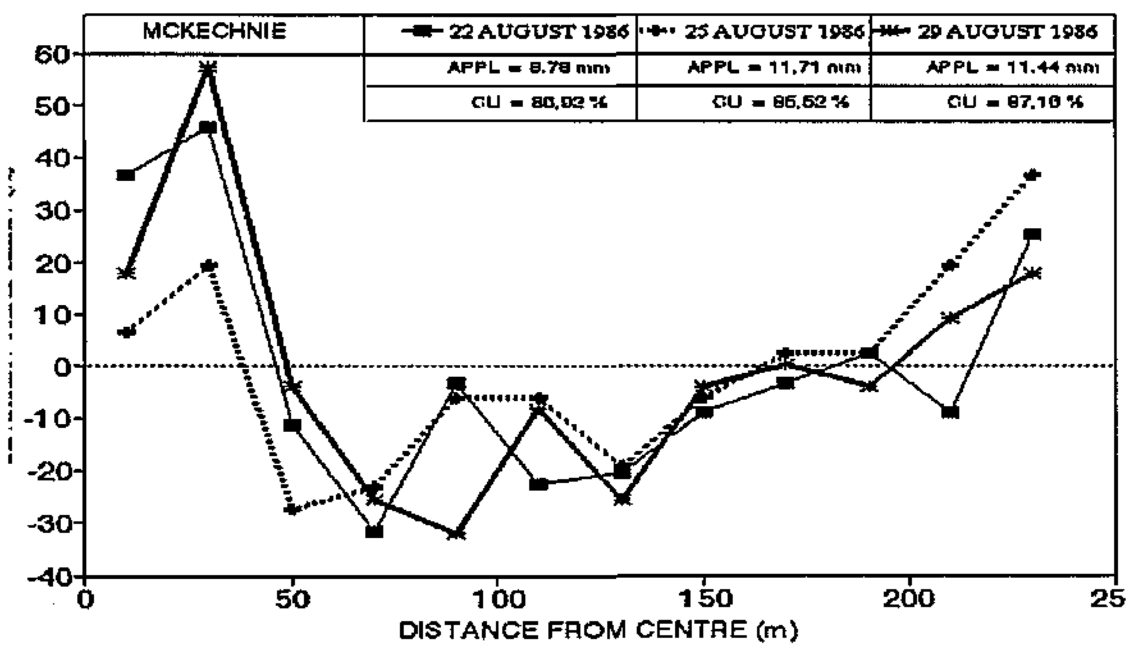

Figure A9 Application distribution and CU-index of centre pivot system on Mr McKechnie's farm

4. DR H SCHEEPERS

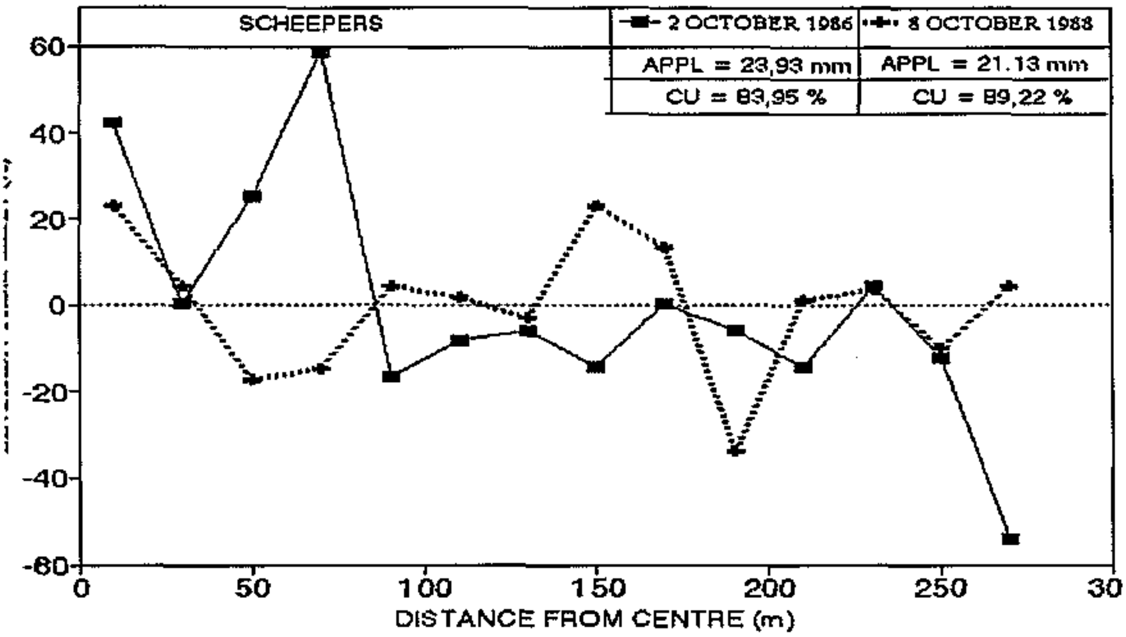

Figure A10 Application distribution and CU-index of centre pivot system on Dr Scheepers' farm

5. MR P BEZUIDENHOUT

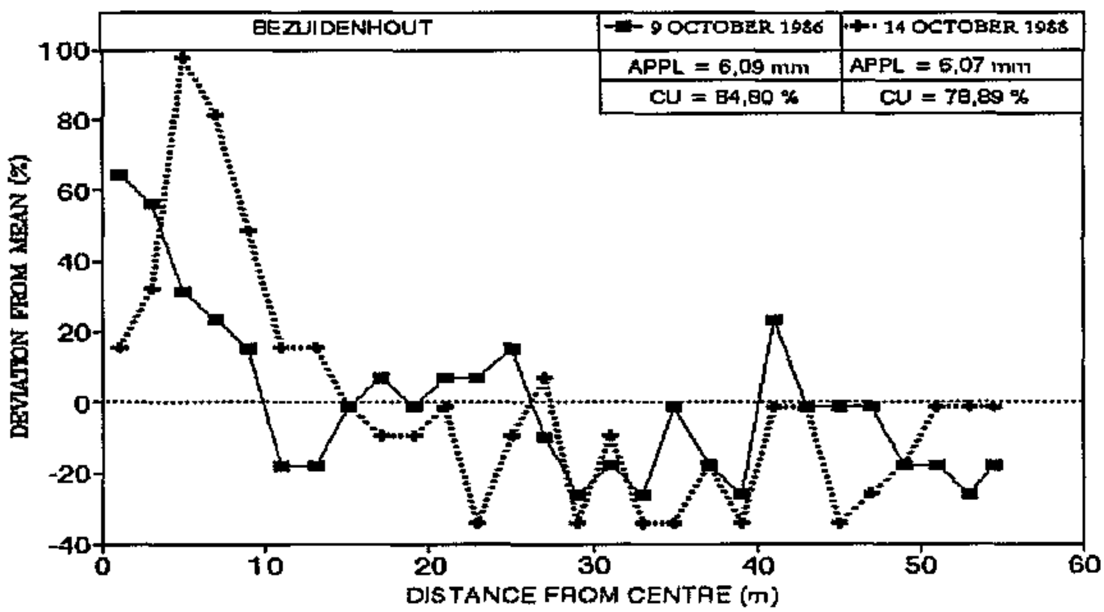

Figure A11 Application distribution and CU-indices of centre pivot system on Mr Bezuidenhout's farm

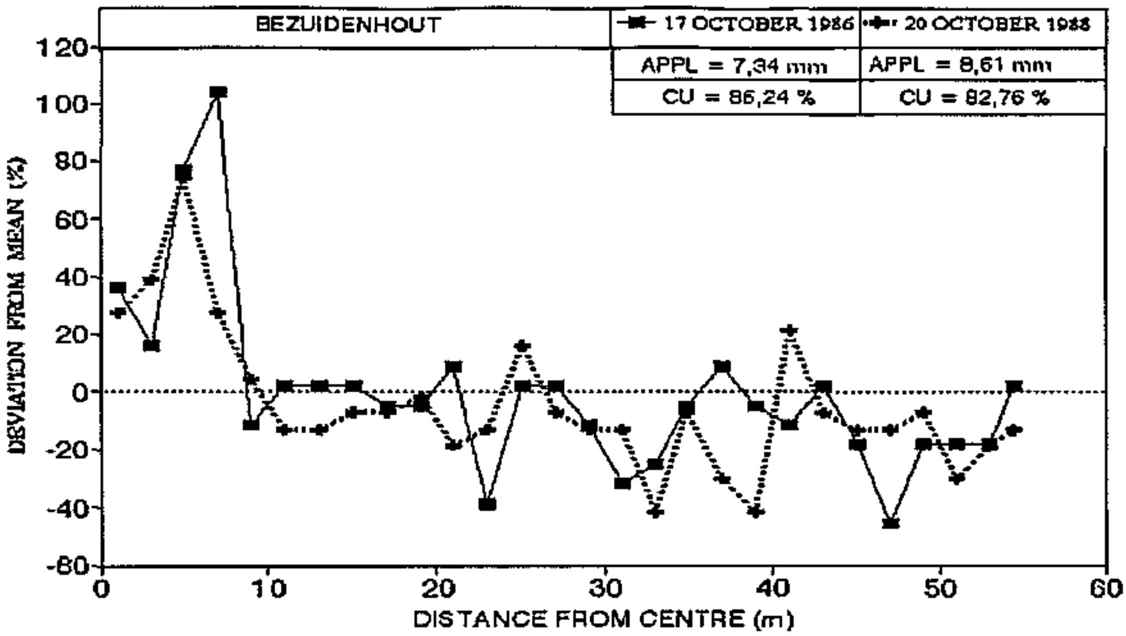

Figure B12 Application distribution of centre pivot system on Mr Bezuidenhout's farm

6. SYFERKUIL

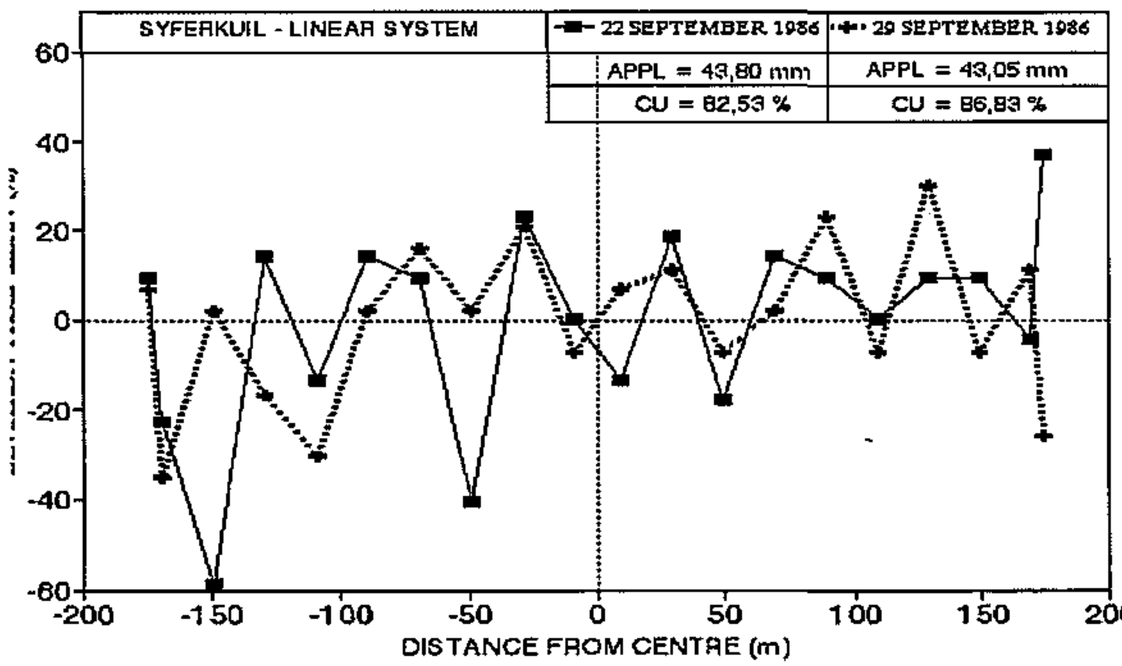

Figure A13 Application distribution and CU-index of linear system on Syferkuil

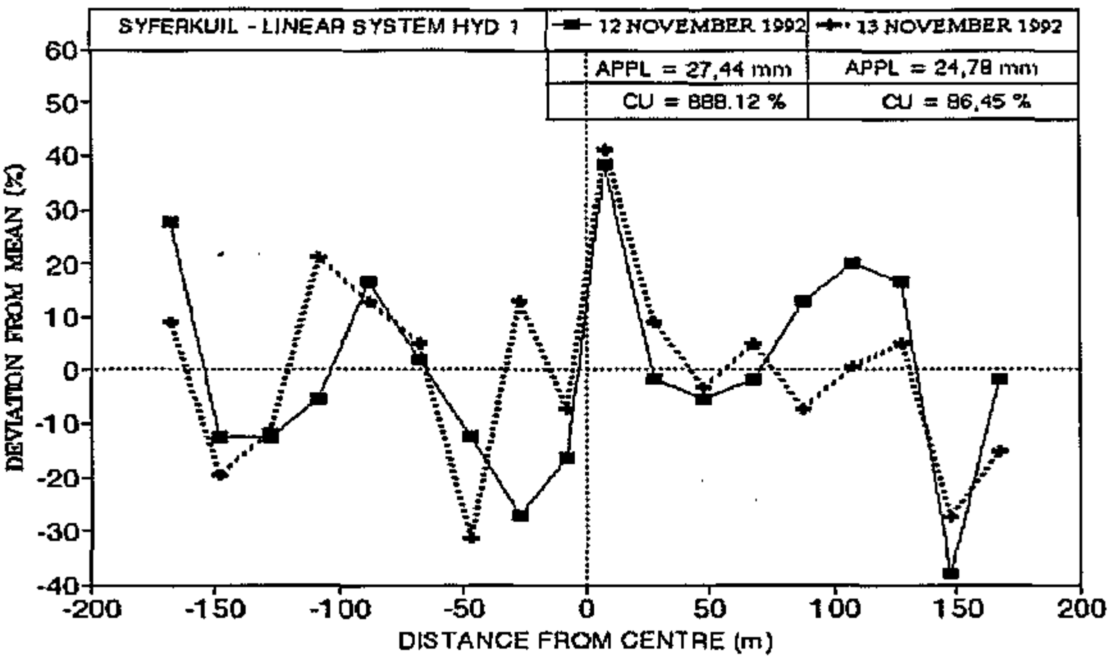

Figure A14 Application distribution and CU-index of linear system on Syferkuil

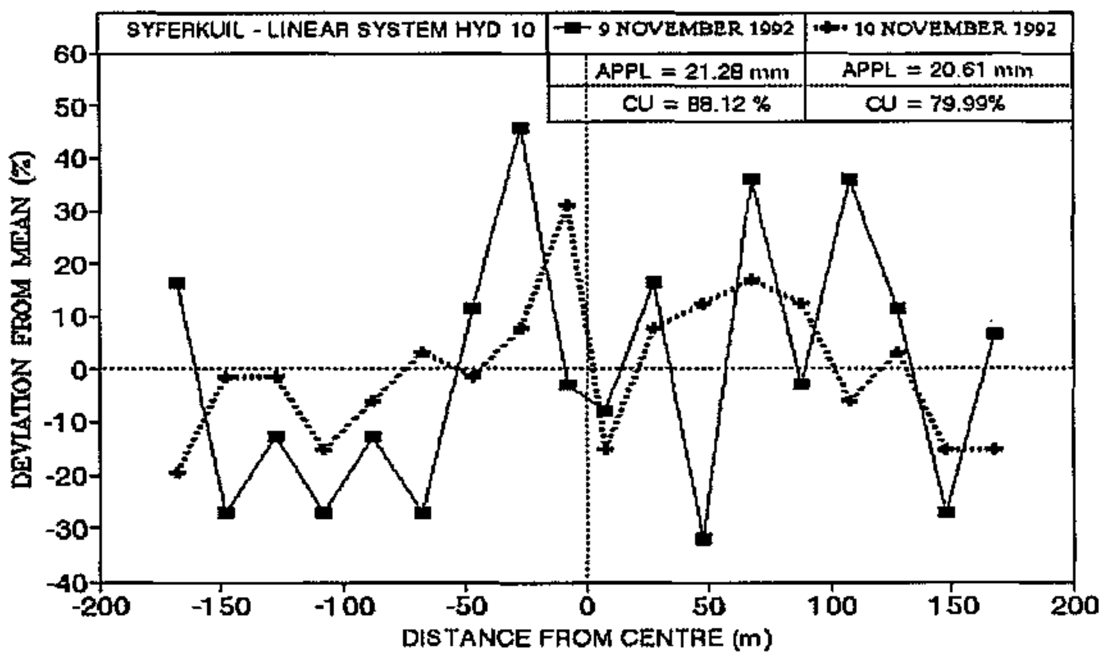

Figure A15 Application distribution and CU-index of linear system on Syferkuil

APPENDIX B

IMPACT SURVEY WITH COLLABORATING FARMERS

B.1 THE QUESTIONNAIRE

The questionnaire consisted of the following questions:

1. *Did the project assist you in any way with regard to:-*

   1.1 *Your understanding of scheduling principles and practices?*

   1.2 *Scheduling of irrigation on the lands tested?*

   1.3 *Scheduling of irrigation on your other lands?*

   1.4 *Saving of irrigation water?*

   1.5 *Increased yield?*

   1.6 *Other benefits?*

2.0 *Did you make use of equipment provided such as Class-A pan, tensiometers in scheduling irrigations? If not, please give reasons e.g.*

   2.1 *Did you consider the instruments to be unreliable?*

   2.2 *Were you too busy or was it too much trouble to take readings daily?*

   2.3 *Did you have alternative methods to guide you in scheduling?*

   2.4 *Other ideas?*

3.0 *Were you able to follow the data provided by the University?*

4.0 *Were you satisfied in the manner in which the readings were taken?*

5.0 *Was there sufficient co-operation between University personnel and yourself or staff to be able to use the information in a practical manner?*

6.0 *Was there additional information and/or equipment which you considered would have been in any way beneficial to your programme?*

7.0 *Are there any other suggestions or ideas you would like to put forward with regard to the project?*

8.0 *Would you be willing to co-operate again with the University should a similar project be undertaken, provided that proper feed-back be given about the results on a more regular basis?*

B.2 RESPONSES FROM INDIVIDUAL FARMERS

Mr A D McKechnie, Balhambra Grove, PIETERSBURG.

1. Mr McKechnie was of the opinion that his understanding of scheduling had been greatly enhanced by the project. However, he had been growing garlic for many years and, therefore, had vast experience in all aspects of this crop. Being an extremely intensive crop with high costs, he constantly monitors the development of the bulbs, checks for insect and disease attacks which means constant digging. This together with the knowledge of his soils enables him to have a natural *feeling* when water should be applied. In his view there is no really reliable crop factor for garlic which meant he could not apply the evaporation x crop

factor formula. For this reason he didn't really benefit from scheduling along these lines. He mentioned, however, that he could see how an inexperienced farmer could derive much benefit from the scheduling method employed. When asked if he had saved water, he maintained that by applying the crop factor x evaporation method more water had been applied than by using his *feel* method and, therefore, there was no water saving. As the yield from the field tested had not been kept separate from his other fields, he was unable to indicate whether he had achieved any beneficial results.

2. He had already acquired his own A-pan and tensiometers and therefore did not require our equipment . He used the project tensiometers as a cross check, but felt that tensiometers tended to be erratic. He did, however, base his scheduling on A-pan readings which he only read twice a week due to pressure of work, although he firmly believed that this was adequate to determine the amount of evaporation.

3. He never saw any data and therefore this question is irrelevant.

4. Readings were taken regularly enough and he was never bothered by the operators coming onto his farm, but he never had an opportunity to check the accuracy of the readings.

5. During the first year of the projects inception, co-operation was very good. His centre pivot was calibrated which he was pleased about. He himself was very enthusiastic and drew graphs of readings. The operators were in constant touch with him and all was going well. It was decided that the Remote Control aircraft be used to monitor crop stress(*refertence is made , here, to another WRC project at the University of the North, in the Dept of Soil Science on Remote Sencing by Model Air crafts)* . He actually went so far as to clear a portion of the veld as an airstrip but nothing materialized. With co-operation and feedback on the wane, his own enthusiasm for the project dwindled away.

6. He would have welcomed more feedback from the project staff. Better still, regular meetings between all collaborators would have been valuable to be able to exchange ideas, suggest improvements and learn from one another about the project as well as other farming aspects.

7. He was of the opinion that the project would be more beneficial to a summer crop such as maize where rainfall tends to be erratic and sometimes very heavy. An exercise which assessed the actual benefit of rain i.e. run-off vs infiltrated, would be valuable to the farmer.

8. Mr McKechnie is disillusioned by university projects. Apart from the Water Research Commission project, the Theological Department had asked him if they could undertake a staff survey on his farm. Daily visits were made and work almost came to a standstill while his staff was interviewed. Apart from wasting a lot of man hours, his staff became confused with different beliefs. After 2 weeks he asked them to terminate the project. He said at this stage he probably would not accept any more university projects.

Mr M.A. (Giel) Jansen, Doringkraal, Pietersburg

1. Mr Jansen follows a maize/wheat rotation under his centre pivot irrigation system. The farmer maintained he had derived much benefit from the project. The soil on his farm is very gravelly, affording very high drainage and leaching properties. By making regular use of tensiometers and the class A-pan evaporation data, he was able to schedule the irrigation to suit the soil type. He applied this principle to all his lands which have basically the same soil structure. Instead of applying say 30 mm once a week he split this into 3 light irrigations of 10 - 12 mm depending on prevailing conditions. In this way he was able to prevent crop stress and to eliminate excess leaching.

   With regard to crop yields, he stated that he increased his maize yield from 4 $t.ha^{-1}$ to 5 $t.ha^{-1}$ with his best yield being 5,7 $t.ha^{-1}$. He maintained this was a good yield considering the conditions. His wheat yields also improved.

2. As stated he made regular use of equipment provided. He did not make use of additional equipment as the equipment provided was considered adequate.

3&4. He didn't see much data but was aware of what was going on and that regular weekly readings were taken by the operators and he was satisfied with this aspect.

5. At first there was good liaison between project staff and himself. He mentioned a lady being involved as well. Unfortunately he hardly spoke to anyone over the latter period of the project.

6&7. He would have appreciated more visits from project staff and more discussion regarding the readings etc. He would have liked to see more rain gauges in the field so that he could establish whether his irrigation was correct or not. Discussions on reports based on data collected, scheduling etc. would also have been useful.

8. This farmer would be willing to co-operate again if asked to do so.

Dr. J H Scheepers, Papkuil, PIETERSBURG

1. In reply to the question regarding the project assisting with his understanding of scheduling principles and practices, Prof. Scheepers replied in the affirmative. In the initial stages of the project, there was a very active study group in the area and the project formed part of their activities. Useful practical discussions were held and courses on irrigation were held at P.P. Rust including instruments used in scheduling irrigation. He learned a great deal from these activities. Unfortunately the study group faded away mainly due to the farmers diversifying away from maize and with each farmer planting a different crop, there was not much in common any more.He made complete use of equipment provided to work out his scheduling on the lands tested as well as other lands. In this way he was able to save water by avoiding over-irrigation. Although scheduling was not the only factor governing yield, he believed he gained optimum results and considered his yields to be reasonably good but not exceptional.

   Regarding other benefits, by not over-irrigating his crops made optimal use of fertilizer applied because it was not leached beyond the root zone.

2. He personally made regular use of the equipment provided to assist him in scheduling his irrigation. In addition a flow-meter was fitted to his centre- pivot which enabled him to double check the water applied. He also made use of a soil auger to examine the moisture content of the soil profile.

3. He never saw any data resulting from readings and, therefore, could not comment.

4. He felt that readings were taken on a regular basis and was never inconvenienced by operators coming onto his farm to take readings.

5. There was not nearly sufficient co-operation between university personnel and himself.

6. He would have welcomed regular reports which should have indicated how progress was being made so that necessary adjustments could be made and put into action if and when necessary. Furthermore, regular meetings with other co-operators should have been arranged as they had been through the study group in the beginning. In this way practical ideas could have been exchanged for the benefit of all.

7. As there was no basis on which to form opinions due to lack of information, there was nothing new he could add to the project.

8. If asked to co-operate, he would gladly do so provided any such project was carried out properly. He again stated that after a promising start the project just seemed to *die*.

Jan van der Merwe, Fort Klipdam,Pietersburg

1. Mr van der Merwe operates two centre pivots, 38 ha and 30 ha respectively. In his opening remarks Mr van der Merwe expressed his displeasure about the project in general indicating that if one starts something one should carry it out properly. When it was pointed out that the Project Leader was aware that due to lack of staff, proper liaison could not be maintained, Mr van der Merwe stated that if that was the case the project should have been terminated. In the beginning when the study group was active, he attended lectures and courses which were very instructive about scheduling and how the various instruments worked.

   He stated that scheduling had saved a fair amount of water but that was the only benefit. He was not happy with the crop factor used, and felt that crop factors utilized did not apply to his conditions. When he applied his rule of thumb method of 25 mm per week, he achieved better results than by applying the scheduling method. His wheat yields dropped from 6 to 4 $t.ha^{-1}$ and his maize from 7,5 to 6 $t.ha^{-1}$ after scheduling. There were no other benefits.

2. He made use of the equipment provided on a regular basis, drew graphs etc. but again emphasised that this information was useless if crop factors were incorrect.

3. He was very concerned by the fact that he had made a considerable effort in the beginning but no feedback, reports, etc. were ever produced. He said "*you can't keep on giving with one hand and getting nothing back in the other*".

4. He stated that readings were taken regularly only in the beginning but then were discontinued.

5. There was definitely not sufficient co-operation. There should have been at least a once weekly contact to discuss readings taken and the application, monitor crop response and in general to guide him in his irrigation practice.

6. He stated that he would have liked to see the data collected used in a more practical manner.

7. In his opinion, the manner in which his centre pivots was calibrated was incorrect. When he suggested that the rain gauges should be placed at ground level, he was told that this was the standard method and it could not be altered. He also built a R.C. airstrip which was only used once in the beginning to take aerial photographs.

8. The farmer said he was disillusioned by this project. He had also carried out field experiments for the Department of Agriculture on wheat and here too made a considerable contribution. However, the co-operation from the Department left much to be desired and he merely harvested the entire field. He was sick and tired of this sort of response and did not feel like wasting any more time again.

APPENDIX C

POSTER-PAPER PRESENTED AT THE SOUTHERN AFRICAN IRRIGATION SYMPOSIUM HELD IN DURBAN: 4-6 JUNE 1991

A COMPUTER-BASED PRACTICAL MANAGEMENT PROGRAMME FOR AUTOMATED LINEAR AND CENTRE PIVOT SYSTEMS

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INTRODUCTION

In an overview of practical irrigation scheduling methods, Burgers (1982) recognised the serious lack of scientifically based methods among those generally adopted by farmers. He then proceeded with the development of the so-called *Irrograph*, which was proposed as a practical on-farm irrigation scheduling aid. However, since then it has became evident that, while the Irrograph may work well with a single uniform field of limited size, the normal circumstances on most farms are not that simple and implementation of the *Irrograph* becomes too complicated for even the most progressive farmer.

It appears that most farmers would prefer to schedule irrigation applications to fit in with routine farm activities, often implying a more or less fixed time schedule. At the same time, however, they would like to have the assurance that the water requirements of their crops are met.

A fixed schedule which is well planned according to the average atmospheric evaporative demand for the time of the year; the soil profile water retention characteristics; and the design features of the irrigation system, could work well, provided the correct amounts of water are applied on the scheduled dates.

An accurate estimate of soil water extraction since the previous scheduled application, taking into account any effective rain during the same period, would be essential to such a scheduling procedure. Any such estimate would necessarily involve fairly complicated calculations, which may not be acceptable to most farmers. However, computers are fast becoming an essential facility on farms, and a user-friendly programme which computes the amount of water to be applied on each of the scheduled dates, may well be the answer to the farmer's scheduling problems.

This paper describes a computer programme called **IRRISCHED**, which should, in particular, facilitate the day to day management of automated centre pivot and linear irrigation systems according to a predetermined time schedule which may be adjusted from day to day, depending on the preferences of the farmer. Crop water use estimates are based on daily pan evaporation readings and all calculations are done by the computer. Graphic displays of the day-to-day profile soil water balance, will indicate to the farmer to what limits his schedule may be stretched without jeopardising his crop due excessive soil water extraction.

DESCRIPTION OF THE PROGRAMME IRRISCHED

The main purpose of the programme is to estimate crop evaporation (E) on a continuous basis, provide for effective rain and then display the estimated soil water deficit (SWD) when the irrigation system arrives at the starting point of a section of the field to be irrigated. The farmer may then decide on an application amount (d) equal to, or smaller than the SWD (as in deficit irrigation) or larger than the SWD (in order to meet the leaching requirements of the soil).

The programme also displays the corresponding speed setting for the control panel of the mechanised irrigation system which would allow the chosen d-value to be applied.

Finally, the programme gives a graphic display of the daily march of the profile soil water balance as affected by soil water extraction, application amounts and effective rain. An imaginary horizontal line on the graph, representing the lower limit of available water or Profile Available Water Capacity (PAWC), as described by Vanassche & Laker (1989), would guide the farmer in the application of a system of deficit irrigation.

The different components of the programme which were highlighted above, as well as the underlying principles on which they are based, are described in more detail in the paragraphs that follow.

Master schedule

The farmer compiles his master schedule according to the way in which he wishes to irrigate his crop by considering the field and crop characteristics, design features of the irrigation system, peak crop water requirements during different growth stages and availability of operators on Saturdays, Sundays and public holidays.

The irrigation field should be divided into convenient units or blocks and properly marked. In the case of the linear system on the University of the North experimental farm, the hydrants on the mother pipe line, spaced at intervals of 200 m, divide the field into 11 blocks of 7 ha each.

The *Master Schedule* is now compiled through the following steps:

1. Commence creating a new schedule at the beginning of a new crop season by entering the planting date on the create a new schedule screen (Fig. 1).

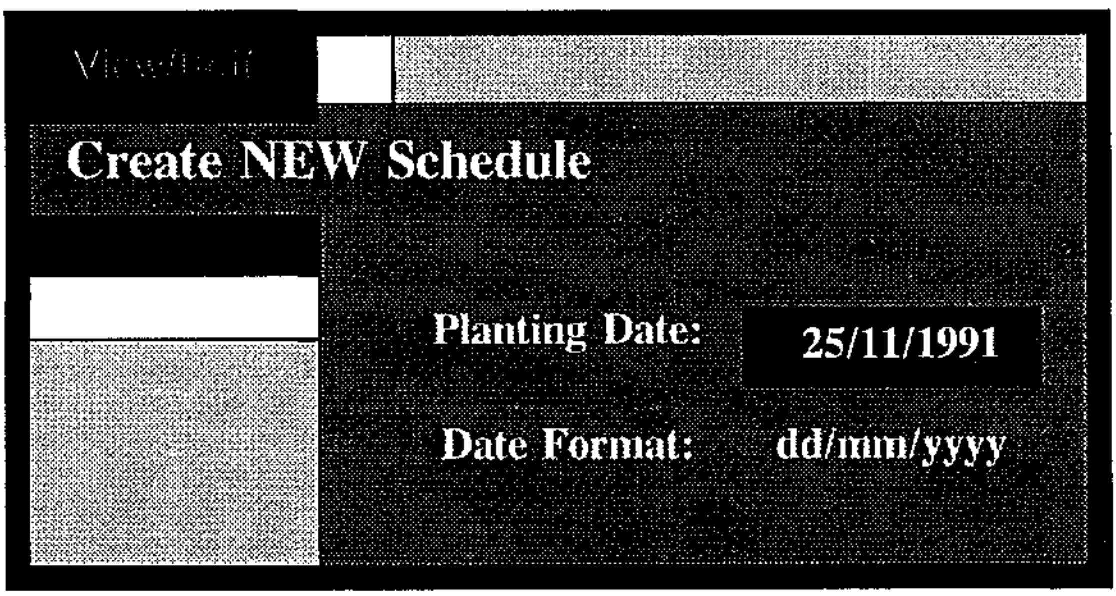

Figure 1 Part of the screen display used to create a new irrigation schedule

2. Enter all relevant information on the *View/Edit* screen regarding: estimated length of crop growing period, number of blocks on the field, minimum application depth (at 100% speed setting), maximum application depth, maximum number of work hours per day, crop planted in each block etc.(Fig. 2).

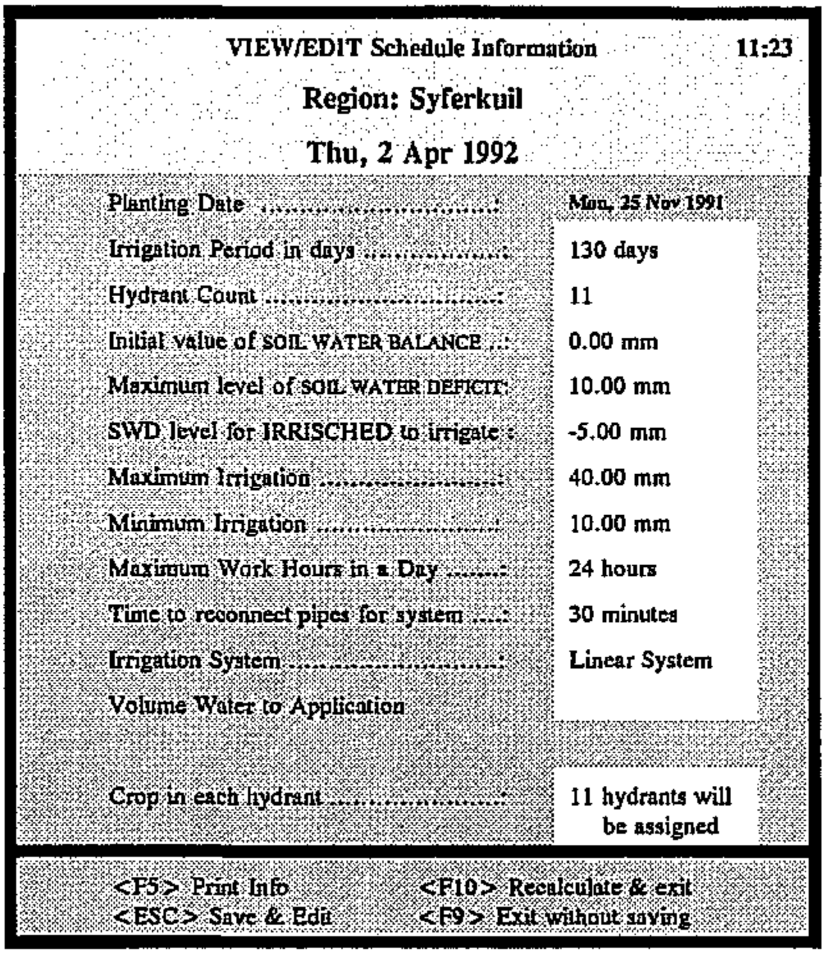

Figure 2 View/Edit screen for setting or editing basic schedule information

3. Having entered all the relevant information, the programme would simulate a time schedule for the whole season, indicating dates of arrival at each of the blocks along the field as well as which blocks should be irrigated on particular dates, how much water to apply and what the speed setting should be. The time schedule is displayed on the *Master Schedule* screen as illustrated in Fig. 3.

4. The farmer may now adjust the scheduled dates to synchronise with other farming activities by using the appropriate function keys as illustrated in Fig. 4.

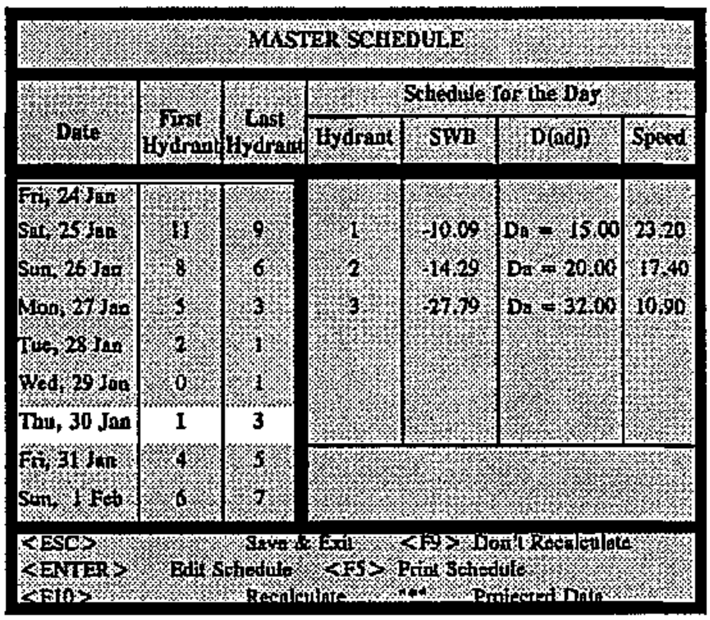

Figure 3 Screen display of Master Schedule as planned by the programme

Date	First Hydrant	Last Hydrant	Schedule for the Day			
			Hydrant	SWB	D(adj)	Speed
			1	-10.09	Da=15.00	23.20
			2	-14.29	Da=20.00	17.40
			3	-27.79	Da=32.00	10.90
			Total Irrigation Time: 20h33			

EDIT SCHEDULE INFO

<ENTER> Edit highlighted hydrant
<F2> Add an extra hydrant for this day
<F3> Move last hydrant to next day
<F5> Print Schedule of the day
<ESC> Return to SCHEDULE

Figure 4 Part of the screen display for adjustments to the Master Schedule using the appropriate function keys

Through these function keys it is possible to add or delete blocks to be irrigated on a particular date. The estimated application amounts will then automatically be adjusted by the programme according to daily crop evaporation or the farmer can adjust them manually on the *Master Schedule edit screen* (Fig 5), in order to satisfy his own circumstances.

TABLE 4 12:33
Master Schedule
Hydrant: 1; Thu, 30 Jan 1992

Day of Season ....:	66
Direction of irrigation system ....:	UP RUN
Accumulated Evaporation ....:	43.50 mm
Rainfall in millimeters ....:	1.30 mm
Soil Water Deficit ....:	-10.09 mm
Final Irrigation application (Da)........:	15.00 mm
Irrigation Duration ....:	4h38
Speed setting of system ....:	23.20%
Adjusted irrigation amount ....:	15.00 mm
Flow meter reading before ....:	56793 m³
Flow meter reading after ....:	57843 m³
Historic/Projected data ....:	Historic Data

<ESC> Update Hydrant & Return <F5> Print Hydrant Info

Figure 5 Sreen display for adjustment of application amounts and entering flow meter readings

Day to day Operation

Simulation of the *Master Schedule* was done with the aid of an *on board data file* (OBDF # 1) which contains long term average E_p-values as illustrated in Table A1 of the Addendum. The *Master Schedule* thus displays only projected dates and projected application depths while no rainfall has been considered. All projected data is indicated by an asterisk (*).

The actual running of the programme with real data comprises the entering of daily pan evaporation readings and daily rainfall data on the *Daily Input Data* screen (Fig. 6). The *Master Schedule* for future dates is then adjusted accordingly and the farmer may also effect his own adjustments where necessary. The field information regarding the block numbers to be irrigated on that day and the *speed settings* for each block can then be printed (Fig 7) and sent to the field operator or conveyed to him/her by two-way radio.

TABLE 1 Daily Input Data 12:21

DATE: Sat, 26 Jan 1991

Date	A-Pan Readings		Evaporation $E_{(p)}$	Precipitation	
	Before Reg	After Reg		RAIN	Hydr
Sat, 25 Jan	71	71	10.50	0.00	1
Sun, 26 Jan	81	81	5.00	0.00	1
Mon, 27 Jan	98	50	8.50	0.00	1
Tue, 28 Jan	69	69	9.50	0.00	1
Wed, 29 Jan	89	50	10.00	0.00	1
Thu, 30 Jan	69	50	9.50	1.30	3
Sat, 1 Feb	0	0	7.00*	0.00	4
Sun, 2 Feb	0	0	7.00*	0.00	4

<ESC> Recalculate & Exit <F2> "*" ON/OFF
<F4> Graph <F10> Save & Exit
"*" Projected Data <F5> Print

Figure 6 Screen display for entering daily input data such as A-pan readings and rainfall

TODAY'S IRRIGATION SCHEDULE

TODAY'S DATE: THURSDAY, 30 JANUARY 1992

START-UP OF FLOW METER READING:		..................m³
HYDRANT NO 1:	APPLICATION:	15.00 mm
	SPEED SETTING:	23.20%
	TIME:	4h23
	Flow meter reading after irrigation:	..............m³
HYDRANT NO 2:	APPLICATION:	20.00 mm
	SPEED SETTING:	17.40%
	TIME:	5h50
	Flow meter reading after irrigation:	..............m³
HYDRANT NO 3:	APPLICATION:	32.00 mm
	SPEED SETTING:	10.90%
	TIME:	9h20
	Flow meter reading after irrigation:	..............m³

Figure 7 Example of a print-out of an application schedule for a particular day

Daily crop evaporation (E_t)

Estimation of daily crop evaporation (E_t) is based on pan evaporation (E_p) and daily crop factors (F_{day}):

$$E = F_{day} \cdot E_p \quad \text{...} [1]$$

The daily crop factor (F_{day}) is a function of crop growth stage and the moisture condition of the soil surface. As indicated by Burgers (1983), the so called *F-curve* of a particular crop (square markers in Fig. 8) actually represents the average values of individual daily crop factor curves for each irrigation cycle throughout the growing season (Fig. 8, curves A1 to A14).

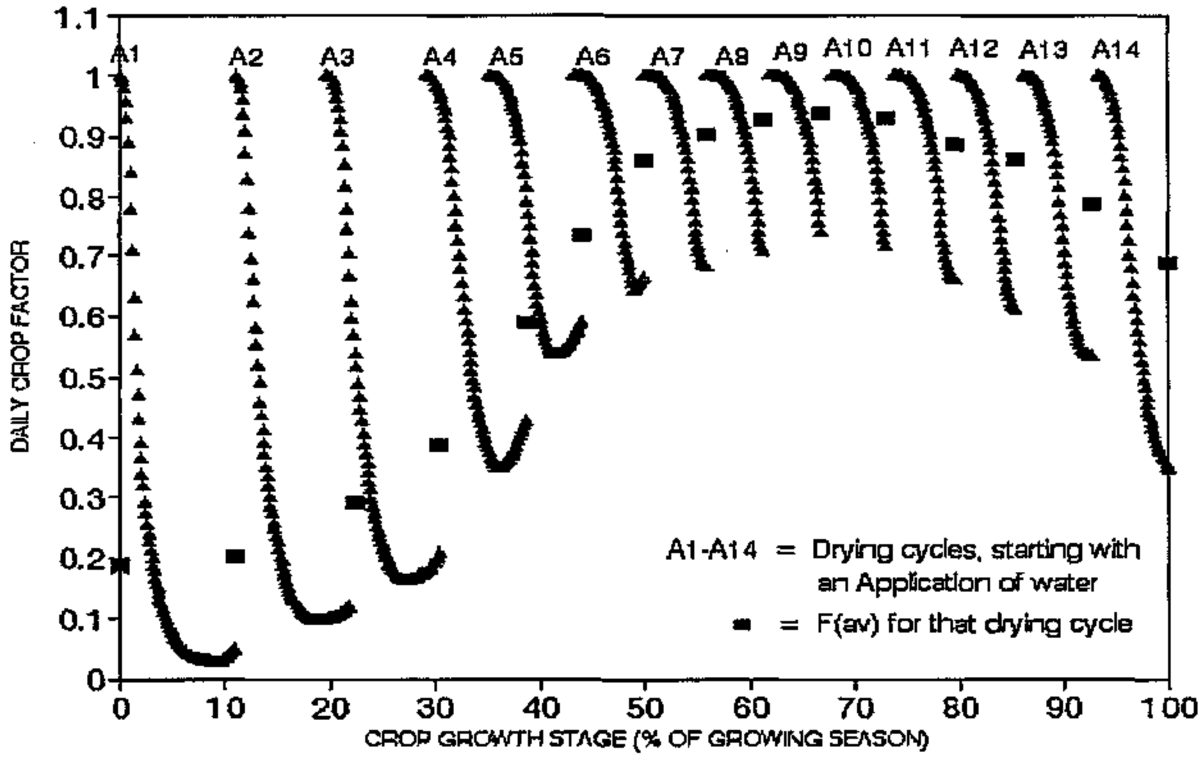

Figure 8 Simulated daily as well as average crop factors for individual irrigation cycles throughout the growing season of a typical annual crop

The average value (F_{av}) of each individual F_{day}-curve depends on the growth stage of the crop, while each F_{day}-value within the F_{day}-curve depends on the wetness of the soil surface which in turn depends on the time lapse and average atmospheric evaporative demand (AED) conditions since the previous water application. For the purposes of this programme the cumulative pan evaporation (ΣE_p) since the previous irrigation or rain shower was used as an indication of both the time lapse and average AED.

$E_{p(av)}$ is a function of the week of the year. After having selected the week number according to the date, the corresponding $E_{p(av)}$ must then be imported from Table A1 into Screen Table 1 (Fig 6) for calculated projections of crop evaporation as well as into *Screen Table 4* (Fig 3) for the calculation of projected or estimated application depths (d_{est}).

To carry out the calculation for a particular day (the i^{th} day) in the equation:

$$E_i = F_{dayi} \cdot E_{pi} \quad \text{...[2]}$$

the programme would first identify the growth stage according to the number of days after planting and select the corresponding F_{av} - value from the **OBDF # 2**, as in Table A2 of the Addendum, which represents the actual values for the F_{av} - curve of Fig.7 curve B. The selected F_{av} - value would now allow the programme to select the corresponding column in **OBDF # 3** (Table A3 of the Addendum) which represents the actual values for the simulated F_{day} -curves in Fig. 7 (curves A1-A14). The F_{day} - value for the day in question can now be selected by comparing the actual ΣE_{pi} on that day with a similar value in column 1 of OBDF # 3 and selecting the corresponding F_{day} - value.

Example

For **January 29** which was day **66** after planting or when **51%** of the growth period of the soyabean crop has lapsed, when **10 mm** evaporated during the previous 24 hours, and when **43,5 mm** evaporation has accumulated since the previous irrigation, the following procedure will be followed:

(i) From **OBDF # 2** the F_{av} - value of **0,72** is identified as being the current F_{av} when **51%** of the crop's growth stage has lapsed

(ii) From **OBDF # 3** an F_{day} - value of **0,6632** corresponds with the ΣE_p - value of **44 mm**, in the column under $\mathbf{F_{av}=0,72}$

(iii) Crop evaporation for **day 65** is now calculated from:

$$E_{65} = 0,6632 \cdot 10,0$$
$$= \mathbf{6,63\ mm}$$

Soil water balance (SWB)

When the soil profile is at *field capacity the SWB* is defined as *0,0 mm*. As soon as the soil water content drops to below *field capacity* due to crop evaporation, a soil water deficit (SWD) develops and the SWB becomes negative. When the initial SWB is known through intensive monitoring, it should be entered on the *View/Edit screen*. Otherwise a default value of 0,0 mm is assumed by the programme, because the soil is usually brought to *field capacity* before or soon after planting.

SWB is calculated by subtracting daily crop evaporation from the previous day's total and adding any irrigation applications or effective rain which occurred during the day in question. In the *example* illustrated above, **day 65** started with a soil water deficit of **40,46 mm** and after subtracting the calculated crop evaporation for the day **(6,63 mm)**, ended the day with a soil water deficit of **47,09 mm**. The daily march of the SWB throughout the growing season as calculated for the Block served by Hydrant # 1, is depicted in the screen display illustrated in Fig. 9.

Since field capacity was taken as zero SWB, a negative value in Fig 9 would indicate a soil water deficit (SWD), while a positive SWB in Fig 9, represents an indication of some excess water (above *field capacity*) occurring in the profile, as is sometimes experienced immediately after an irrigation application or rain shower. For the Syferkuil soils, provision was made for a maximum of 10 mm which could be accommodated in the soil profile in such an event. This amount would vary according to soil texture, depth and sub-soil permeability. Consequently an option is provided in the *View/Edit screen* where this value could be entered when creating or editing the *Master schedule*.

It should be noted that Block # 1, as well as Block # 11, are at the end of the irrigation field, and may thus be irrigated on the same or consecutive days during the **UP** - and **DOWN** - **Run** of the Linear system. In Fig 10 the situation for Block # 6, served by Hydrant # 6 which is situated in the middle of the field, is illustrated.

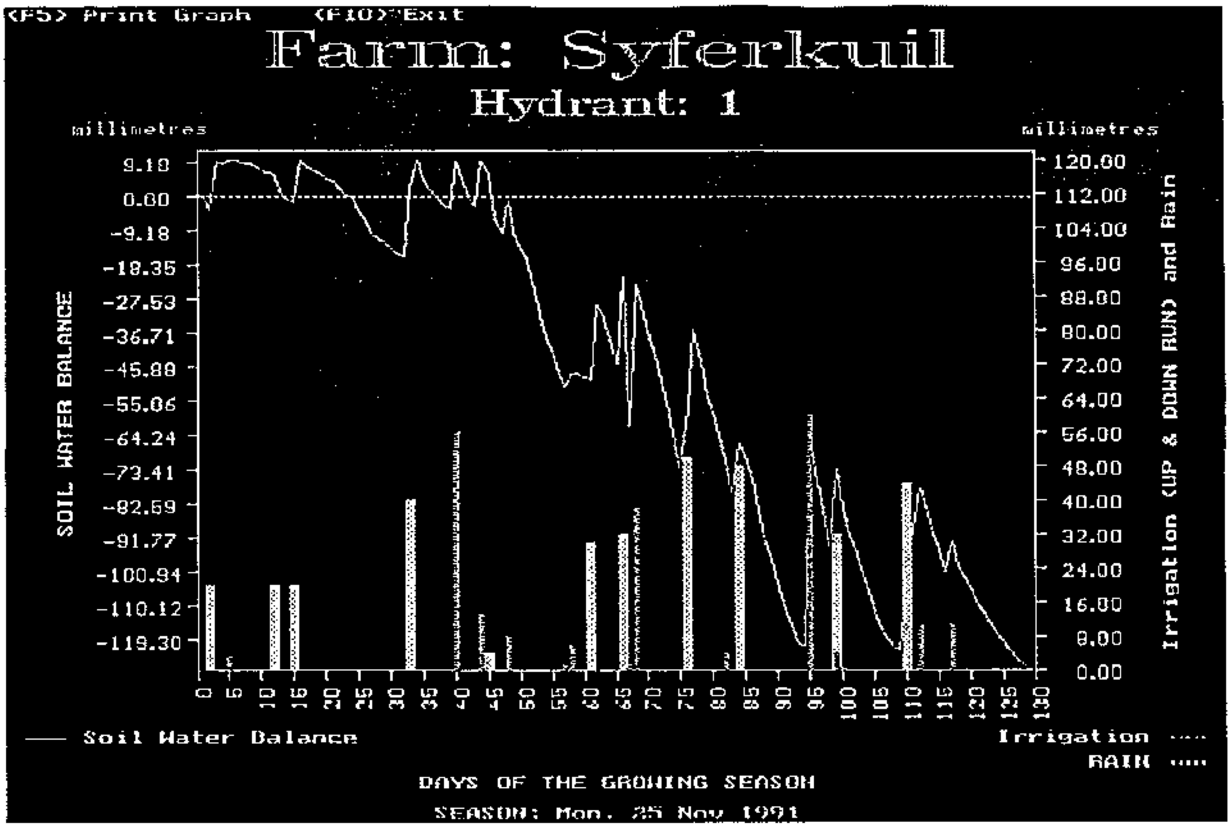

Figure 9 Soil water balance, irrigation applications and rainfall record for Block # 1

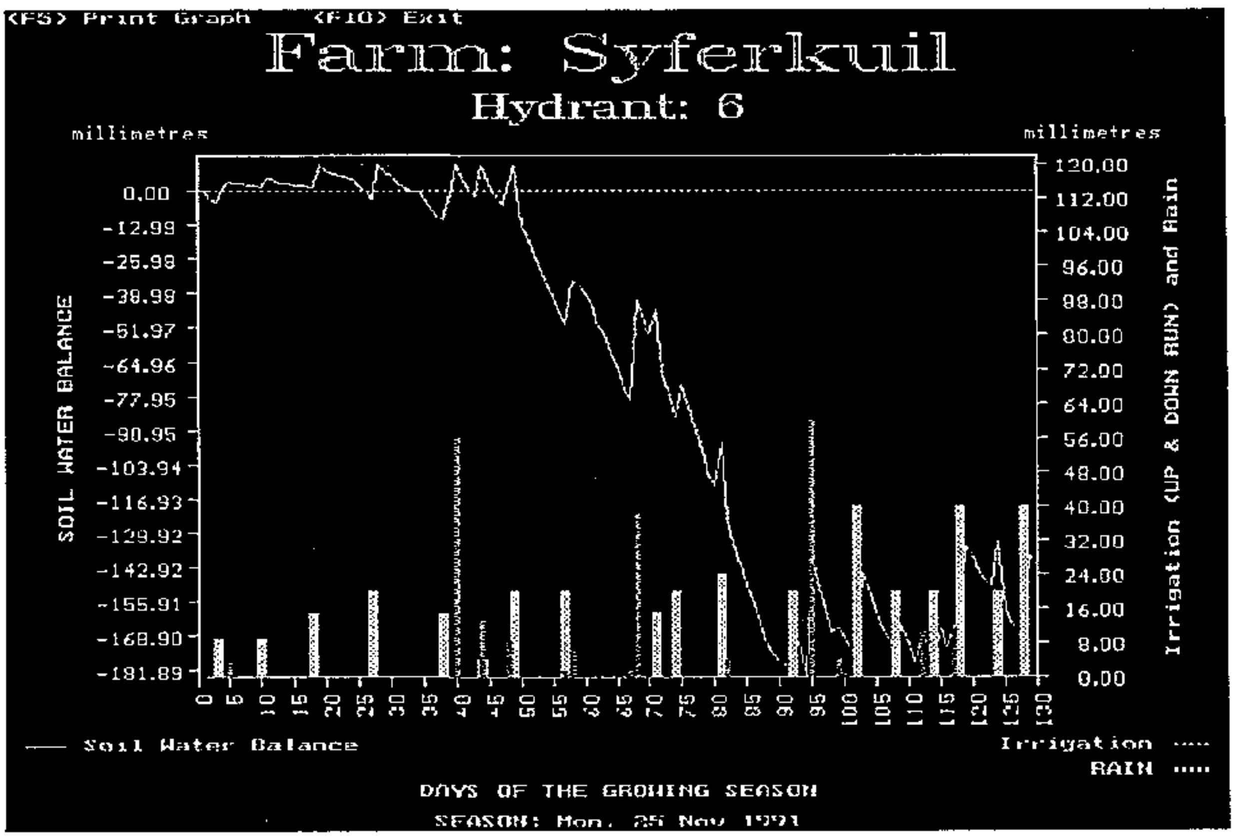

Figure 10 Soil water balance, irrigation applications and rainfall record for Block # 6

Computed SWB values depicted in Figures 9 and 10 ended the season with soil water deficits of 63 mm and 113 mm respectively, which correspond reasonably well with actual measurements of the profile water content which revealed a progressive decline in SWB, ending the growing season with soil water deficits of between 53 mm and 127 mm at different blocks along the field.

Speed Setting (SS)

OBDF # 4 (see Fig 4A of the Addendum) contains possible application amounts (d - values) of up to 50 mm with corresponding speed settings and travelling times (TT) to cover the 200 m distance between two hydrants. However, both SS and TT can also be calculated from:

$$SS = \frac{d_{100} \cdot 100}{d} \qquad \text{[3]}$$

and

$$TT = \frac{T_{100} \cdot d}{d_{100}} \qquad \text{[4]}$$

Where d = intended application amount;

d_{100} = application at 100% SS and

T_{100} = travelling time between two hydrants at 100% SS.

In a future version of Irrisched, these equations may be used to calculate SS and TT, instead of the OBDF # 4.

DISCUSSION

The Irrisched programme is now in its second season of testing under commercial circumstances on the experimental farm of the University of the North and appears to be working well. The manager of the linear system is a former farmer, Mr J T van As, who has been trying to schedule irrigation applications with a Class A-pan according to the Irrograph of Burgers (1982), for the past five years without a great deal of success. After the introduction of Irrisched, Mr van As listed several important advantages of the new method. These include user friendliness; ease of learning; minimal input data requirements and elimination of the need for record keeping and performing complex calculations. Furthermore, the programme is adaptable to forced deviations from the schedule, during spraying of pesticides and herbicides or application of fertilizers. It copes efficiently with intermittent rain showers and provides a visual display of changes in soil water status as well as a permanent record of historical data for later comparisons and possible explanations.

There seems to be little doubt that Irrisched may facilitate the practical management of irrigation systems. However, the method must still be tested over a wider range of farmers and irrigation systems.

The problems that beset the validity of using A-pan evaporation for computing crop evaporation, as discussed by Maree (1988) and Van Zyl, Maree & de Jager (1989), are acknowledged but the method used to compute E is not contentious and the programme can easily be modified for the introduction of alternative methods and corresponding crop factors as they become available.

The *average crop factors* for soyabeans used in this version of Irrisched are based on the standard F-curve for annual crops of Metelerkamp (1968), which may or may not be the most accurate information currently available. Furthermore, *the daily crop factors* in Table A3 depicted as curves A1 - A13 in Fig. 8, were chosen to logically fit the average values and there are no experimental results available against which their validity can be verified. However, the principle is consistent with publicised results of several researchers, particularly concerning the early growth stages (Jensen, 1969; Meyer, Walker & Green, 1979; Van Zyl, de Jager & Van Rooyen, 1981; Wright, 1981; Wright, 1985) and it remains only to be refined for particular crops grown under specified circumstances, like zero tillage.

Wright(1981) suggested that the effects of surface wetness on the crop coefficient (K_s) may be estimated by:

$$K_s \quad = \quad f_w\,(K_1 - K_{cb})\,[1 - (t/t_d)^{0.5}] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad [5]$$

where K_1 is the maximum crop coefficient usually occurring after rain or irrigation, K_{cb} is a basal crop coefficient, t is the number of days after rain or irrigation, t_d is the usual number of days for the soil surface to dry, and f_w is the relative portion of surface soil surface originally wetted.

It is doubtful whether the same pattern as depicted in Fig. 7 will prevail during the later growth stages, especially when high frequency irrigation is practised. The model may therefore have to be modified as soon as more results become available. However, under conditions of limited soil water, the daily crop factors may well follow the pattern shown in Fig. 7. This view is supported by Wright (1985), citing Jensen, Wright & Pratt (1971) and Jensen (1974) who suggested that K_a (crop coefficient related to available soil water) may be assumed to be proportional to the logarithm of the percentage of remaining available soil water(AM) by:

$$K_a \quad = \quad \ln\,(AM + 1)/\ln 101 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad [6]$$

These, and other, refinements can easily be incorporated into the model, without affecting its simplicity and user-friendliness for the farmer.

It is believed that, should Irrisched be proved to find favour with farmers and researchers in the field, it might provide much needed direction to research programmes concerned with water requirements of crops and methods of irrigation scheduling.

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ADDENDUM

TABLE A1 - ON-BOARD DATA FILE # 1: Long-term average pan Evaporation data $\{E_{p(av)}\}$ for Syferkuil

WEEK nr	$E_{p(av)}$ mm	WEEK nr	$E_{p(av)}$ mm	WEEK nr	$E_{p(av)}$ mm	WEEK nr	$E_{p(av)}$ mm
1	8,0	14	5,0	27	4,0	40	7,5
2	8,0	15	5,0	28	4,0	41	7,5
3	8,0	16	5,0	29	4,0	42	7,5
4	8,0	17	5,0	30	4,0	43	7,5
5	7,5	18	4,5	31	5,0	44	7,8
6	7,5	19	4,5	32	5,0	45	7,8
7	7,5	20	4,5	33	5,0	46	7,8
8	7,5	21	4,5	34	5,0	47	7,8
9	7,0	22	4,0	35	6,0	48	7,8
10	7,0	23	4,0	36	6,0	49	8,0
11	7,0	24	4,0	37	6,0	50	8,0
12	7,0	25	4,0	38	6,0	51	8,0
13	5,0	26	4,0	39	6,0	52	8,0

TABLE A2 - ON-BOARD DATA FILE # 2: Average crop factors for different growth stages of Soyabeans

GROWTH STAGE NUMBER	PERCENTAGE OF GROWTH PERIOD	DAYS AFTER PLANTING	$F_{(av)}$
1	0 - 12	0 - 16	0,16
2	13 - 26	17 - 34	0,25
3	27 - 35	35 - 46	0,35
4	36 - 43	47 - 60	0,45
5	44 - 50	61 - 65	0,57
6	51 - 57	66 - 74	0,72
7	58 - 64	75 - 83	0,80
8	65 - 74	84 - 96	0,85
9	75 - 82	97 - 107	0,84
10	85 - 88	108 - 114	0,75
11	89 - 93	115 - 121	0,66
12	94 - 100	122 - 130	0,54

TABLE A3 - **ON-BOARD DATA FILE # 3: Full range F_{day} - values at various F_{av} - values for various stages within an irrigation cycle in terms of ΣE_p since the previous application**

ΣE_p	F_{day} at F_{av}=0,19	F_{day} at F_{av}=0,29	F_{day} at F_{av}=0,39	F_{day} at F_{av}=0,49	F_{day} at F_{av}=0,59	F_{day} at F_{av}=0,74	F_{day} at F_{av}=0,77	F_{day} at F_{av}=0,80	F_{day} at F_{av}=0,83	F_{day} at F_{av}=0,85	F_{day} at F_{av}=,90
2	0,9990	0.9992	0.9995	0.9996	0.9997	0.9999	0.9999	1.0000	1.0000	1.0000	1.0000
4	0,9800	0.9888	0.9975	0.9980	0.9985	0.9993	0.9995	0.9997	0.9999	1.0000	1.0000
6	0,9300	0.9610	0.9919	0.9939	0.9958	0.9984	0.9988	0.9991	0.9995	0.9999	1.0000
8	0,8400	0.9084	0.9768	0.9836	0.9905	0.9978	0.9982	0.9985	0.9989	0.9995	0.9999
10	0,7100	0.8287	0.9473	0.9647	0.9820	0.9963	0.9968	0.9973	0.9978	0.9988	0.9993
12	0.5700	0.7384	0.9068	0.9386	0.9705	0.9929	0.9937	0.9945	0.9953	0.9973	0.9987
14	0.4700	0.6613	0.8525	0.9030	0.9535	0.9862	0.9880	0.9895	0.9914	0.9944	0.9973
16	0.3900	0.5834	0.7768	0.8536	0.9305	0.9768	0.9800	0.9827	0.9860	0.9900	0.9942
18	0.3382	0.5213	0.7044	0.8028	0.9017	0.9648	0.9698	0.9741	0.9791	0.9841	0.9893
20	0.2900	0.4581	0.6261	0.7460	0.8658	0.9501	0.9573	0.9636	0.9708	0.9768	0.9827
22	0.2561	0.4131	0.5701	0.6972	0.8243	0.9328	0.9416	0.9491	0.9578	0.9658	0.9742
24	0.2272	0.3710	0.5147	0.6457	0.7766	0.9142	0.9246	0.9335	0.9439	0.9539	0.9640
26	0.2000	0.3339	0.4678	0.5976	0.7274	0.8912	0.9039	0.9147	0.9274	0.9394	0.9520
28	0.1776	0.3018	0.4261	0.5525	0.6789	0.8562	0.8741	0.8894	0.9073	0.9203	0.9381
30	0.1574	0.2728	0.3881	0.5112	0.6343	0.8152	0.8389	0.8591	0.8827	0.9017	0.9216
32	0.1400	0.2478	0.3555	0.4753	0.5951	0.7703	0.7992	0.8240	0.8529	0.8779	0.9014
34	0.1243	0.2252	0.3261	0.4425	0.5589	0.7301	0.7611	0.7876	0.8185	0.8495	0.8769
36	0.1101	0.2049	0.2996	0.4127	0.5258	0.6893	0.7215	0.7491	0.7813	0.8123	0.8471
38	0.0975	0.1866	0.2756	0.3857	0.4958	0.6525	0.6850	0.7129	0.7454	0.7764	0.8127
40	0.0863	0.1702	0.2541	0.3615	0.4689	0.6220	0.6531	0.6798	0.7090	0.7400	0.7754
42	0.0765	0.1560	0.2355	0.3405	0.4451	0.5972	0.6279	0.6542	0.6805	0.7115	0.7427
44	0.0681	0.1441	0.2201	0.3222	0.4243	0.5773	0.6080	0.6343	0.6605	0.6875	0.7177
46	0.0610	0.1343	0.2077	0.3072	0.4066	0.5615	0.5935	0.6209	0.6483	0.6683	0.6993
48	0.0551	0.1268	0.1985	0.2952	0.3920	0.5497	0.5844	0.6142	0.6439	0.6639	0.6877
50	0.0503	0.1204	0.1905	0.2853	0.3801	0.5419	0.5795	0.6117	0.6438	0.6638	0.6821
52	0.0462	0.1145	0.1828	0.2763	0.3697	0.5381	0.5773	0.6108	0.6543	0.6643	
54	0.0427	0.1096	0.1766	0.2687	0.3608	0.5377	0.5774	0.6114	0.6453	0.6653	
56	0.0397	0.1055	0.1713	0.2600	0.3500	0.5383	0.5784	0.6127	0.6471		
58	0.0371	0.1017	0.1664	0.2566	0.3502	0.5398	0.5803	0.6150	0.6496		
60	0.0349	0.0993	0.1637	0.2544	0.3511	0.5325	0.5832	0.6181	0.6530		
62	0.0330	0.0976	0.1624	0.2541	0.3534	0.5463	0.5872	0.6222			
64	0.0315	0.0972	0.1629	0.2569	0.3569	0.5509	0.5919	0.6270			
66	0.0302	0.0967	0.1632	0.2592	0.3616	0.5563	0.5974				
68	0.0291	0.0966	0.1642	0.2622	0.3675	0.5625	0.6038				
70	0.0283	0.0971	0.1658	0.2659	0.3746	0.5695	0.6109				
72	0.0276	0.0976	0.1675	0.2700	0.3829	0.5773					
74	0.0271	0.0983	0.1696	0.2748	0.3924	0.5859					
76	0.0266	0.0994	0.1722	0.2802	0.4031						
78	0.0263	0.1008	0.1753	0.2816	0.4150						
80	0.0260	0.1024	0.1788	0.2929	0.4231						
82	0.0279	0.1043	0.1827	0.3012							
84	0.0319	0.1070	0.1882	0.3094							
86	0.0359	0.1102	0.1946								
88	0.0399	0.1134	0.2009								
90	0.0439	0.1166	0.2072								
92	0.0479	0.1198									
94	0.0519	0.1230									
96	0.0559										
98	0.0599										
100	0.0639										

TABLE A4 - **ON-BOARD DATA FILE # 4: Speed Settings (SS) for the control panel of the Linear System, as well as the Travelling Time between hydrants (TT), which would facilitate the application of the required application depth (d)**

d mm	SS %	TT minutes	d mm	SS %	TT minutes
3,5	100.0	61	27	12.9	473
4	87.1	70	28	12.4	490
5	69.7	88	29	12.0	508
6	58.1	105	30	11.6	525
7	49.8	123	31	11.2	243
8	43.6	140	32	10.9	560
9	38.7	158	33	10.6	578
10	34.9	175	34	10.3	595
11	31.7	193	35	10.0	613
12	29.0	210	36	9.7	630
13	26.8	228	37	9.4	648
14	24.9	245	38	9.2	665
15	23.2	263	39	8.9	683
16	21.8	280	40	8.7	700
17	20.5	298	41	8.5	718
18	19.4	315	42	8.3	735
19	18.5	333	43	8.1	753
20	17.4	350	44	7.9	770
21	16.6	368	45	7.7	788
22	15.8	385	46	7.6	805
23	15.2	403	47	7.4	823
24	14.5	420	48	7.3	840
25	13.9	438	48	7.1	858
26	13.4	455	50	7.0	875

The application amount (d) is a function of the speed at which the linear system is travelling because at the appropriate pressure of, say 120 kPa, the pump delivers 240 $m^3.h^{-1}$.

After having calculated and adjusted the d-value, the corresponding speed setting must be selected from OBDF # 4.

After having entered the **STARTING TIME**, the **APPROXIMATE COMPLETION TIME** can then be calculated by taking the **TRAVELLING TIME** from OBDF # 4 into account.

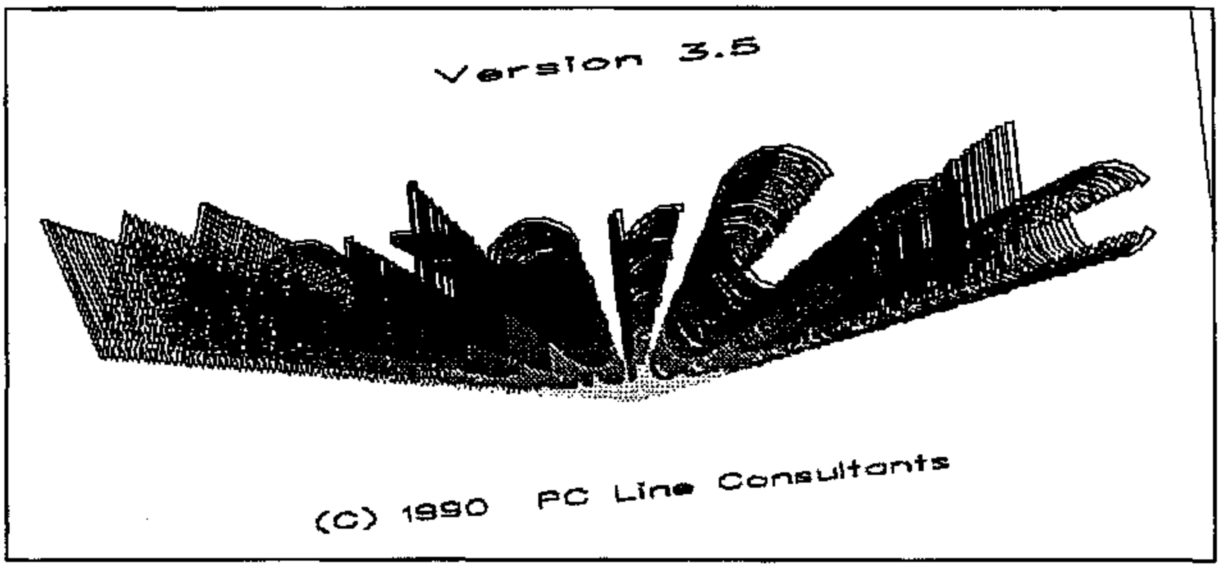
UNIVERSITY OF THE NORTH

WATERCALC USERS' MANUAL

APPENDIX D

WATERCALC

Version 3.5



Any inquiries concerning this package must be directed to PC LINE Consultants at the following address:

P.O. Box 916-1815
Garsfontein
Pretoria
0042

Tel. (012) 998 9628

CONTENTS

Installing

WaterCalc Version 3.5

What do you need?

To use *WaterCalc Version 3.5* you need an **IBM compatible PC** or **AT** computer with a **HERCULES, VGA** or **EGA** graphics card. *WaterCalc* will work on **CGA**, but the resolution of the graphs will not be satisfactory. *WaterCalc* can be run on a computer with only one floppy drive, but the best results are obtainable if you install *WaterCalc* on a hard disk.

Installing WaterCalc on a Harddisk

Unpack the *WaterCalc* disk and insert it in your **A:** drive. At the **A>** prompt type *SETUP Drive:* where Drive: is the disk drive on which you want to install *WaterCalc*. This procedure will create the directories **Drive:\WATER** and **Drive:\WATER\DATA**. It will copy all your *WaterCalc* files into the directory **Drive:\WATER**.

The following files are on your *WaterCalc* disk:

WATER.EXE	*Main program*
WATER3.CFG	*Configuration of WATERCALC*
R.BAT	*Displays the README file*
README	*Extra information on WATERCALC*
SETUP.BAT	*To install WATERCALC on your Harddisk*
***.PRD**	*Printer Definition files*

After installation has been completed, you may return to **DOS** or proceed with *WaterCalc*.

Be sure to make a backup copy of your *WaterCalc* disk.

With the current configuration of *WaterCalc*, all your data files will be saved in the **Drive:\WATER\DATA** directory.

Using WaterCalc with a floppy drive

WaterCalc will run from a floppy drive, but it is advisable to save your data files on a separate floppy disk. No special installation is needed to run *WaterCalc* from a floppy disk. You will have to change the configuration of *WaterCalc* in the program itself. *(See Customizing WaterCalc)*

Customizing

WaterCalc Version 3.5

The default settings

If you have installed *WaterCalc* on a harddisk, you actually don't need to change any system settings on *WaterCalc* right now. The default data directory is **C:\WATER\DATA**. The color combination has been chosen to be used on both color and mono screens. *WaterCalc* will determine by itself whether a **maths co-processor** is present and activate it.

To change system settings

If the title screen of *WaterCalc* is still shown on the monitor, press any key to go to the *Main Menu*.

The screen in *figure 1* will appear. On the bottom line of the screen you will see information on the function keys.

Press **F9** to change the configuration.

Figure 2 is an example of the configuration screen of *WaterCalc 3.5*.

Figure 1

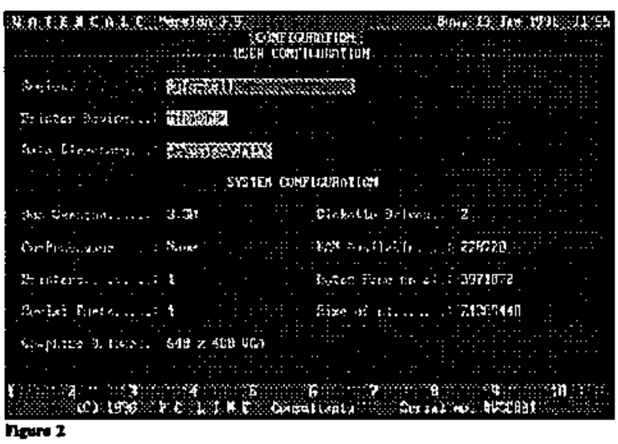


Figure 2

Type the name of the region where the program is used. This information is not used in this version of *WaterCalc 3.5*. It will be used in later versions.

You can choose a printer by moving the highlighted bar to the **printer device option**. By using the **left** and **right arrow keys** you can select a printer.

If you don't know which printer to choose or your printer isn't listed, then you must choose the **STANDARD** printer.

To change the data directory, move the highlight to that option and type the data directory. If it doesn't exist, *WaterCalc* will inform you.

Drive:\directory\ies

If you are using a floppy system, you must change the drive to **A:**.

On the same screen some system information is displayed:

Graphics driver
Usable memory
Presence of a Co-processor
Current Directory
Memory available
Current disk drive
Disk space on data drive
Disk space free on data drive

Saving the configuration

To save this configuration, press **F2**. Be sure that the write-protect tab on your floppy disk is removed if you are using a floppy system. The configuration is saved in the file **WATER3.CFG**. It must be in the same directory as the **WATER.EXE** file.

Functioning

Of WaterCalc Version 3.5

What is the main function of WaterCalc Version 3.5?

A file for a specific recording station is opened. For each day the following data can be entered **Neutron Probe Readings, Tensiometer Readings, Pan Evaporation Readings** and **Rainfall** or **Irrigation Readings**. For the days where there are no data available, *WaterCalc* will ignore those days.

From this data, *WaterCalc* calculates the following:

Profile moisture content in mm for each day
Soil water balance
Soil water extraction for the day

For each station you can compile a report after all the data has been entered for a specific growing season. **Tables, Graphs** and a **Title Page** with all the original data and results can be printed for each station.

The WaterCalc routine in short

The first step is to create a new station. You enter the start of the growing season as well as the end, the name of the farm, the field and position. From these information *WaterCalc* will create a file name for this station.

The data is entered. Then you are ready to print your results.

The chapters following this one will explain in full details how to operate WATERCALC Version 3.5.

The Menu System

WaterCalc consists of a **Main Menu** and three **Submenus** which are displayed on the screen through windows. Each time you enter a different section of *WaterCalc* a window is opened and is closed when you are finished with that section.

MAIN MENU

With the arrow keys you can select your option by moving the highlight to your option.

Press **RETURN** after you have decided where to position your highlight.

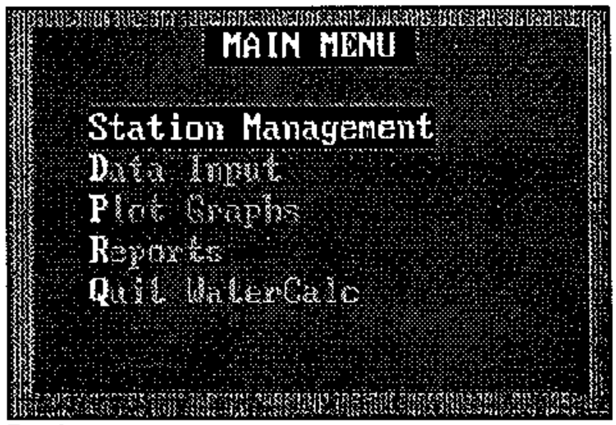


Figure 3

By pressing the first letter of an option, you can also select an option.

If that option has a submenu, then its submenu will be opened. The same procedure to choose an option on a submenu must be used as the one for the **Main Menu**. If you make a mistake or want to return to the **Main Menu** again, choose the option **Return to Main Menu**, or press **ESC**. **ESC** is a very handy key in *WaterCalc*, because it can help you out of almost any trouble.

The **Main Menu** options that have submenus are:

Station Management
Your first choice when you start a new station

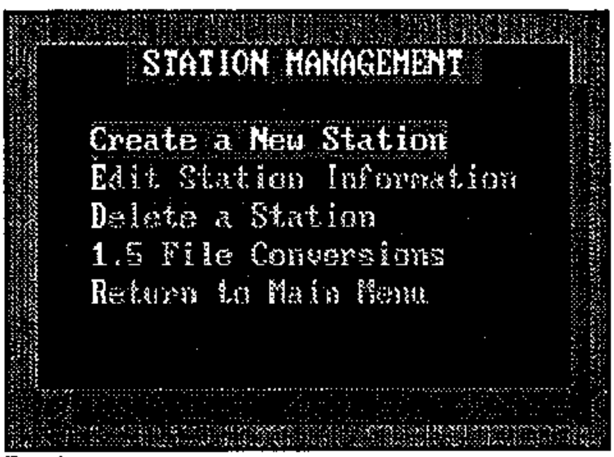


Figure 4

Plot Graphs
Display and Printing of Graphs

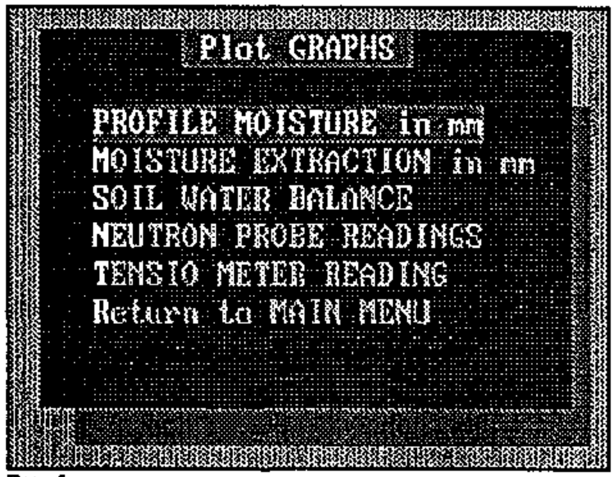


Figure 5

Reports
Printing of Tables and Title Pages

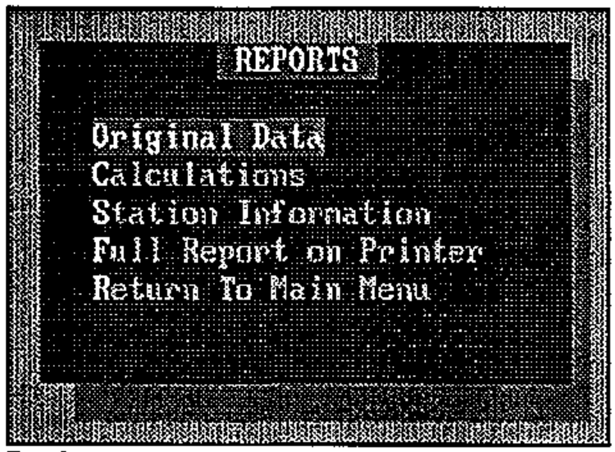


Figure 6

Those without submenus:

Data Input	*Without data WATERCALC will be useless*
Quit WaterCalc	*Return to DOS*

Menu option which operates on the data of a station will not work if no station has been selected. It means that when the block under the main menu *(figure 7)* displays no station selected.

Figure 7

In the following chapters there will be more information on the contents of the submenus.
If you get lost, press F1 to get some help!

Getting Started

With WaterCalc Version 3.5

Create a new Station

Select the option **Station Management** on the **Main Menu** *(figure 3)*. On the **Station Management** menu choose **Create a new Station** *(figure 8)*.

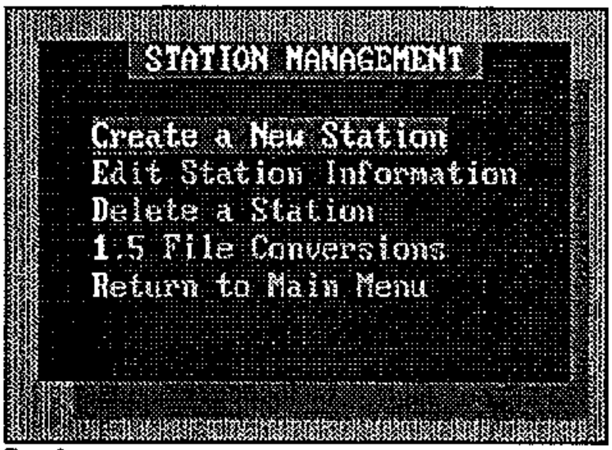


Figure 8

The other options on this menu are to organize your files in a very simple way.

More about them later!

By this time the **Create a new Station** screen will be on you monitor *(figure 9)*.

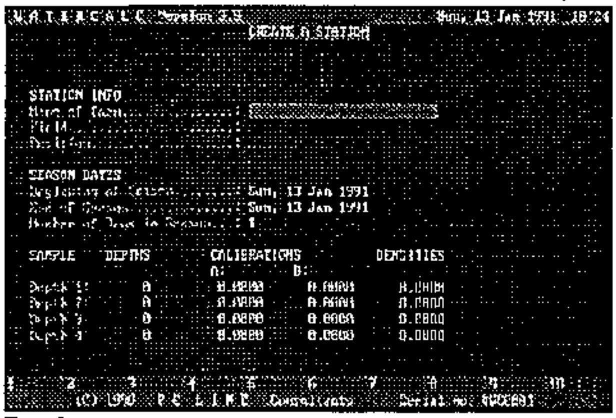


Figure 9

Read carefully through the next few paragraphs, as the initial steps to create a new station are very important to do it correctly the first time.

The farm name

Enter the name of the farm, the field and the position. The first two characters of the name of the farm, the field, the position and the last two digits of the end of the season date are combined to create a name for this station.

Enter the start of the season. The date must be typed in correctly, in the following order: *day/month/year.*

WaterCalc will check the date in any case.

Do the same with the end of the season date. You must press **RETURN** to enter the next field. The days will be calculated automatically. If the **End of season** date is unknown at this stage it can be estimated and edited later.

Soil Depths

Enter FOUR different depths. Please enter them in ascending order. Without this information no calculation will be possible.

Calibrations

For each depth there are different parameters that must be entered to obtain the correct results from the formulas in *WaterCalc*. The calibration parameters are:

A	*Intercept*
B	*Regression Coefficient*
Density	*Bulk Soil Density*

If the values of the parameters cannot be entered at this stage, *WaterCalc* will assume the following standard values: **A = 1.0; B = 12.0; Density = 1.5**

To create this new station on disk, press **F2**. If you get an error message, check if the disk where you are creating this station isn't full, or if you are creating it on a floppy disk, check if the write-protect tab has been removed.

Edit a station

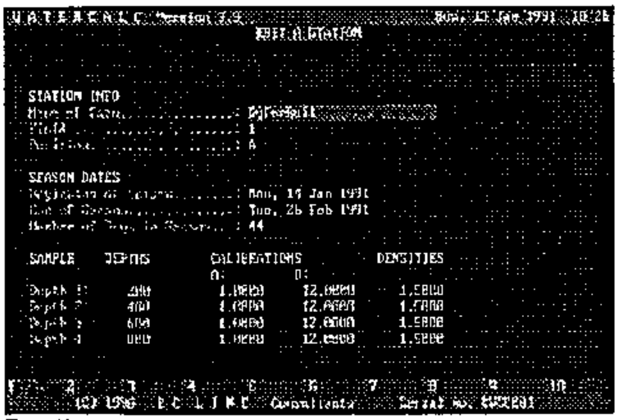


Figure 10

Select **Edit Station Information** on the **Station Management** *(figure 8)* menu. If no station has been selected, press **F3** to select a station. A list window *(figure 11)* will appear. Select the station you want to select, or press **F4** to change the directory. It is very easy to select a station from the disk, if the directory in the system settings exists on the disk.

Move the **Highlight** with the arrow keys to the station you want to select.

Press **RETURN** when you have found your station. If the list is very long, use **PAGE UP** or **PAGE DOWN** to move faster in the list.

This station now becomes your **Selected station.** When you want to enter data, this station will be used to save the data on the disk.

The current information of the station will be displayed *(figure 10)*. Edit the information that you want to change and press **F2** to save the changes. To recalculate the station with the changes, select **Data Input** on the **Main Menu** and save the station.

HINT: First create all your stations, then you can start entering all the data.

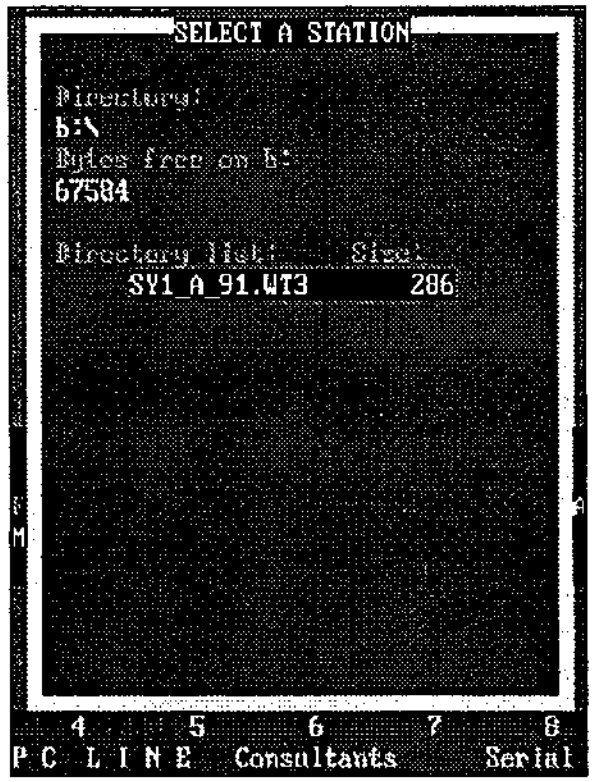


Figure 11

Erase a station

Sometimes you may want to remove a station from disk, especially if it was created with the wrong information and you couldn't correct it under **Edit a station.** The easiest way out is to erase the station from disk.

The erasing of a station from disk works exactly the same as selecting a station. There is but one difference, the station you select will be erased. To make very sure that you aren't making a mistake, *WaterCalc* will ask you if you really want to erase the station. Answer Yes when you are sure and No when you have made a mistake.

Additional information

WaterCalc has no selected station in the beginning of a session. You must select or create a station before you can start using *WaterCalc*. If you choose any of *WaterCalc*'s functions and you still haven't selected a station, the function will refuse to work.

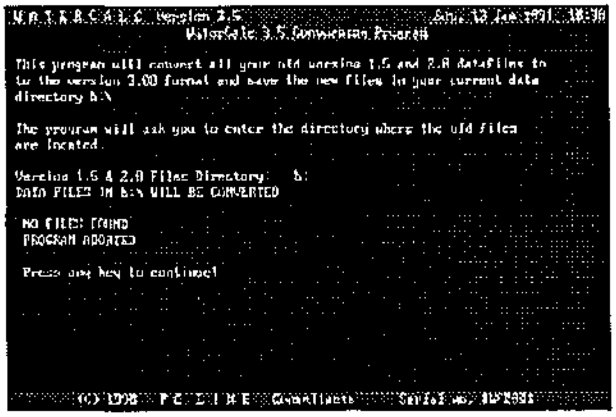
Remember that HELP is always available by pressing F1!

Function keys

The function of the function keys are always displayed at the bottom of the screen, for an example see *figure 12.*

Figure 12

Old Version 1.5 and 2.0 Files



Select **1.5 File Conversions** on the Station **Management Menu.** Use this option only when you want to convert files from the old WaterCalc releases prior to version 3.0.

You will be asked to enter the directory of the old files. If *WaterCalc 3.5* finds any, it will start converting immediately and put the converted files in the current data directory. If some of the parameters of the old files are missing, *WaterCalc 3.5* will automatically enter standard values.

Enter Data

For a Station

The ENTER DATA screen

Choose **Data Input** on the **Main Menu** *(figure 3)*. If you haven't selected a station yet, press **F3** to select a station if none is selected. After you have selected your station, the following information will be displayed *(figure 13)* under the **Main Menu**.

Figure 13

After you have selected the option **Data Input** and selected a station the screen in *figure 14* will be displayed.

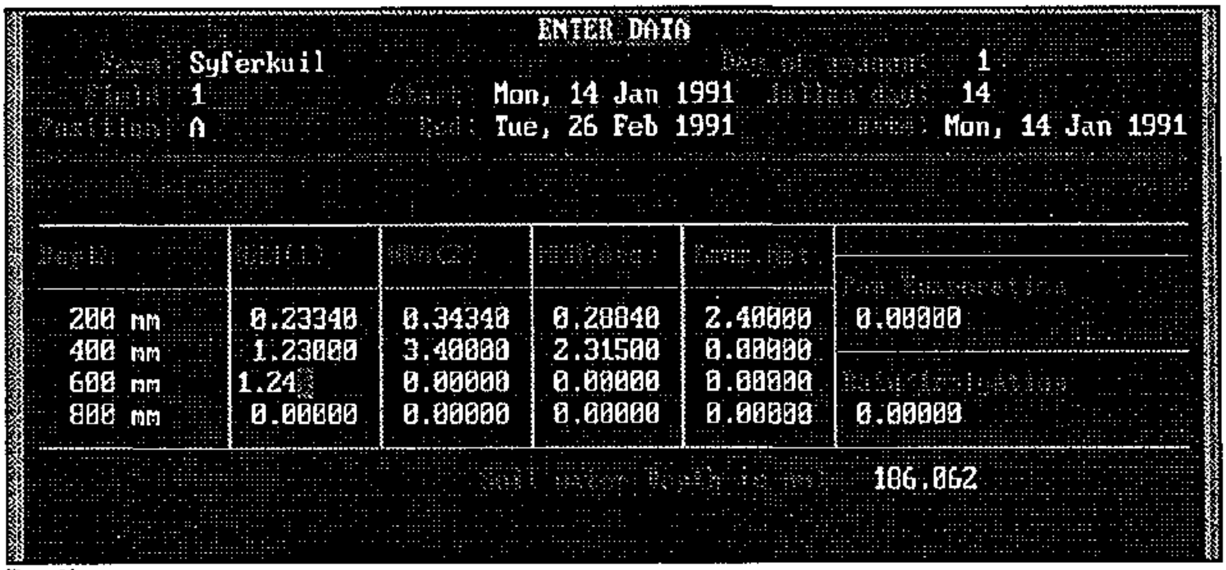


Figure 14

Most of the station information is displayed in the upper part of the screen. An extra piece of information is the Julian Day, meaning the n^{th} day of the year is also displayed.

The first column displays the **Soil Depths**. The next two columns display the two **Neutron Probe Readings**. In the fourth column *WaterCalc* calculates the average of the two readings.

If you have only one reading, leave the third column at 0.000000. *WaterCalc* will duplicate the first reading in that column and calculate the average correctly.

In the fifth column you enter the **Tensio meter Readings**. The last column has only two fields: **Pan Evaporation** and **Rain/Irrigation readings.**

Enter your data

Starting with the first day of the growing season, the first entry that you will make is the **Neutron Probe Reading** of depth 1. Press **RETURN** when you have done that. The cursor will move automatically to the next field.

If you have no data for a specific field entry, just leave it. *WaterCalc* will ignore empty fields and empty days.

Press **PAGE DOWN** to move to the next day and continue your entering of data. If you want to go back to a previous day, press **PAGE UP**.

Continue this process until you have entered all the data for this station. To save the data, press **F2**. *WaterCalc* will calculate the entire worksheet before saving the data. If you want to change some of the initial parameters when you created the station, return to **Edit a Station** and change them. When you save the worksheet with the new parameters *A, B and Density,* the entire worksheet will be recalculated according to the new parameters.

Graphs and Printouts

Displaying Graphs

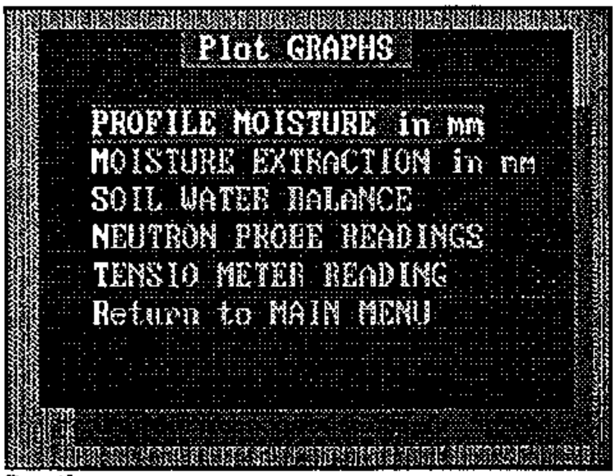
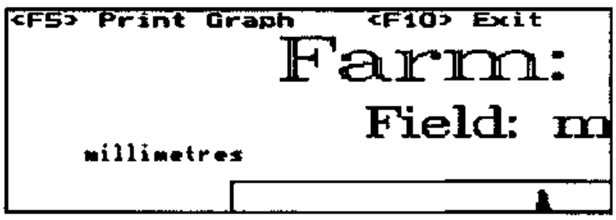


Figure 15

Select the option **Plot Graphs** on the **Main Menu** *(figure 15)*. It is possible to display five different graphs with *WaterCalc*. *Future versions of WATERCALC will be able to have a much larger selection.*

Move the **Highlight** to the graph you want to have a look at and press **RETURN OR** press the first letter.

If you are using a **CGA** graphics adapter, then the graph will look somewhat squeezed. The best graphs can be seen on **HERCULES, EGA** or **VGA** adapters.



To make a printout of a graph, get your printer ready and press **F5**. Press **F10** to return to the **Graph Menu.**

Figures 16-20 are examples of graphs generated by *WaterCalc 3.5.*

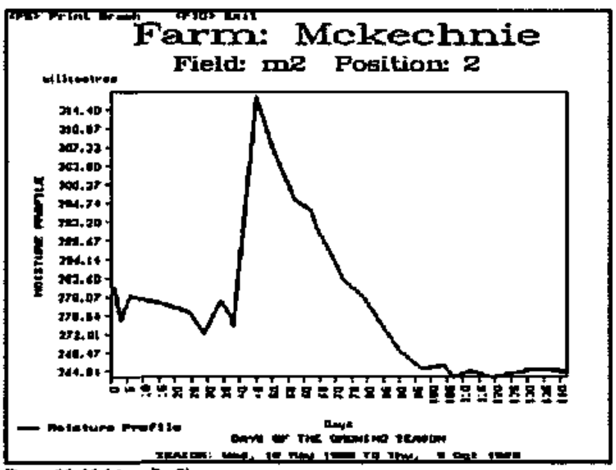


Figure 16: Moisture Profile

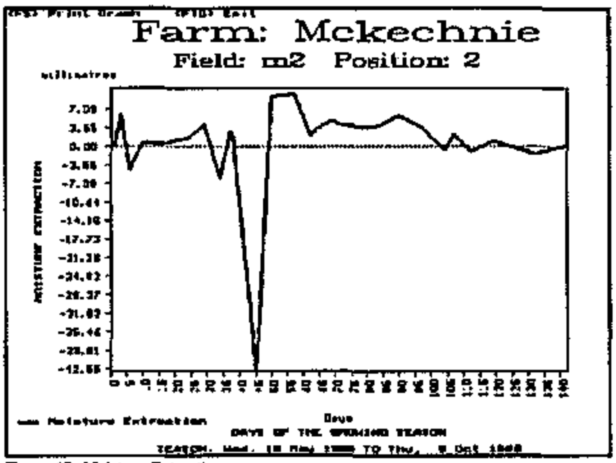


Figure 17: Moisture Extraction

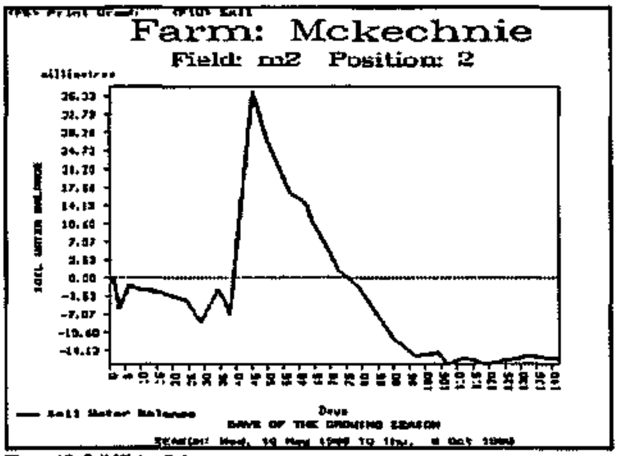


Figure 18: Soil Water Balance

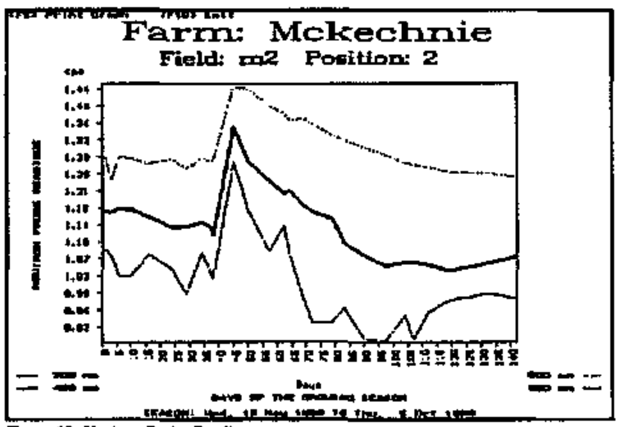


Figure 19: Neutron Probe Readings

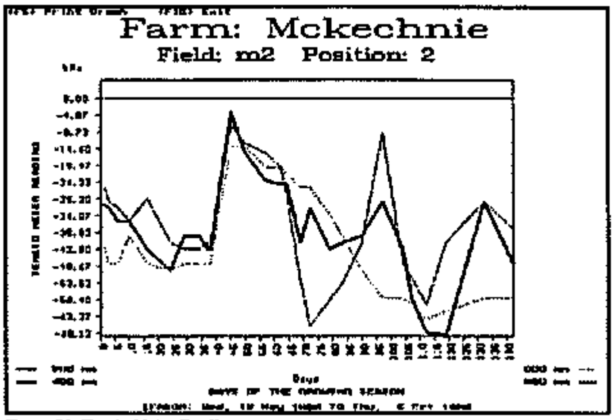


Figure 20: Tensio Meter Readings

Printing of the data

Select the **Reports** option on the **Main Menu**. The **Print Menu** will appear on your screen.

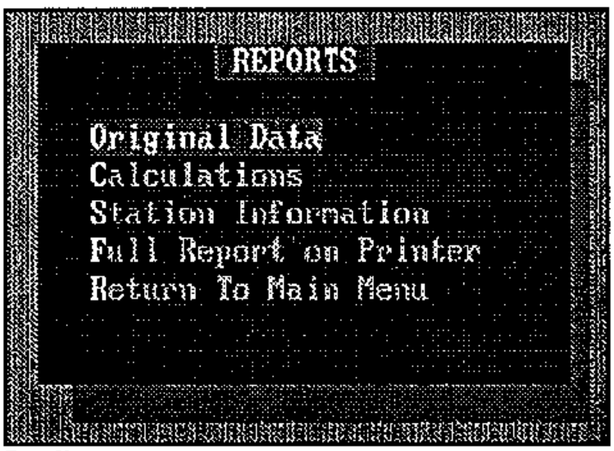


Figure 21

The easiest way to order your printouts neatly, is to print all the **Station Information** pages first.

When you start to print the data of the different stations, you only need to sort the data with each **Station Information** page and combine them.

After you have selected your print option, *WaterCalc* will display *figure 22*, prompting you to get the printer ready. Press **SPACE BAR** to start printing.

Figure 22

To print all the possible printouts of a specific station select **Full Report** on the **Report Menu.** This option will print all the information in the following sequence:

Station Information
Conversions an Calculations
Original Data

You are now ready to enter a new dimension of data processing!

INDEX

UNIVERSITY OF THE NORTH

IRRISCHED USERS' MANUAL

APPENDIX E

IRRISCHED

Version 1.0

This is the first official release of IRRISCHED Version 1.0. This manual belongs to the IRRISCHED Program with serial number #IS0001.

CONTENTS

Preface

The development of IRRISCHED commenced in July 1990. IRRISCHED was developed subsequent to the successful launching of another program, WaterCalc, which is used to process field data obtained with Neutron Moisture Probe. Both programs were developed in conjunction with the Dept Plant Production at the University of the North as part of a research project sponsored by the Water Research Commission.

IRRISCHED is an irrigation management program which will assist farmers to improve their irrigation practices. A further benefit will be minimizing the cost of water and electricity.

A farmer will know when and how much to irrigate. If a farmer wants to adjust the predicted schedule of IRRISCHED, he will be able to do so, as IRRISCHED has the versatility to adjust to a farmer's needs. Though, when IRRISCHED calculates that circumstances are critical, it will advise the farmer to stick to the schedule.

As IRRISCHED's calculations and functions are based on regional research, it can only be used in regions where the necessary research has been done. The importance of this research will be discussed in the chapter on the On-board data files.

To use IRRISCHED successfully, it is important to read and understand this manual thoroughly. If any questions may arise, then the following persons can be contacted:

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Installing Irrisched Version 1.0

This chapter explains which equipment will be needed to use IRRISCHED and how to install the master program. Be sure to understand the contents of this chapter, as it is of critical importance that all the procedures are followed correctly to guarantee reliable performance of IRRISCHED.

Equipment

IRRISCHED can be used on any IBM-Compatible computer. This means it will run on an 8088, 80286, 80386 or an 80486 type computer. The computer must use a hard disk as a storage device with at least 1 mega byte of storage space left on the hard disk.

IRRISCHED has been designed to run on the following display adapters, i.e. the type of monitor or screen your computer has:

CGA
Hercules
EGA
VGA
IBM 3270 PC
and Compatibles

IRRISCHED supports a wide range of printers which include:

EPSON
IBM
SEIKOSHA
GEMINI
HP LaserJet
and Compatibles

For best performance use a computer running at, at least 16 MHz with a VGA-type monitor adapter.

Master Diskettes

The IRRISCHED package consists of two diskettes, the program diskette and the On-Board Data Files diskette. As there is a special On-Board Data File diskette for every region, please check that you have received the correct diskette. The region's name has been printed on the label of the diskette.

On the program diskette you will find the following files:

I25.BAT
Runs IRRISCHED in 25 line mode

I43_50.BAT
Runs IRRISCHED in 43/50 line mode if screen type allows it.

IRRISCH.EXE
Main program of IRRISCHED

IRRISCH.CFG
Configuration file of IRRISCHED

R.BAT
Batch file to display README file

README
Contains latest information on IRRISCHED

INSTALL.EXE
Program to install IRRISCHED on a hard disk

Remember that you cannot use IRRISCHED on a floppy drive system. There isn't enough disk space on floppy diskettes, except when you use 1.2 Mb or 1.44 Mb floppy diskettes.

IRRISCHED has been copy protected in every possible way. It will however allow you to make one archival copy of the master diskettes. Please be sure to store your diskettes in a safe place. If your diskettes are damaged, you must return the master diskettes and the archival copy to your dealer who will replace them for you. Do not use illegal copies of IRRISCHED. They will not work properly and you may loose all your data if you activate the protection program hidden in IRRISCHED.

Installing IRRISCHED Version 1.0

Boot your computer with DOS 3.2 or higher. At the **A:\>** prompt, type **INSTALL**. Follow the instructions of the installation program. It will ask you where to install IRRISCHED. It will prompt you to insert the On-Board Data Files diskette. As default, IRRISCHED will be installed in the following manner:

C:\IRRISCH	- *Program files*
C:\IRRISCH\OBDF	- *On-Board Data Files*
C:\IRRISCH\DATA	- *Schedule Files*

After the installation has been completed, you are ready to use IRRISCHED.

Running IRRISCHED

IRRISCHED can be used in three different screen modes. On Monochrome, CGA and compatibles there is only one mode available, namely the 25 line screen mode. On EGA monitors, you can use IRRISCHED in either the 25 line mode or the 43 line mode. On VGA monitors, you can use IRRISCHED in either the 25 line mode or the 50 line mode.

To use IRRISCHED in the 25 line mode, type **I25** at the DOS prompt in the **C:\IRRISCH** directory.

To use IRRISCHED in the 43 or 50 line mode, type **I43_50** at the dos prompt in the **C:\IRRISCH** directory.

It is advisable to use the 43 or 50 line mode only when you have to enter data for the On-Board Data Files, as you will be able to see a larger window of the data. For the normal use of IRRISCHED, it is recommended that you use the 25 line mode, because the text on the screen will be more readable.

If you followed these instructions carefully, you will now be ready to begin studying the functioning of IRRISCHED.

Customizing IRRISCHED Version 1.0

This chapter explains how to configure IRRISCHED for your own particular needs.

Before you learn how to customize IRRISCHED, you will be introduced to the IRRISCHED menu system.

The Menu System

Begin IRRISCHED by typing **I25** or **I43_50** at the DOS prompt. IRRISCHED will at first show a title screen *(fig. 1)*. You don't need to wait for the title display to finish before you can enter the IRRISCHED program, press any key to skip the title display. The next screen is the copyright notice *(fig. 2)*. Press any key to continue.

Figure 1

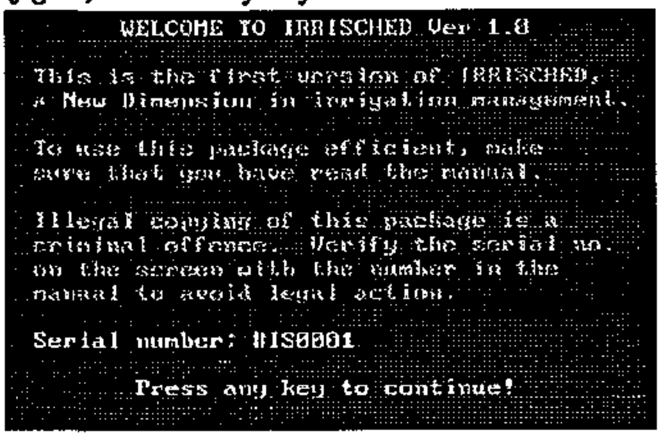


Figure 2

IRRISCHED will then ask you to verify today's date. Please check if the date is correct. If it is not correct, type the correct date. If the date is correct, press **ENTER**. *(fig. 3)*

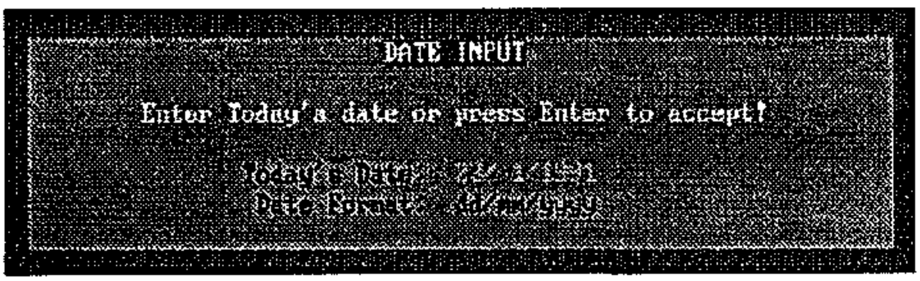


Figure 3

The next screen is the **Main Menu** of IRRISCHED *(fig. 4)*. There are seven menu options, each of which will be discussed in a different chapter. The last menu option enables you to quit IRRISCHED. A menu option with an arrow head indicates that this particular menu option has a sub menu.

Select a menu option by moving the highlighted bar to the menu option you want to select or press the letter highlighted in the menu option. To move the highlighted bar, use the *up* and *down* arrow keys on the keyboard. If the highlighted option has a sub menu, the sub menu will be displayed when **ENTER** is pressed (fig. 5).

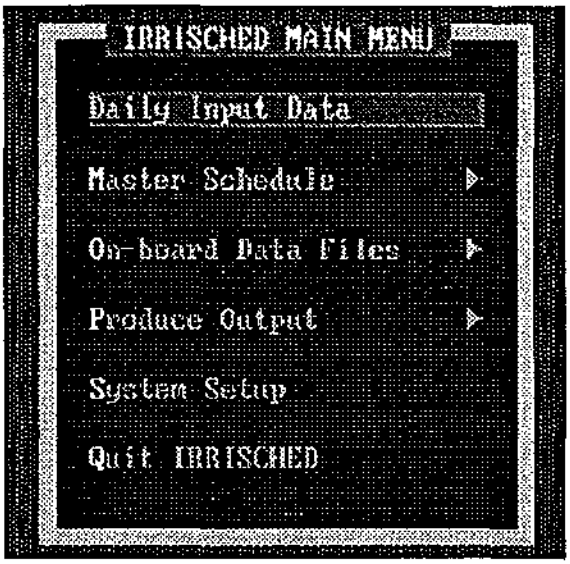


Figure 4

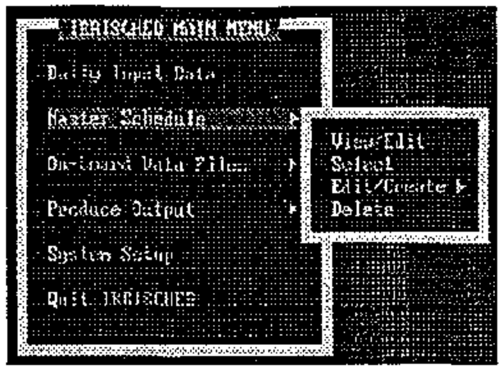


Figure 5

Press **ENTER** to select a menu option. To select a sub menu, you can follow the same procedure, or you can press the right arrow key to move to the sub menu. To return to a previous menu, you can press **ESC** or you can press the left arrow key to return.

In most cases, pressing the **ESC** key will return you to the previous menu or screen. If you have entered data, it will not be lost, because IRRISCHED will always save the data automatically, unless otherwise instructed.

System Setup

Select **System Setup** on the main menu. This menu has no sub menu, so IRRISCHED will immediately enter this function. The screen in *fig. 6* will be displayed. This screen is divided into two different sections. The top section is the **USER CONFIGURATION.** This information can be changed by you, the user of the IRRISCHED program. The bottom section of the screen is the **SYSTEM CONFIGURATION.** This information cannot be changed and displays only the current status of your computer.

There are six different fields of information in the **USER CONFIGURATION** which you can change. Use the up and down arrow keys to move the highlighted bar between the different fields.

See Figure 6 on the next page.

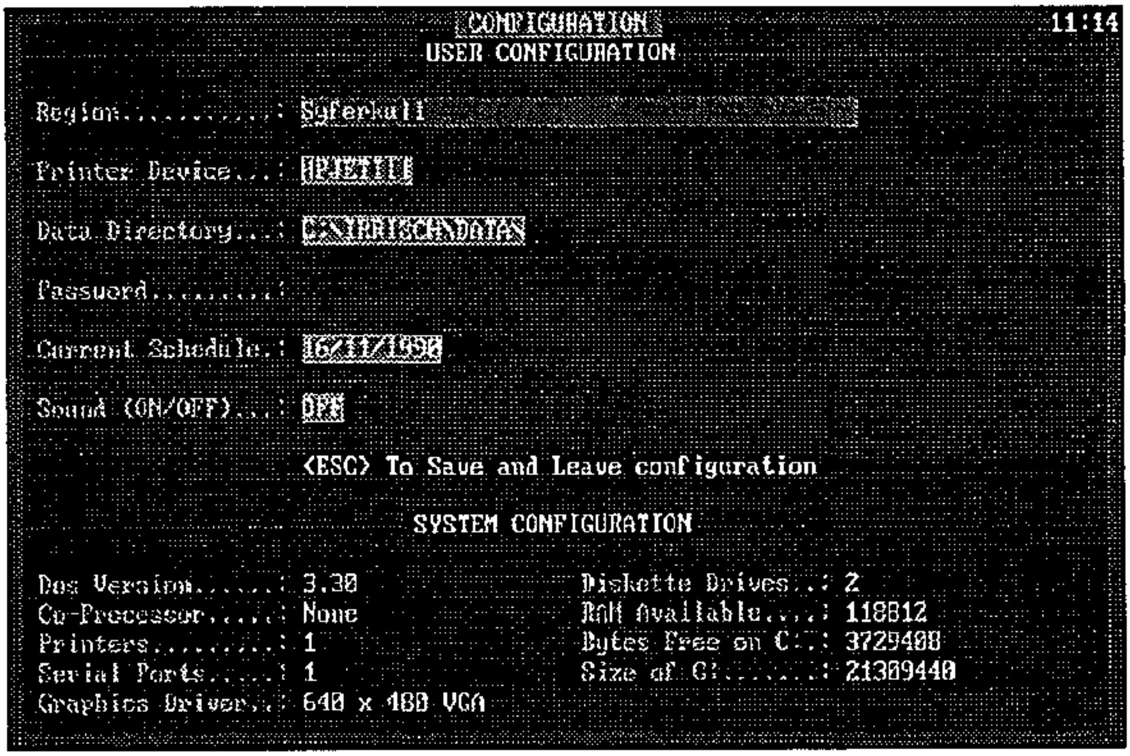


Figure 6

The following is an explanation of the different fields that can be changed.

Region

The region is the name of the region in the country where your irrigation system is situated. Type the name of the region using the keyboard. If you make a mistake, use the text editing keys **BACK SPACE, INSERT** or **DELETE** to correct it. The editing of data you enter from the keyboard is valid in every situation where you have to enter data for the IRRISCHED program. Pressing **ENTER** will move you to the next field.

Printer Device

This field lets you specify the printer which is attached to your computer. Use the left and right arrow keys to switch between the different printer drivers which are available. If your printer is not available, select the **STANDARD** printer. Press **ENTER** to move to the next field.

Data Directory

The information for this field has already been specified during the installation of IRRISCHED. If you want to use a different data directory, type the name of the directory where you want to create or store your data. Make sure the directory exists, otherwise IRRISCHED will not accept it. Press **ENTER** to move to the next field.

Password

If you specify a password, only individuals who are familiar with the password will be able to change this configuration and have access to the On-Board Data Files. Press **ENTER** to move to the next field.

Current Schedule

This information indicates the planting date of the current schedule which will be used during this growing season. This schedule doesn't have to be created, IRRISCHED only uses this information to know which files will be used during this scheduling program. Press **ENTER** to move to the next field.

Sound (ON/OFF)

Use the left and right arrow keys to switch the sound which IRRISCHED generates during its operations to on or off.

When you have finished this input procedure, IRRISCHED is ready for use according to your special configuration. If you entered a password, be sure not to forget or misplace it, otherwise you won't be able to use some of the functions on IRRISCHED. Press **ESC** to save this configuration and to return to the main menu.

The next few paragraphs explain the information shown in the **SYSTEM CONFIGURATION** section.

Dos Version

This is the current version of DOS you are using on your computer. IRRISCHED will work properly with versions 3.2, 3.21, 3.3, 4.0, 4.1 and 5.0.

Co-processor

This indicates whether a 8087, 80287 or 80387 microprocessor has been installed. Such a processor will speed up all the mathematical functions of IRRISCHED.

Printers

Displays the number of printers attached to your computer. IRRISCHED will always use the printer connected to the **LPT1:** printer port.

Serial Ports

Displays the number of serial interfaces installed in your computer.

Graphics Driver

Displays the graphics screen type you are using and the mode it will use when displaying graphs.

Diskette Drives

Number of diskette drives attached to your computer.

RAM Available

This is not the total random access memory available on your computer, but the extent of memory IRRISCHED has reserved for your data in the memory and what is left of it.

Bytes free on (drive:)

Drive: is the drive the current data directory is located in. It displays the free space in bytes available on that drive.

Size of (drive:)

Displays the total size in bytes of the drive where the data directory is located.

When IRRISCHED doesn't perform as well as you expected, check the configurations on this screen. Most of the errors experienced by software users, are the result of incorrect configurations of their programs.

On-Board Data Files

This chapter deals will the use and importance of the On-Board Data Files, the heart of IRRISCHED.

Why On-Board Data Files?

IRRISCHED performs a wide range of calculations to project and forecast an irrigation period. To be as accurate as possible, IRRISCHED needs to have information on the specified region, e.g.: the average daily A-pan evaporation for each week of the year; the type of crop being irrigated; the crop's full range of crop factors; system capacity at various speed settings, etc. This information is provided by the On-Board Data Files, from here on referred to as **OBDF's**.

The information in the OBDF's is thus of vital importance for IRRISCHED to function properly. Without the OBDF's IRRISCHED will be useless. Please be sure that you understand the OBDF's before you change any of the information stored in them, as the wrong values may cause IRRISCHED to malfunction.

The Structure and Editing of the OBDF's

Select **On-Board Data Files** on the main menu. There are four OBDF's. Each OBDF option has a sub menu *(fig. 7)*. You can edit or view each OBDF or you can delete them. If you select **Edit/View**, and the OBDF doesn't exist, it will be created automatically.

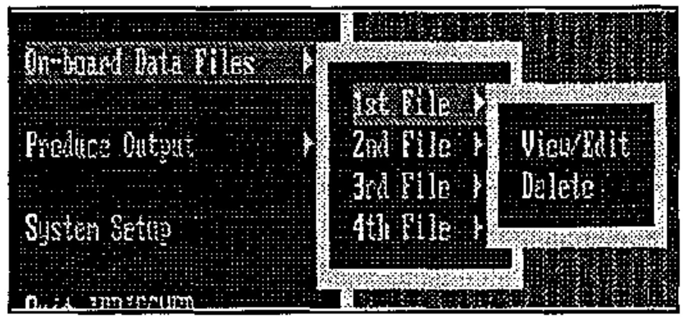


Figure 7

The first and fourth OBDF's are crop independent, all the other OBDF's are crop dependent. This means you have to select a crop for the OBDF. You do this by pressing **F1** after you have selected the **Edit/View** option. The fourth OBDF is system dependant, this means you can select a **Linear or a Centre Pivot** irrigation system. You have to press **F1** to accomplish this.

Use the *up* and *down* arrow keys to move between the different entries in the OBDF's. Use **TAB** and **Shift-TAB** to move between the different columns. Use **Page Up and Page Down** to page through the different entries. **ENTER** will move you automatically to the next field.

In the next few paragraphs a closer look will be taken to the OBDF's.

On-Board Data File 1

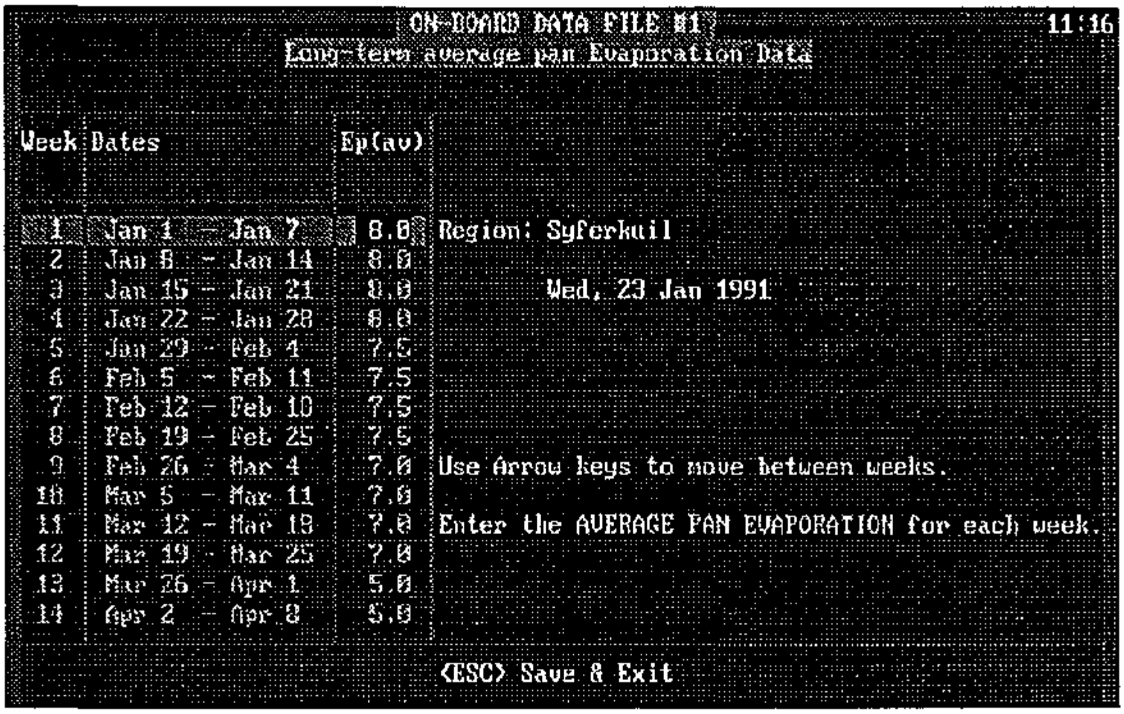


Figure 8

Select **1st File** on the sub menu in *fig. 7.* The screen in *fig. 8* will be displayed. This OBDF stores the **Long-term average pan evaporation data.** There are exactly 52 entries, one for every week of the year. The information which you enter into this OBDF are values generated after years of recording of daily pan evaporation for the specified region.

There is only one column of data which has to be entered in the $\mathbf{E_{p(av)}}$ column. After you have entered the data, press **ESC** to save and return to the sub menu.

On-Board Data File 2

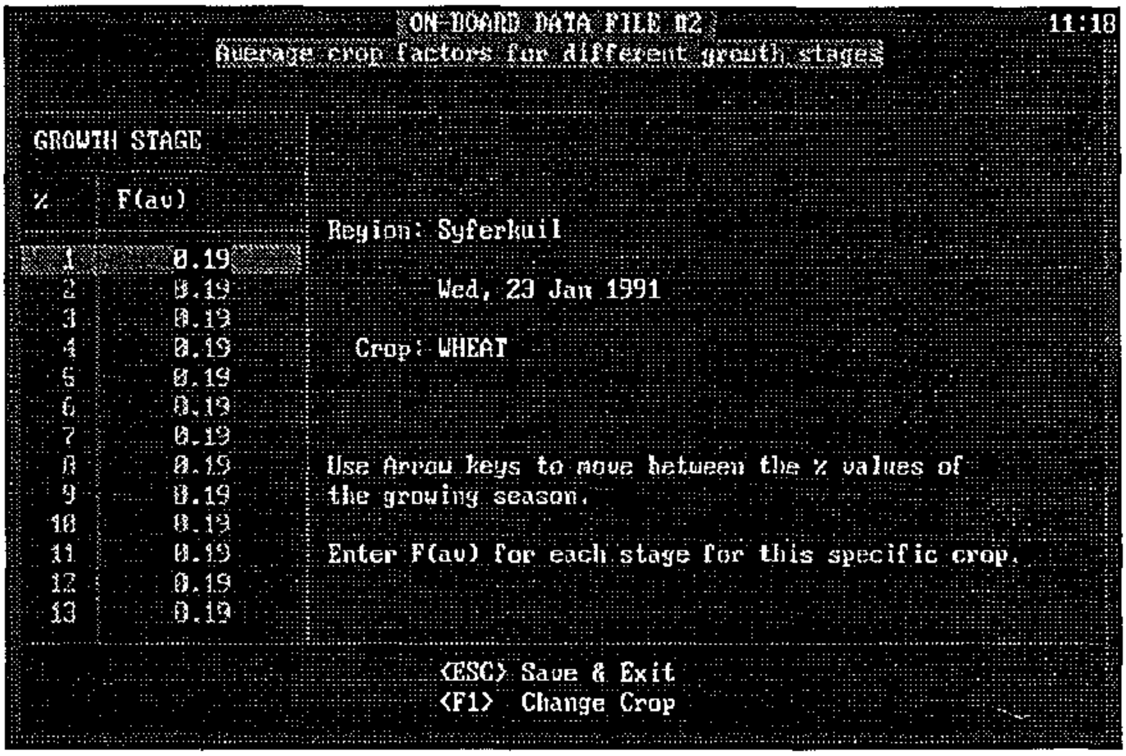
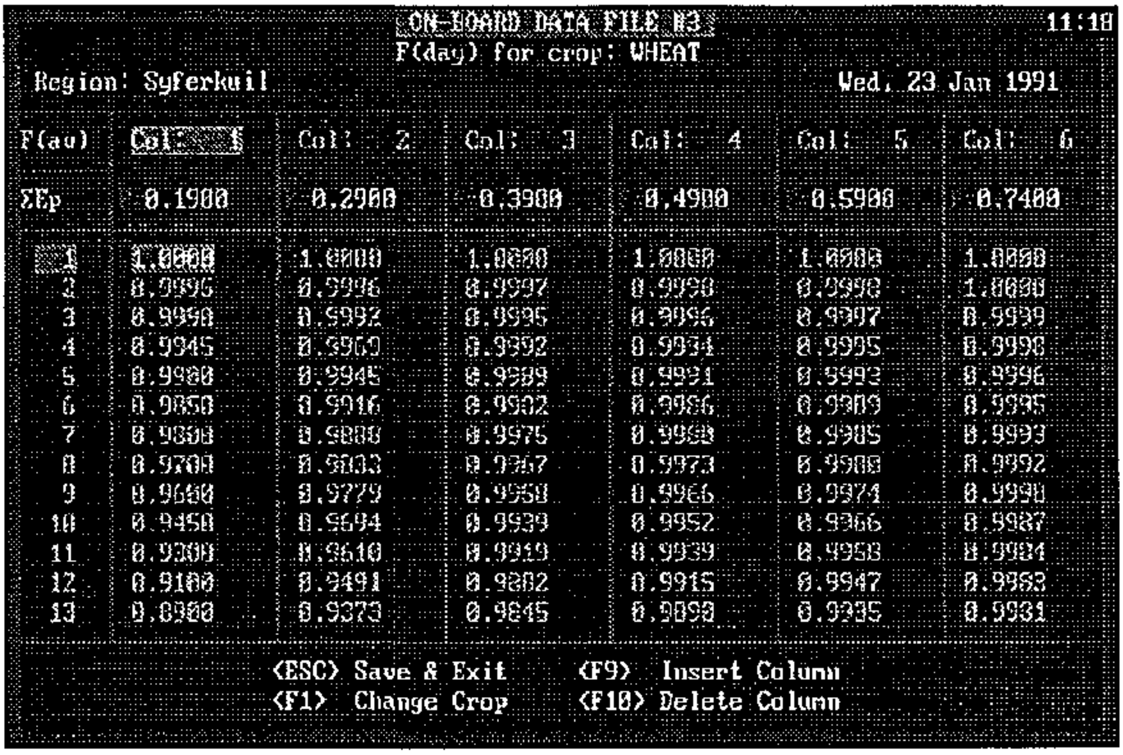


Figure 9

Select **2nd File**, then press **ENTER** on the **View/Edit** high light. The screen in *fig. 9* will be displayed. This OBDF stores the **Average crop factors for the different growth stages**, expressed as a percentage of the growth total growth period. There are 100 entries to be made, one for each one percent of the growth period. Press **F1** to change the crop.

There is only one column of data to be entered in the $F_{(av)}$ column. Press **ESC** to save the data and return to the sub menu.

On-Board Data File 3



F(av)	Col: 1	Col: 2	Col: 3	Col: 4	Col: 5	Col: 6
ΣEp	0.1900	0.2900	0.3900	0.4900	0.5900	0.7400
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.9995	0.9996	0.9997	0.9998	0.9998	1.0000
3	0.9990	0.9992	0.9995	0.9996	0.9997	0.9999
4	0.9945	0.9969	0.9992	0.9934	0.9995	0.9998
5	0.9980	0.9945	0.9989	0.9991	0.9993	0.9996
6	0.9850	0.9916	0.9982	0.9986	0.9989	0.9995
7	0.9800	0.9888	0.9975	0.9980	0.9985	0.9993
8	0.9700	0.9833	0.9967	0.9973	0.9980	0.9992
9	0.9600	0.9779	0.9958	0.9966	0.9974	0.9990
10	0.9450	0.9694	0.9939	0.9952	0.9966	0.9987
11	0.9300	0.9610	0.9919	0.9939	0.9958	0.9984
12	0.9100	0.9491	0.9882	0.9915	0.9947	0.9983
13	0.8900	0.9373	0.9845	0.9898	0.9935	0.9981

Figure 10

Select **3rd File**, then press **ENTER** on **View/Edit.** The screen in *fig. 10* will be displayed. This OBDF stores the **Daily crop factors of a specified crop.** The $\mathbf{F_{(day)}}$ is a function of the current $\mathbf{F_{(av)}}$ as well as the time lapse since the most recent application of water (in the form of rain or irrigation), measured in terms of the cumulative pan evaporation $\mathbf{E_{pi}}$ since the date of the last application. Press **F1** to change the crop.

Before you begin to enter the date in the columns, a column must be created for each different $\mathbf{F_{(av)}}$ value. Press **F9** to insert or create a column. Press **F10** to delete a column. Enter the $\mathbf{F_{(av)}}$ values in ascending order at the top block *(fig. 11)* of each column. You can access the top block by pressing the *up* arrow key in each column.
Each column has 200 entries. Press **ESC** to save and return to the sub menu.

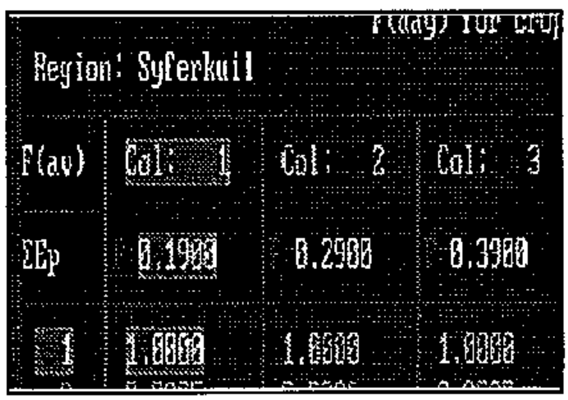


Figure 11

On-Board Data File 4

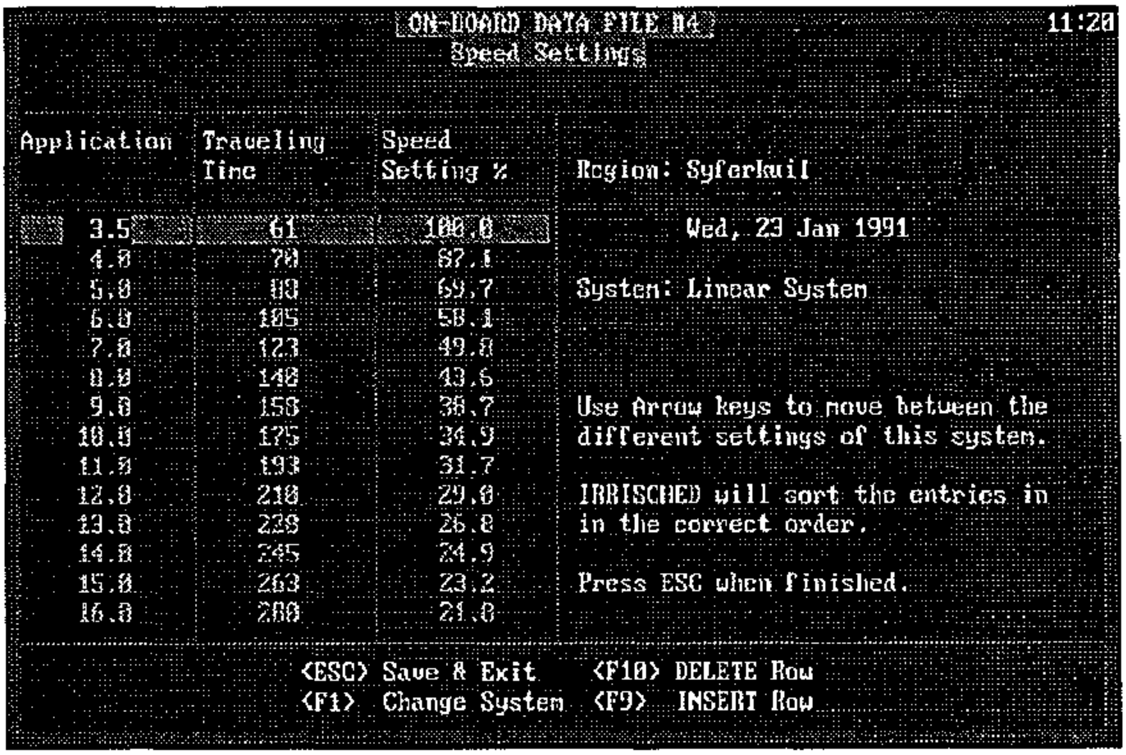


Figure 12

Select **4th File**, then press **ENTER** on **View/Edit**. The screen in *fig. 12* will be displayed. This OBDF stores the **Speed settings of the irrigation system**. There are an unlimited number of entries and three columns to be entered. Press **F1** to change the irrigation system.

Type the **Application amount** in the first column. Press **ENTER** or **TAB** to move to the next column. Type the **Travelling Time** in the middle column. Move to the 3rd column and type the **Speed Setting**. Pressing **ENTER** will create a new row of data to be entered. Enter the **Applications** in ascending order. Press **F9** to insert a row and **F10** to delete a row.

Press **ESC** to save the data and return to the sub menu.

Check that an OBDF exists for each region in which you are using IRRISCHED. There must be a OBDF for each crop. The OBDF's are stored in the \IRRISCHED\OBDF directory. The first two letters of the name of the OBDF indicates region and the extension of the file name indicates the number of the OBDF.

Start a New Schedule

In this chapter you create your first irrigation schedule.

Entering the Planting Date

Select **Master Schedule** on the main menu *(fig. 13)*. Select **Edit/Create** on the sub menu. Another sub menu will be displayed. If you select **View/Edit** on that sub menu and no schedule has been created for the current planting date, IRRISCHED will display the error message in *fig. 14*.

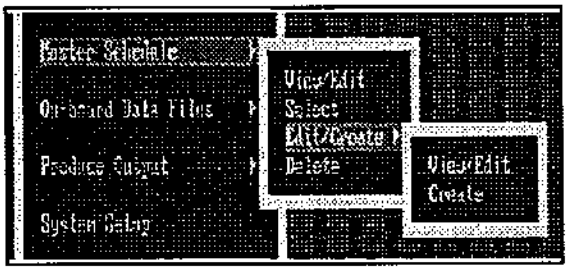


Figure 13

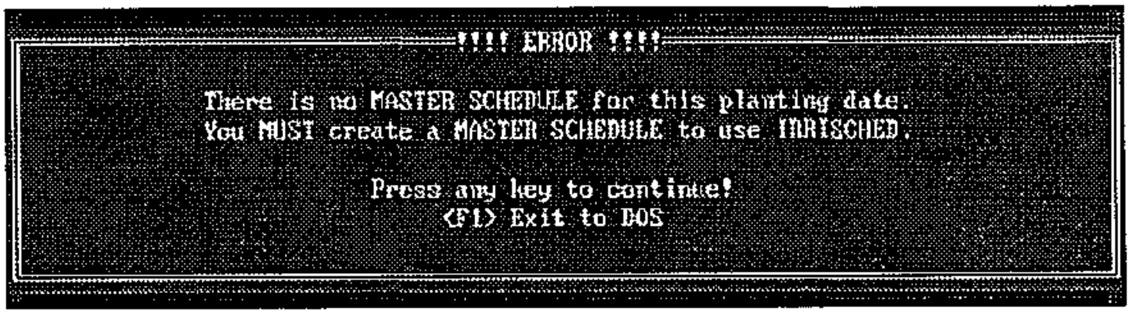


Figure 14

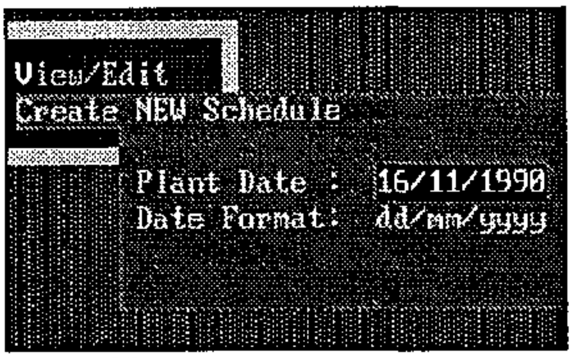


Figure 15

Select **Create** on this sub menu. IRRISCHED will prompt you to enter a planting date *(fig. 15)*. If the date is correct, press enter. This date will become the current schedule date.

You are now ready to enter the information for a new schedule. IRRISCHED will display the input screen in *fig. 16*.

Schedule Info

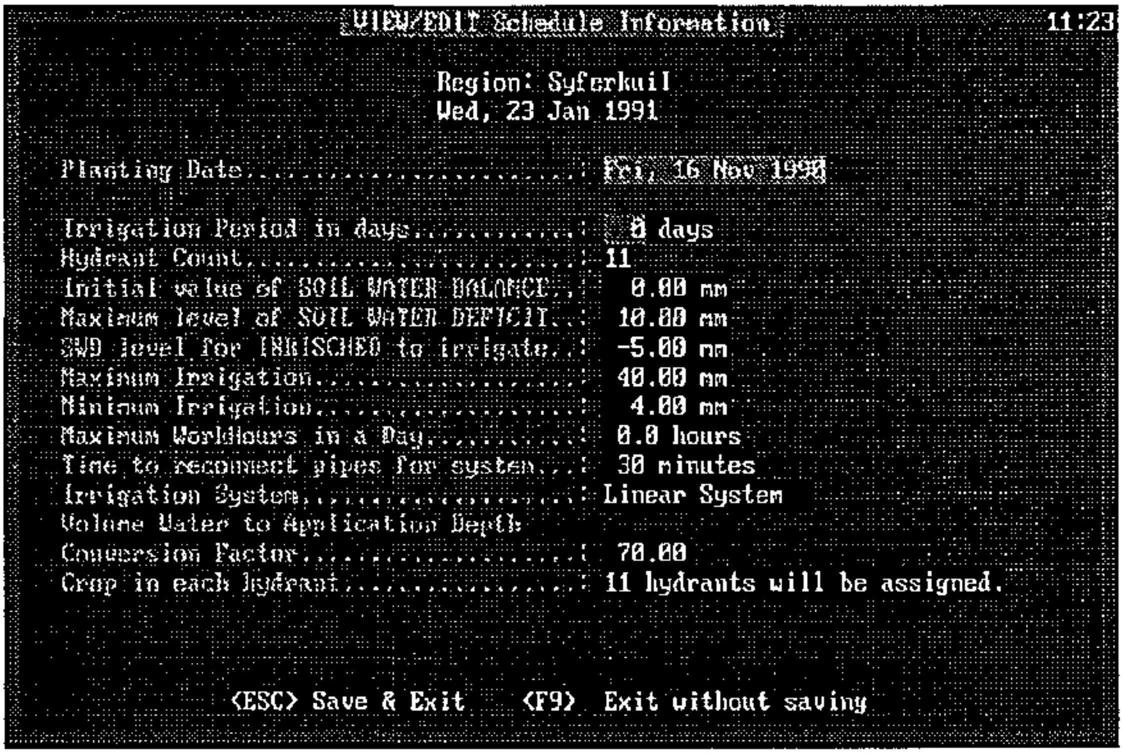


Figure 16

The information on this screen is of vital importance to IRRISCHED to calculate a new schedule correctly. The following will give a brief description of all the fields which have to be entered and their initial values assigned by IRRISCHED.

Irrigation Period
This is the number of days you expect the irrigation period to last.

Hydrant Count
The number of hydrants indicate the number of blocks the irrigation field has been divided into, a maximum of 15 has been allowed (in the case of a linear system). In the case of a centre pivot system, the field should be divided into a convenient number of sub-sections. IRRISCHED assigns the value of 11 as default.

Initial Soil Water Balance
This value is normally 0.0mm when the soil profile is at field capacity, but if you know exactly what the value is, or when the soil water deficit can be estimated, that amount should be entered as a negative value.

Maximum level of Soil Water Deficit
The maximum SWD value represents the maximum (positive) amount of excess water which the soil profile can accommodate above field capacity. IRRISCHED assigns the value of 10.00mm as default.

SWD level for IRRISCHED to commence with irrigation
If the SWD reaches this value, IRRISCHED will begin to irrigate. The default value is -5.00mm.

Maximum Irrigation
This is the maximum amount of irrigation IRRISCHED will allow during any one application. The default value is 40mm.

Minimum Irrigation
This is the minimum application according to the system specifications. The default value is 4mm.

Maximum Work hours per day
This is the maximum, approximate time in hours IRRISCHED will allow the system to be in operation per day. The default is 0.0 hours, and should be adjusted according to operational characteristics of the farm.

Time to connect pipes for system
This is the average time in minutes allowed to reconnect the pipes for the system between each hydrant. The default value is 30 minutes. IRRISCHED adds this time to the application time to determine how many hydrants can be irrigated on each day.

Irrigation System
You can select different irrigations systems for IRRISCHED. Use the arrow keys to switch between the different systems. The default is a LINEAR SYSTEM.

Volume Water to Application Depth Conversion Factor
This value is of vital importance for IRRISCHED to convert the actual volume of water in m^3 that has been applied into an application depth in mm. The default value is a factor of 70,0[1] (indicating a land area of 7,0 ha between hydrants.

Crop in each hydrant
If there are different crops in each hydrant, you must specify the crop which grows in each hydrant. Use the arrow keys to switch between the different crops. See fig. 17.

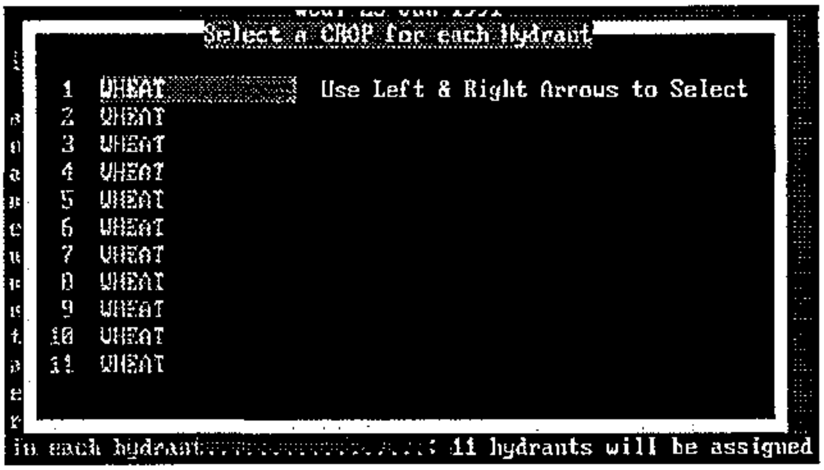


Figure 17

Press **ESC** to save and calculate the new irrigation schedule. Press **F9** to exit without saving the schedule.

If you pressed **ESC** the schedule has been created. You are now ready to start your irrigation cycle. In the following chapters you will learn how to manipulate this schedule and how to manage your irrigation system with IRRISCHED.

Managing Your Schedule

This chapter will explain how to manipulate IRRISCHED's calculated schedule to obtain the best results during the irrigation schedule. It will show you how to update IRRISCHED each day, in order to utilize the latest weather information.

What does IRRISCHED require everyday?

Each day you must have the following information before you begin to irrigate:

Before Regulation Pan Evaporation Reading
After Regulation Pan Evaporation Reading
Rainfall Reading

These values must be entered everyday, in order for IRRISCHED to make the correct calculations for the irrigation schedule.

Daily Input Data

Select **Daily Input Data** on the main menu *(fig. 18)*. If you haven't created a schedule by now, IRRISCHED will ask you to do so.

To create a schedule, please follow the instructions in the previous chapter.

After you have selected **Daily Input Data** on the main menu, IRRISCHED will display the screen in *fig. 19 (next page)*.

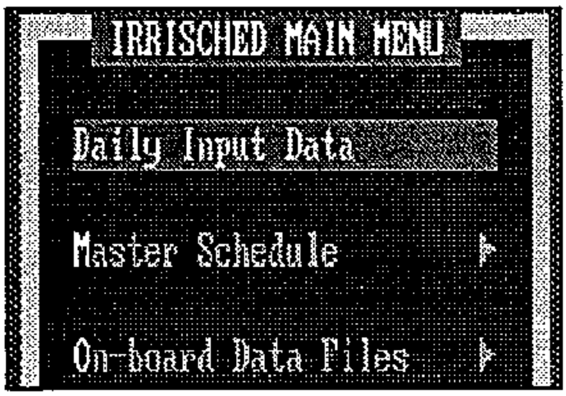


Figure 18

Each day, before you start the day's irrigation schedule, you must enter the pan evaporation and rainfall readings of the previous day for IRRISCHED. IRRISCHED will then calculate the exact amount of water, which has to be applied for the current day's schedule.

It is therefore very important that this information must be correct. Incorrect information will cause IRRISCHED to miscalculate the schedule which can be disastrous for the crops.

The following pages will deal with the entering of this information and how to manage your irrigation system with the calculated results.

TABLE 1 Daily Input Data 12:21

Sat, 26 Jan 1991

Dates since Previous Entering	A-Pan Readings		Evaporation E(p)	Precipitation	
	BEFORE REG	AFTER REG		RAIN	HYDRANT
Fri, 30 Nov 1990	0.0	0.0	7.0 *	0.0	0 *
Sat, 1 Dec 1990	0.0	0.0	7.0 *	0.0	0 *
Sun, 2 Dec 1990	0.0	0.0	0.0 *	0.0	2 *
Mon, 3 Dec 1990	0.0	0.0	0.0 *	0.0	3 *
Tue, 4 Dec 1990	0.0	0.0	0.0 *	0.0	4 *
Wed, 5 Dec 1990	0.0	0.0	0.0 *	0.0	5 *
Thu, 6 Dec 1990	0.0	0.0	0.0 *	0.0	6 *
Fri, 7 Dec 1990	0.0	0.0	0.0 *	0.0	7 *
Sat, 8 Dec 1990	0.0	0.0	0.0 *	0.0	8 *
Sun, 9 Dec 1990	0.0	0.0	0.0 *	0.0	9 *
Mon, 10 Dec 1990	0.0	0.0	0.0 *	0.0	10 *
Tue, 11 Dec 1990	0.0	0.0	0.0 *	0.0	11 *
Wed, 12 Dec 1990	0.0	0.0	0.0 *	0.0	11 *

<ESC> Recalculate & Exit <F2> "*" ON/OFF <F4> Graph
<F10> Save & Exit "*" Projected Data <F5> Print

Figure 19

The screen is divided into six columns. The first column indicates the **Date**, the second the **Before Regulation Reading**, the third the **After Regulation Reading**, the fourth the computed **Pan Evaporation**, the fifth the actual **Rainfall** and the sixth the starting **Hydrant** for each day.

The data in columns 2,3 and 5 must be entered.

If this is a new schedule *fig. 20*, then the information of the first day will be entered slightly different from the rest of the days.

Dates since Previous Entering	A-Pan Readings		Evaporation E(p)	Precipitation	
	BEFORE REG	AFTER REG		RAIN	HYDRANT
Fri, 30 Nov 1990	0.0	0.0	7.0 *	0.0	0 *

Figure 20

Usually the **Pan Evaporation** is calculated by subtracting the previous day's **After Regulation Reading** from the current day's **Before Regulation Reading** and divide the answer by two. As there is no previous day for the first day of the schedule, IRRISCHED will subtract the first day's **After Regulation** from the first day's **Before Regulation** and divide it by two *(fig. 21)*.

Dates since Previous Entering	A-Pan Readings		Evaporation E(p)	Precipitation	
	BEFORE REG	AFTER REG		RAIN	HYDRANT
Fri, 30 Nov 1990	0.0	0.0	7.0 *	0.0	0 *
Sat, 1 Dec 1990	0.0	0.0	7.0 *	0.0	0 *

Figure 21

Use **TAB** to move between the columns. The information will only be accepted if you press **ENTER** in the **Rainfall** column. Use the arrow keys to move the highlighted bar up or down.

After the first day, you can enter the information in the normal way. IRRISCHED will always copy the **Before Regulation Reading** to the **After Regulation** column. If the **After Regulation Reading** differs, then you can change it. Pressing **ENTER** will move to the next column. *(fig. 22)*

Dates since Previous Entering	A-Pan Readings		Evaporation E(p)	Precipitation	
	BEFORE REG	AFTER REG		RAIN	HYDRANT
Fri, 30 Nov 1990	70.0	50.0	18.0	0.0	0
Sat, 1 Dec 1990	64.0	64.0	7.0 *	0.0	0 *
Sun, 2 Dec 1990	0.0	0.0	0.0 *	0.0	2 *

Figure 22

Other functions keys on this screen

ESC: Recalculate the schedule and return to the main menu

F2: Switch between **Historical data** and **Projected data.** The **Projected data** is indicated by an "*" adjacent to the data. When you have finished with the input of one day, IRRISCHED will automatically mark it as **Historical.** If you made a mistake, you can use this function to edit the day.

F4: Draw a graph of **Pan Evaporation and Rainfall** *(fig. 23)*

When the graph is displayed, press **F5** to print it on a printer. **ESC** will halt the printing. **F10** will return you to the **Daily Input Screen.**

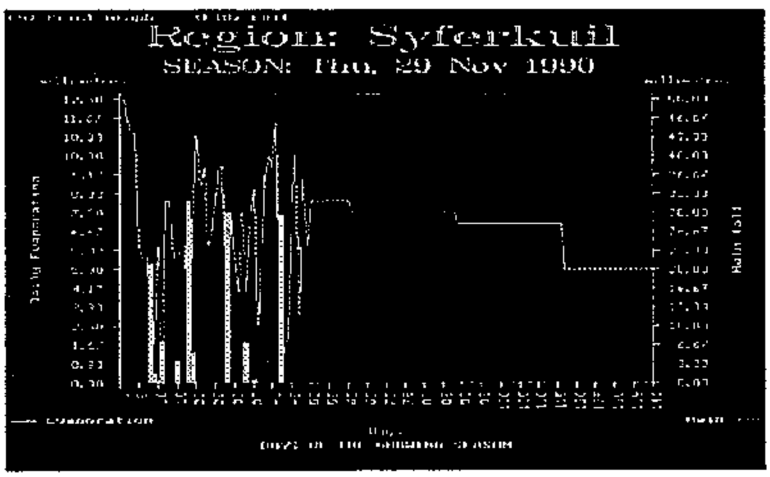


Figure 23

F5 Print the **Daily Input Data** on a printer.

F10 Save the data but don't recalculate the schedule. This function returns to the main menu.

After this procedure, you can return to the main menu.

Editing the Master Schedule

Select **Master Schedule** on the main menu. On its sub menu, select **View/Edit** *(fig. 24)*.

The screen in *fig. 25* will appear.

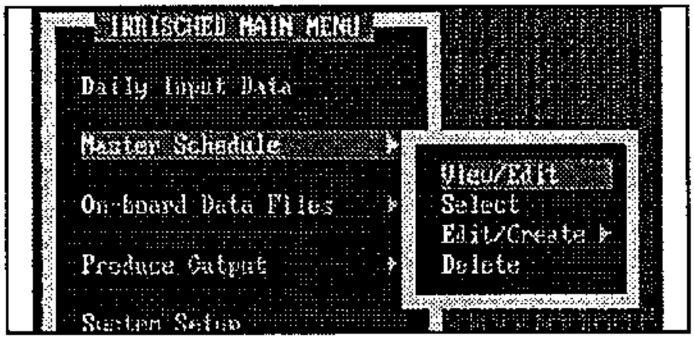


Figure 24

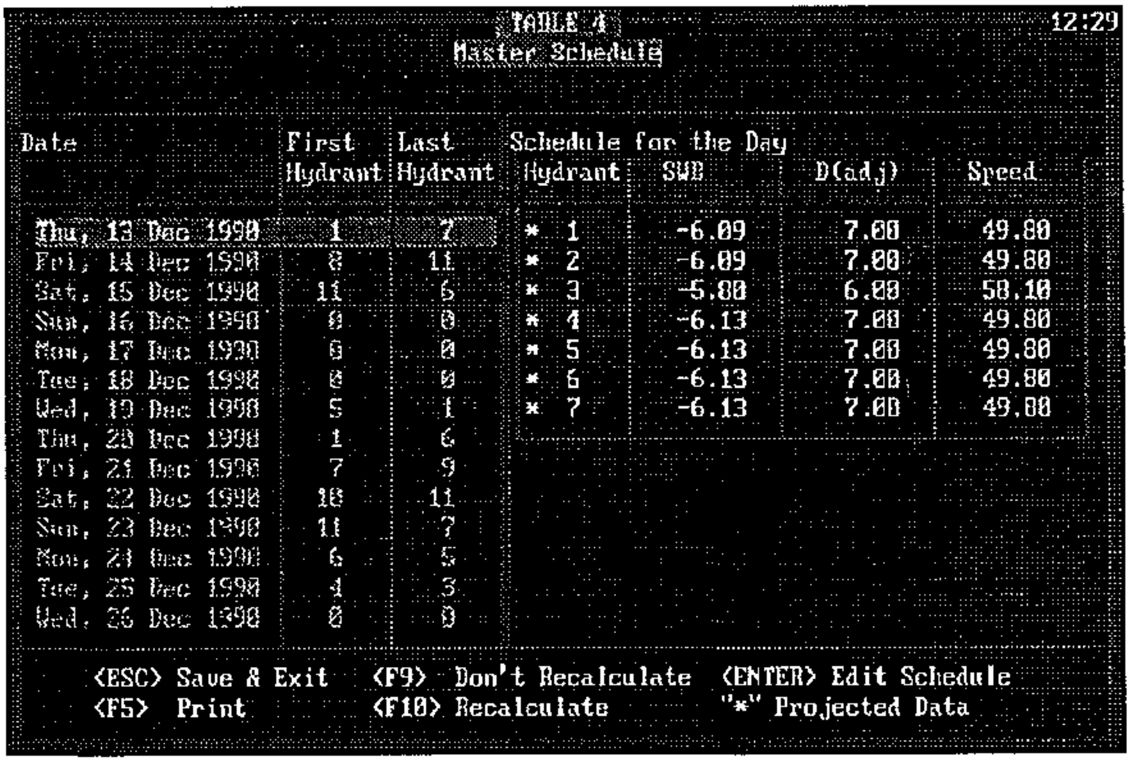


Figure 25

This screen shows the master schedule IRRISCHED has calculated. The first column indicates the date. The second column the starting hydrant, the third the ending hydrant and the fourth displays a hydrant list which indicates the hydrant number, the Soil Water Deficit, the Application and the Speed Setting on the irrigation system.

Scheduling of irrigation always commences the day after the planting date.

The following functions are available on this screen:

ESC Save, recalculate the schedule and return to the sub menu.

F5 Print the application schedule for the day.

F9 Save information, recalculate, and return to the sub menu.

F10 Recalculate the schedule.

IMPORTANT: The recalculation on this screen doesn't change the schedule, it only updates the Soil Water Deficit values and application values.

If you press **ENTER**, you can edit the schedule. The screen in *fig. 26* will appear.

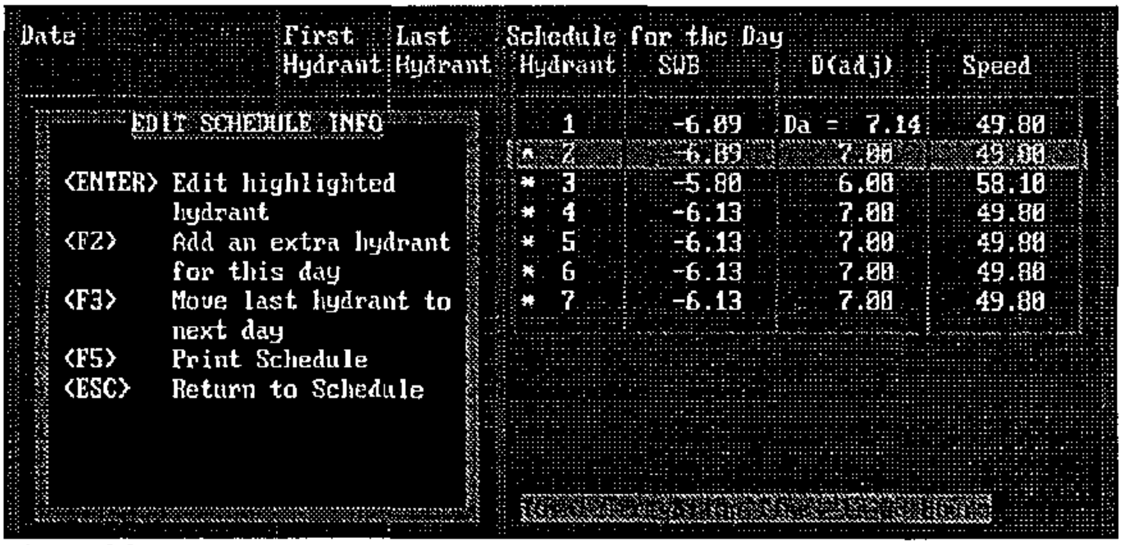


Figure 26

The following functions are available on this screen:

ESC Return to the master schedule.

F2 Add an extra hydrant. This will remove the hydrant from the next day.

F3 Remove a hydrant. This will move the last hydrant to the next day.

F5 Print today's schedule. On the printed form there will be a space to write the **Flow meter readings**. When the irrigation process has been completed, the **Flow meter readings** has to be entered for IRRISCHED.

A "*" indicates projected information. When the hydrant has been irrigated and the **Flow meter readings** have been entered, IRRISCHED will display the application as for example **"Da = 7,14"**.

Move the highlighted bar with the arrow keys to the hydrant you want to edit. Press **ENTER**. The screen in *fig. 27* will be displayed.

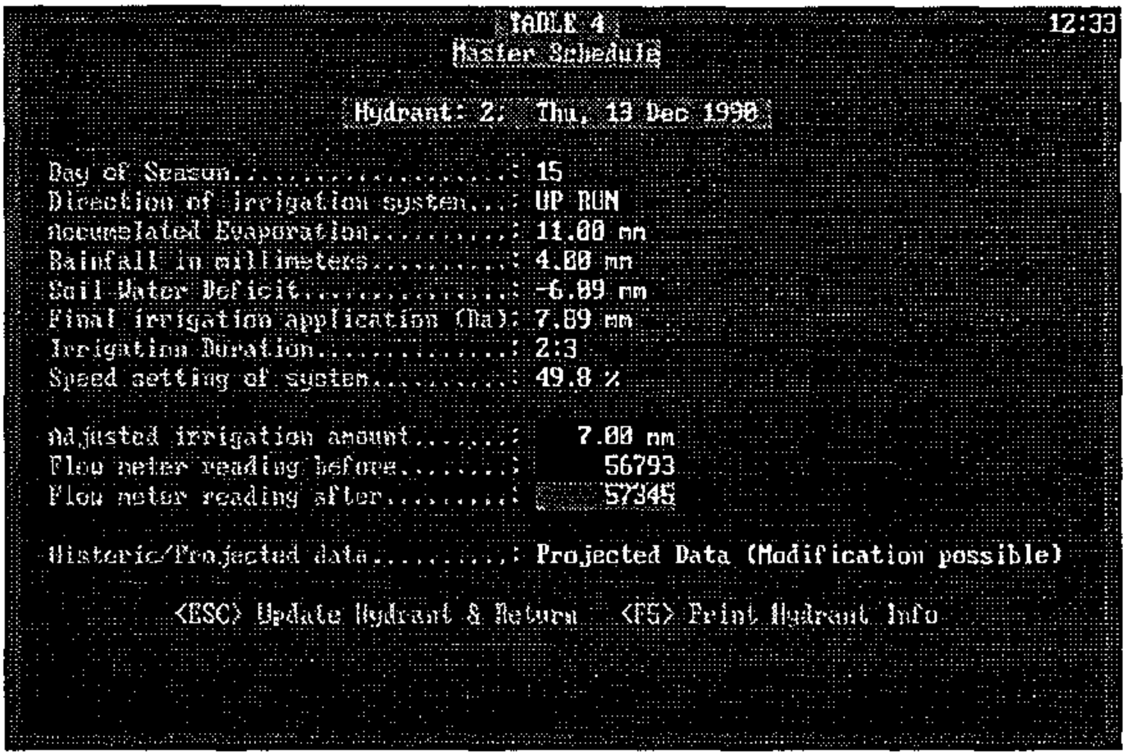


Figure 27

On this screen you can modify the **Application** and enter the **Flow meter readings**.

If you press **F5**, the information of this hydrant will be printed on a printer. **ESC** will return to the hydrant list screen.

Every time a hydrant has been irrigated, you have to enter the **Flow meter readings** for IRRISCHED to determine the exact amount of water applied. You must press **ENTER** on each field to have it accepted. If the data has already been entered, IRRISCHED will regard it as historical data *fig. 28*. You can press **F2** to modify the settings if you made a mistake.

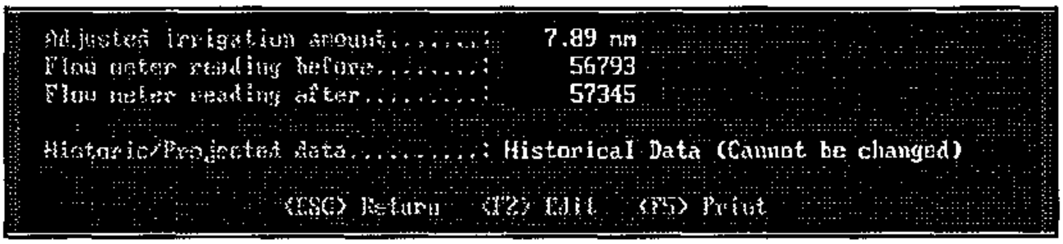


Figure 28

This procedure must be repeated each day of the irrigation period.

Other Functions

This chapter will inform you of the extra functions available on IRRISCHED.

Produce Output

Select **Produce Output** on the main menu. Select **Calculations** on its sub menu. *(fig. 29)*

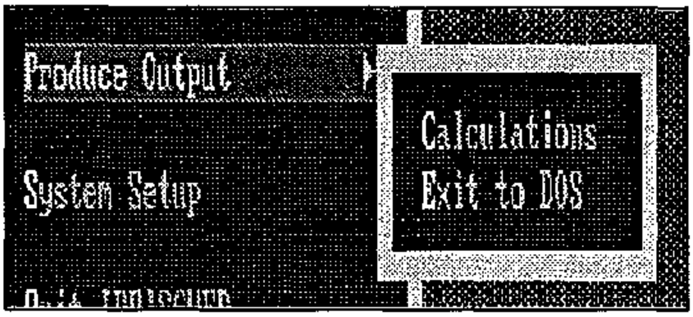


Figure 29

The screen in *fig. 30* will be displayed.

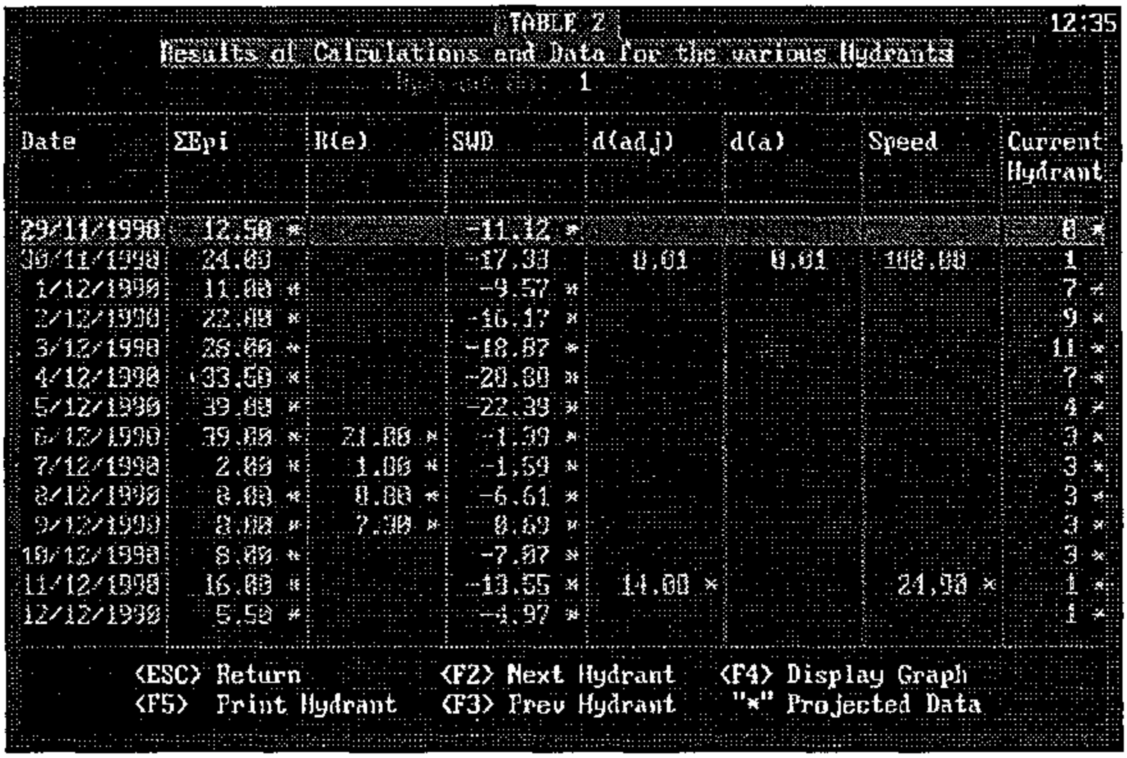


TABLE 2 12:35

Results of Calculations and Data for the various Hydrants

1

Date	ΣEpi	R(e)	SWD	d(adj)	d(a)	Speed	Current Hydrant
29/11/1998	12.50 *		-11.12 *				0 *
30/11/1998	24.00		-17.33	0.01	0.01	100.00	1
1/12/1998	11.00 *		-9.57 *				7 *
2/12/1998	22.00 *		-16.17 *				9 *
3/12/1998	26.00 *		-18.87 *				11 *
4/12/1998	33.50 *		-20.80 *				7 *
5/12/1998	39.00 *		-22.39 *				4 *
6/12/1998	39.00 *	21.00 *	-1.39 *				3 *
7/12/1998	2.00 *	1.00 *	-1.59 *				3 *
8/12/1998	8.00 *	0.00 *	-6.61 *				3 *
9/12/1998	8.00 *	7.30 *	0.69 *				3 *
10/12/1998	8.00 *		-7.07 *				3 *
11/12/1998	16.00 *		-13.55 *	14.00 *		21.90 *	1 *
12/12/1998	5.50 *		-4.97 *				1 *

<ESC> Return <F2> Next Hydrant <F4> Display Graph
<F5> Print Hydrant <F3> Prev Hydrant "*" Projected Data

Figure 30

This screen shows you all the available information of a hydrant, day by day. Press **F2** to see the next hydrant or **F3** to see the previous hydrant.

If you press **F5** a list of all the days on which this hydrant was or will be irrigated, will be printed.

Only the days which have been irrigated, will be displayed as **Historical** data. This means an "*" will not appear next to the data.

By pressing **F4** a graph showing the daily march of the **Soil Water Balance** and the all applications in the form of irrigation or rain, of the particular hydrant block will be displayed*(fig. 31)*

On the graph screen, the following functions are available:

F5 - print the graph

F10 - return to the previous screen.

ESC - return to the sub menu.

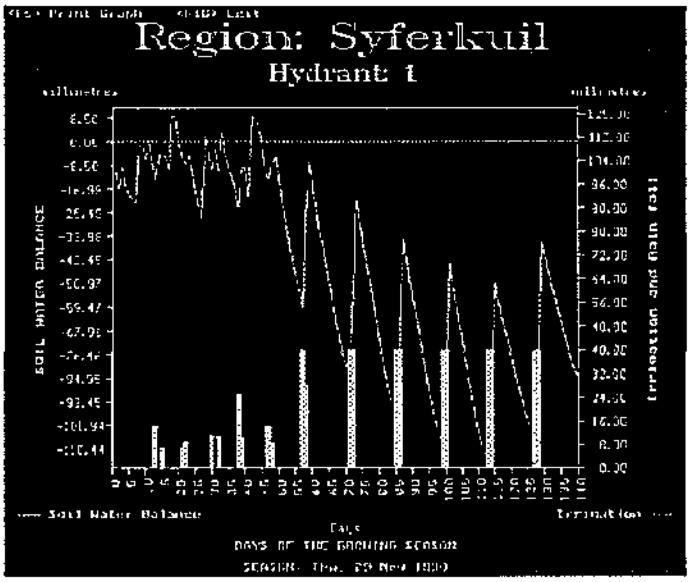


Figure 31

Exit to DOS

If you need to enter the DOS Command processor, you can select **Exit to DOS** on the sub menu of produce output menu. To return to IRRISCHED, type "**EXIT**" at the DOS prompt.

Select or Delete a schedule

You can select a saved schedule on the disk. Select **Master Schedule** on the main menu. On the sub menu you must choose Select. The screen in *fig. 32* will appear.

Use the arrow keys to move the highlighted bar to the schedule you want to select. Press **ENTER**. This schedule will now be you current schedule.

If you want to delete a schedule, you must select **Delete** on the sub menu. The same screen will appear. Select the schedule you want to delete and press **ENTER**.

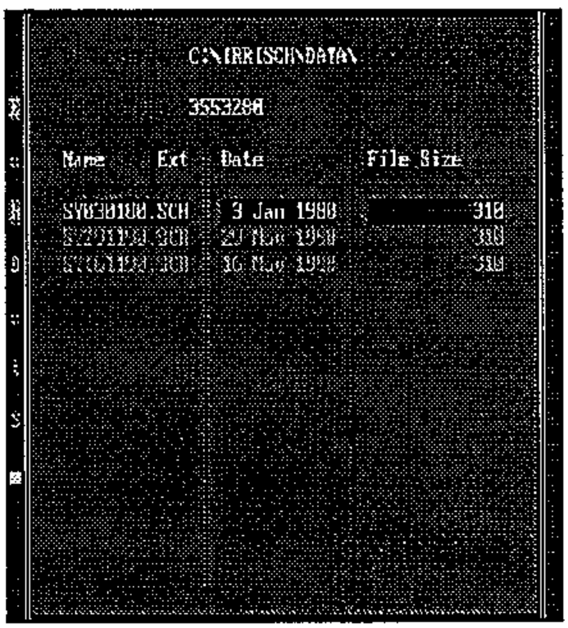


Figure 32

This concludes this manual. If you experience any problems, please refer to the Preface in the beginning of the manual.