



Soil Water Measurements at the 2005 Marrar Grazing Wheat Trial

Warren J Bond
CSIRO Land and Water, Canberra



CSIRO Land and Water Science Report 7/06
February 2006

Copyright and Disclaimer

© 2006 CSIRO To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of CSIRO Land and Water.

Important Disclaimer:

CSIRO advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, CSIRO (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

Cover Photograph:

Description: Wireless logger antennae in the three plots monitored in Rep 3 of the 2005 Marrar Grazing Wheat Trial
Photographer: Warren Bond
© 2005 CSIRO

Soil Water Measurements at the 2005 Marrar Grazing Wheat Trial

Warren J Bond

CSIRO Land and Water, Canberra

CSIRO Land and Water Science Report 7/06

February 2006

Acknowledgements

The work described in this report was commissioned by FarmLink Research as the host agency for Murrumbidgee Grain & Graze, in collaboration with the Murrumbidgee Catchment Management Authority (MCMA), NSW Agriculture, CSIRO and Charles Sturt University. Grain & Graze is a national research program funded by Meat and Livestock Australia, Australian Wool Innovation Ltd, Grains Research and Development Corporation, and Land & Water Australia.

The assistance of Cathie and David Fox, on whose property Brigadoon the trial was carried out is gratefully acknowledged, as is that of Kिरrily Condon (FarmLink Research and Communication Manager).

The author is also grateful for the assistance of Paul Hutchinson, Gordon McLachlan and Chris Drury (CSIRO Land and Water) in carrying out this project.

Executive Summary

Measurements of soil water potential were made in one replicate of each of three treatments in the 2005 Marrar Grazing Wheat Trial of the Murrumbidgee Grain & Graze project. The three treatments allowed the comparison of grazed Whistler and ungrazed Wedgetail grazing wheats with a normal (ungrazed) spring wheat, Diamondbird.

The main conclusions drawn from the results were:

- the winter rain penetrated to an average depth of 1.2 m across the plots, 0.4 m deeper than in 2004
- as well as wetting deeper, the soil was wetter at all depths and stayed wetter longer than in 2004
- there was evidence of strong soil water extraction by crop roots to at least 1 m, and some soil water extraction to 1.4 m, in all treatments, only slightly deeper than in 2004
- although the crops extracted water from deeper depths in 2005, the soil was not dried as thoroughly at each depth, and plant available water was left in the soil
- as in 2004, there were no strong treatment differences in the depth of wetting or depth of drying of the soil
- the rate of soil drying, and therefore water use, by the grazed Whistler treatment was slower relative to Diamondbird after the completion of grazing in late August; the resulting difference in soil wetness persisted almost to harvest
- water use by the ungrazed Wedgetail treatment was inconsistent relative to the other treatments, but fell between the two
- this slower water use immediately after August had little effect on the total drying achieved by the different treatments at harvest because it was made up for by more water use just prior to harvest; it is inferred that, as in 2004, there was little difference in total seasonal water use between the treatments

Table of Contents

Acknowledgements	ii
Executive Summary	iii
1 Background and Introduction	1
2 Overview of the Methodology	1
3 Depth of soil wetting	1
4 Depth and extent of soil drying	3
5 Comparison of water use between treatments	3
6 End of season wetting	5
7 Summary and Conclusions	5
Appendix A. How the measurements were made	6
Appendix B. Interpreting the measurements	9
Appendix C. Data Summary	11

1 Background and Introduction

The Marrar Trial is one of three Grazing Wheat Trials that form part of the Murrumbidgee Grain & Graze Project. The other trials are located at Yerong Creek and Harden. In each trial, three grazing wheat varieties are being evaluated: Whistler, Wedgetail (grazed and ungrazed) and Marombi. These are being compared to a spring wheat, Diamondbird. These trials are similar to those carried out in 2004.

CSIRO Land and Water was commissioned to provide real-time monitoring of soil water status, from which to infer water use, at the Marrar Trial in 2004 and 2005. This report describes the measurements and results from the 2005 trial. The results are discussed in three sections:

- depth of penetration of the winter rainfall
- depth of soil drying by the crops
- comparison of water use between treatments

The Report from the 2004 trial can be found at:

www.clw.csiro.au/MoistureWeb/GrainGraze/Takada/report.html

2 Overview of the Methodology

Measurements were made in three plots of the Marrar Grazing Wheat Trial: the Whistler (grazed), Wedgetail (ungrazed) and Diamondbird treatments in Replicate 3 of the Trial. They were carried out at one location, approximately the centre, of each 2.5 x 10 m plot.

The chosen soil moisture sensors were Watermark[®] gypsum blocks. These have the primary advantages of low cost, and ease of installation at depths up to 2 m or more. The prime disadvantage is that these sensors measure soil water potential, rather than soil water content, and soil water potential cannot be directly related to soil water storage in mm of water. Nevertheless, much useful information can be obtained, as described later in this report, at a substantially lower cost compared with reliable measurements of soil water content.

Sensors were installed at 0.2 m intervals from 0.2 m to 1.6 m below the soil surface prior to the sowing of the trial.

The sensors were measured with data loggers, one in each plot. To facilitate the ready availability of the data, the loggers were linked by radio communication to a receiver at the nearby shearing shed, which in turn communicated by cdma telephone link to a computer at the CSIRO Laboratories, from where the data were uploaded daily to a website. By this means, data from the previous day were usually available by 6 am each morning.

A more detailed description of the methodology can be found in Appendix A. In addition, some notes on interpreting the measurements are attached in Appendix B.

The complete data set for each plot is presented in Appendix C. Unfortunately the sensors failed at 0.4 and 0.8 m depths in the Wedgetail plot. A continuous record was obtained for all other depths and treatments.

Full details of the methodology, results and a running commentary on them can be found at: www.clw.csiro.au/MoistureWeb/GrainGraze/Brigadoon/

3 Depth of soil wetting

The arrival of winter rainfall at individual depths can be seen quite clearly in the data traces (see Appendix C), particularly at the shallower depths. This is illustrated in Fig. 1 for the Whistler plot. The first wetting at 0.2 m (16 Jun), in response to the commencement of rainfall

on 10 June, was abrupt and followed soon after by wetting at 0.4 m (19 June). The soil at 0.2 m quickly drained after the first wetting event, and can be seen to rewet with subsequent rainfall events. Although not draining between rainfall events, the same pattern of more rapid wetting can be seen at 0.4 m. As the rainfall continued, wetting occurred deeper in the soil: 0.6 m (27 June), 0.8 m (7 July), 1.0 m (13 July) and 1.2 m (25 July), but individual rainfall events are smoothed out at these deeper depths. It is unclear whether wetting occurred at 1.4 or 1.6 m or not. Although there was a gradual wetting trend at the end of July, it was small, short-lived, and quite unlike the patterns at the shallower depths. The gentle increase from August onwards at both those depths is attributed to soil warming and the effect of the increasing temperature causing the sensor output to indicate an apparent wetting (as described in Appendix B). The slightly faster increase at 1.4 compared to 1.6 m may suggest that there is some wetting superimposed on the temperature effect at the shallower depth. The other important feature of the wetting patterns is that the soil wet to at least 20 kPa at all but the deepest three depths; once this was reached, they stayed there until the end of September.

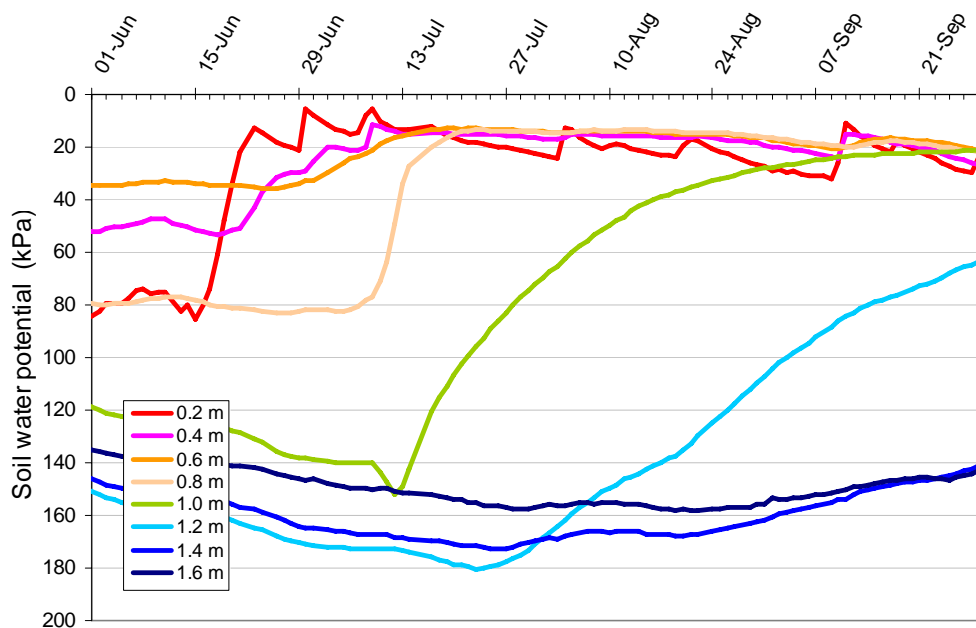


Figure 1. Soil water potential data for Whistler, showing profile wetting during winter and spring.

The same pattern is evident in the data from the other two treatments (Appendix C); both show definite wetting to 1.3 m, with possible wetting at 1.4 m. This is consistent with observations from other paddocks where similar rainfall totals were received around the Wagga Wagga and Temora districts in 2005.

These results are distinctly different from those in 2004, which received much less rainfall:

- The soil wet deeper (1.2 m in 2005 compared with 0.8 m in 2004)
- The soil wet closer to saturation (only the 0.2 m depth reached 20 kPa in 2004, compared with the top 1 m in 2005)
- The wetted depths stayed wet for long periods of time, and until at least the end of September in 2005, whereas in 2004 they started drying before becoming fully wet.

4 Depth and extent of soil drying

The soil water potential data also give a clear indication of how deep in the soil profile drying occurred. Unfortunately the WaterMark[®] sensors used for the measurements are capable of measuring accurately to only 200 kPa, which is somewhat less than the notional maximum crop drying potential (or "wilting point") of 1500 kPa. While the data therefore do not allow any statement about complete drying at a particular depth, they do indicate whether or not crop roots have reached that depth as evidenced by a sharp increase in the rate of drying. Table 1 summarizes the results of applying this criteria to the data in Appendix C. All plots were dried substantially to 1.2 m. There was some evidence of drying at 1.4 m but no evidence of drying at 1.6 m. An effective depth of root water extraction of 1.2 to 1.4 m is comparable to that observed at other sites in the Wagga Wagga region for a range of crops over a number of years. The depth of drying in 2005 was 0.2 to 0.4 m greater than that in 2004, probably reflecting the generally better season and crop growth. However, the soil layers that were dried in 2004 were drier than in 2005. The crops left accessible soil water behind in 2005, probably because of the larger in-season rainfall.

Table 1. Extent of soil drying at the different measurement depths in each treatment.

Treatment	Whistler (grazed)	Wedgetail (ungrazed)	Diamondbird
0.2	Drier than 200 kPa		
0.4			
0.6	Significant drying		
0.8			
1.0	Some drying		
1.2			
1.4	No drying		
1.6			

5 Comparison of water use between treatments

Until after grazing at the end of August, there was very little difference in the behaviour of the soil water potential traces in the different plots. Comparisons between treatments were easier this year compared with 2004 because the heavy winter rainfall brought all plots to the same level of soil water potential down to a depth of at least 0.6 m by early August (Fig. 2).

In early September after grazing of the Whistler treatment was completed and once persistent drawdown of soil water by the crops started, the measurements from different plots started to diverge.

The grazed Whistler plot dried more slowly than Diamondbird at 0.2 m, 0.4 m and 0.6 m, as can be seen in Fig. 2. The ungrazed Wedgetail dried at the same rate as Diamondbird at 0.2 m, and at a similar rate to the Whistler at 0.6 m; data was missing at 0.4 m for the Wedgetail treatment because of sensor failure.

Although the results are not as clear as in 2004, they still point to the effect of grazing causing decreased water use. Unlike the 2004 results, when the grazed and ungrazed treatments came back together within 6 to 8 weeks, the differences persisted longer in 2005. By the time the crop had matured and the effects of the early December rainfall were observed, all treatments had dried the soil by about the same amount.

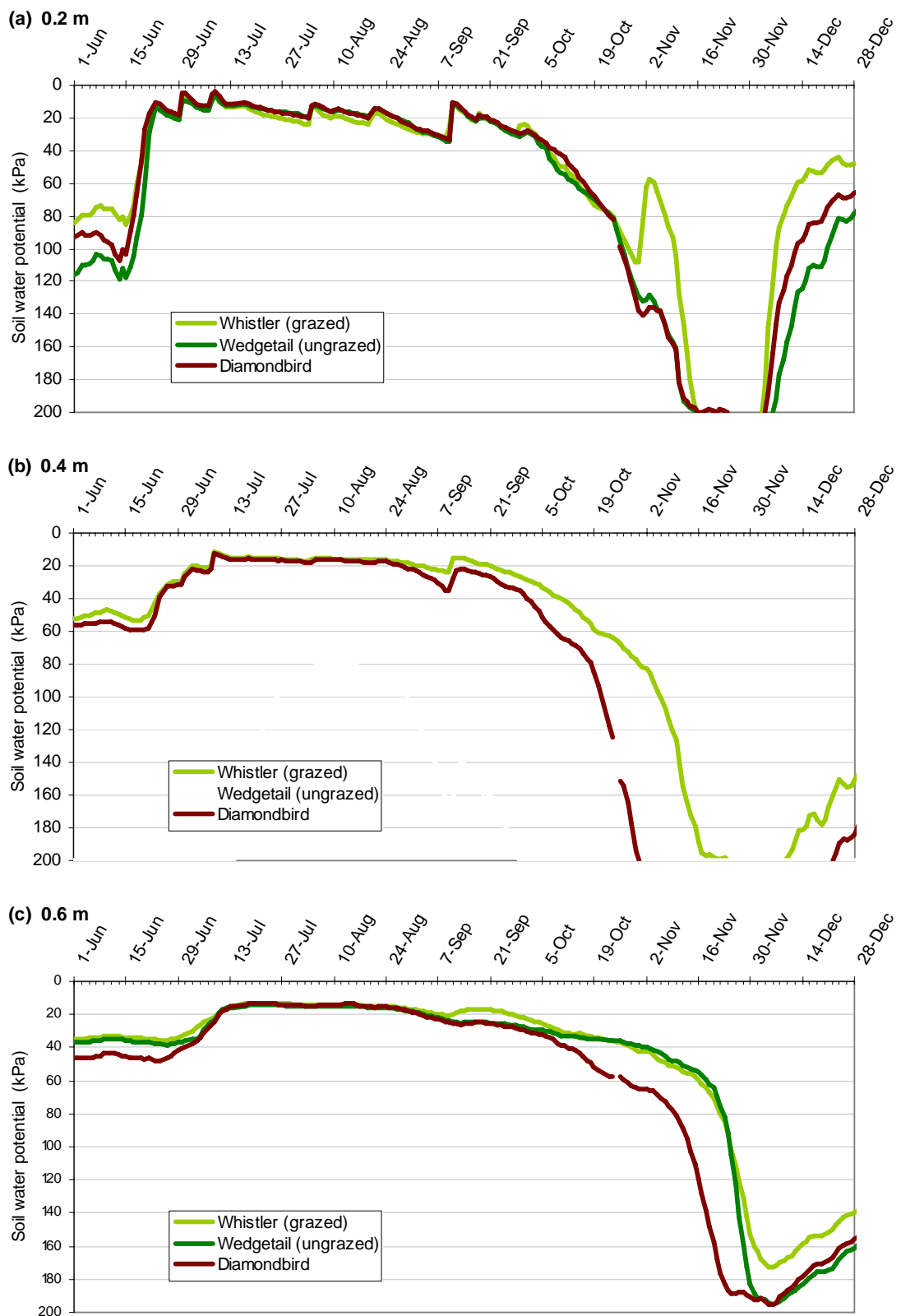


Figure 2. Comparison of soil water potential in all plots at (a) 0.2 m, (b) 0.4 m, and (c) 0.6 m (d), showing the good agreement between treatments until the end of August, and the slower drying of the grazed whistler treatment relative to the others between August and November.

6 End of season wetting

From Fig. 2 and the data summary in Appendix C it can be seen that the soil rewet at nearly all depths after early December. At the shallow depths (down to 1 m) this can be attributed, at least in part, to real soil wetting as a result of early December rainfall. However at the deeper depths (1.2 – 1.6 m) the apparent wetting is attributed to the temperature effect on the sensors, similar to that illustrated in Fig. B1 and described in Appendix B.

Nevertheless, it is clear that much of the December rainfall has been captured and retained in the soil, a consequence of the effective barrier to surface evaporation by the mature crop, initially, and then by the standing and fallen stubble. Retention of the stubble, and prevention of weed growth should see this water, plus that from any subsequent summer rainfall, retained for the 2006 crop. This was seen in 2005, even though it had a dry start. Rains late in 2004 (60 mm after mid-November at Coolamon Post Office) and in January and February 2005 (64 mm), resulted in the soil not being completely dry down to 1 m depth (soil water potential between 30 and 120 kPa) prior to the breaking rainfall in June 2005 (see Appendix C).

7 Summary and Conclusions

- the winter rain penetrated to an average depth of 1.2 m across the plots, 0.4 m deeper than in 2004
- as well as wetting deeper, the soil was wetter at all depths and stayed wetter longer than in 2004
- there was evidence of strong soil water extraction by crop roots to at least 1 m, and some soil water extraction to 1.4 m, in all treatments, only slightly deeper than in 2004
- although the crops extracted water from deeper depths in 2005, the soil was not dried as thoroughly at each depth, and plant available water was left in the soil
- as in 2004, there were no strong treatment differences in the depth of wetting or depth of drying of the soil
- the rate of soil drying, and therefore water use, by the grazed Whistler treatment was slower relative to Diamondbird after the completion of grazing in late August; the resulting difference in soil wetness persisted almost to harvest
- water use by the ungrazed Wedgetail treatment was inconsistent relative to the other treatments, but fell between the two
- this slower water use at times after September had little effect on the total drying achieved by the different treatments at harvest, and it is inferred that, as in 2004, there was little difference in total seasonal water use between the treatments

Appendix A. How the measurements were made

Overview

Measurements were made in each of three plots: the Whistler (grazed), Wedgetail (ungrazed) and Diamondbird treatments of Replicates 3 of the Marrar Grazing Wheat Trial. The measurement locations were about 2.5 m downslope of the centre of each plot. A schematic representation of the measurement methodology is shown in Figure A1.

At each measurement location Watermark® gypsum blocks were installed at 8 depths (0.2 m intervals from 0.2 to 1.6 m). They were installed in a single 50 mm diameter borehole; each sensor was packed in moist diatomaceous earth to ensure good contact with the soil, and the sensors were separated from each other by layers of bentonite.

Each set of 8 sensors was connected to a buried CSIRO Wireless micrologger located 1.5 m downslope from the sensors, the connecting cables being buried in a trench 0.4 m deep.

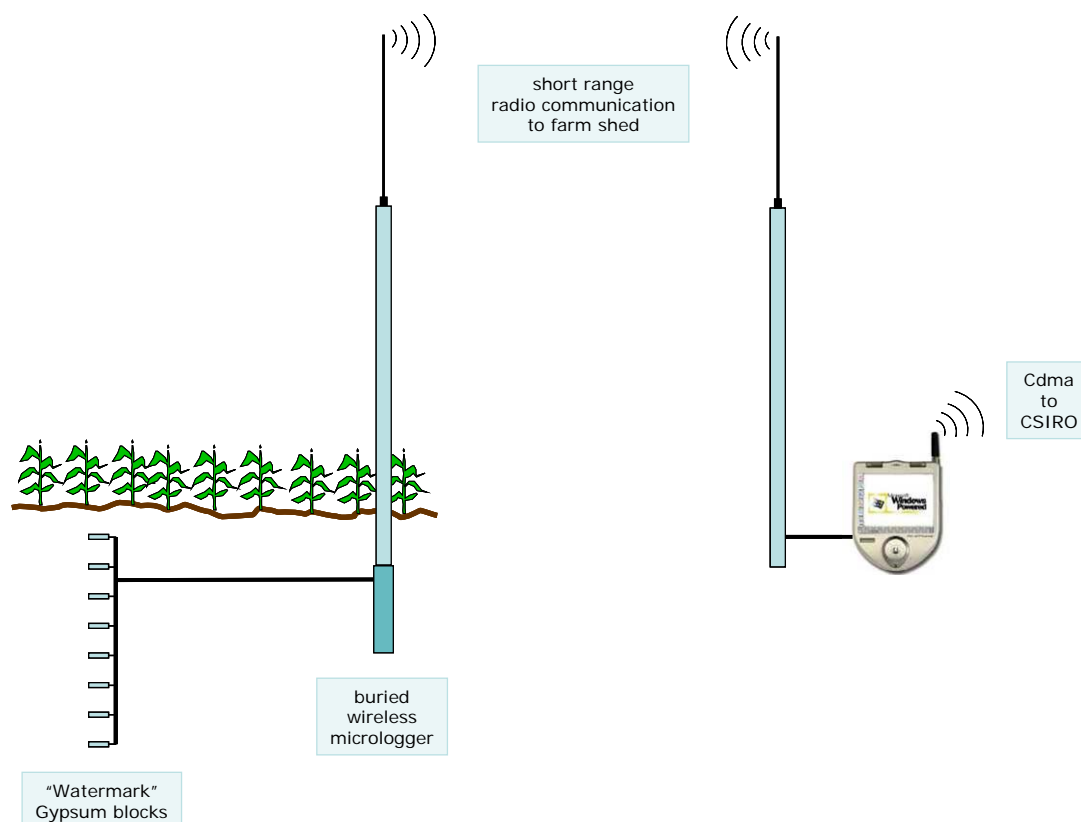


Figure A1 Overview of the measurement methodology.

At pre-programmed intervals (every 6 hours in this case), the microloggers read each sensor and radioed the results to a receiver located at the farm house 1 km away. The receiver was connected to a small computer with a built-in cdma telephone. The computer stored the sensor results. Once each day it connected to the internet via the cdma telephone and sent the day's data file to a CSIRO computer. Before 6 am each day, the previous day's data was automatically added to an excel spreadsheet and graphs of the data were updated. These graphs were copied to the web server and displayed on the project website. All going well, the previous day's data were available for viewing after 6 am each day.

Occasional glitches occurred when the radio link failed because of excessive interference, or the cdma signal was not strong enough for the call to be made. Built-in fail-safe procedures keep these to a minimum and prevent data loss when it does happen. Provided the microloggers kept functioning, the data could also be recovered directly from their memories and patched into the dataset at a later date, although this was not necessary in this case.

Watermark[®] gypsum blocks

The Watermark sensor was used for this project because it provides an inexpensive way to measure soil water status. It measures soil water potential rather than soil water content, which has advantages and disadvantages. Advantages include: inexpensive; easy to install; and provides an absolute measure of soil wetness or dryness. Disadvantages include: measurements cannot be directly related to soil water content or storage in mm; and the limit of accurate calibration is 200 kPa, whereas the theoretical lower limit for water extraction by crops is 1500 kPa.

The Watermark sensor is a type of gypsum block. These are porous blocks that wet and dry as the soil they are in contact with wets and dries. The water content of the block is measured by measuring its resistance. The gypsum in the block provides a buffer against background soil salinity so that it does not affect the resistance measurement.

The water content of the block does not equal the water content of the soil, but is related to the 'soil water potential' of the soil with which the block is in contact. Soil water potential provides an absolute measure of how wet or dry the soil is; a value of zero indicates that the soil is 'saturated', a value of ~10 to 20 kPa indicates that the soil is at 'field capacity' or 'drained upper limit', while a value of 1500 kPa indicates that the soil is at 'wilting point' - ie so dry that plants cannot extract more water from it. [In contrast for a measurement of water content to be interpreted relative to the soil's upper and lower limits, the actual water contents at these limits needs to have been determined previously for the specific soil.]

Sensors such as the Watermark, which measure soil water potential, require less care to be taken during installation. They do not need to be in intimate contact with the soil, as is required for most sensors that measure water content. Instead, the sensor can be bedded in a contact material (usually diatomaceous earth) that ensures good contact between the sensor and the soil and allow it to equilibrate with the soil's water potential. In contrast, if a soil water content sensor is bedded in a contact material instead of being perfectly in contact with the soil, it measures the water content of the contact material instead of the water content of the soil.

For more information, see [Appendix B: Interpreting the measurements](#).

Wireless microloggers

The Wireless micrologger has been custom-designed by CSIRO Land and Water. Each logger can measure up to 8 sensors. At a pre-programmed time (or times) each day, the logger automatically turns on, measures the sensors and stores the data. Every time measurements are made, the logger has the capability to radio the results to the receiver, as described below. Alternatively, to save power, results from several measurement times can be radioed together.

The micrologger has been designed to be buried and left unattended for long periods of time. It has a low power requirement, and its high capacity batteries will last several years at daily or sub-daily measurement intervals. The data are stored in memory (up to 5,000 individual measurements can be stored), so that if radio transmissions are interrupted, the data can be recovered by manually interrogating the logger with a PC.

Each logger is sealed in a watertight PVC housing and lowered down a PVC casing. While the casing extends to the soil surface, the top of the logger is at least 0.3 m below the soil surface. Thus, although the top of the casing may occasionally be damaged by, for example, tillage operations, the logger remains protected. However, to transmit the radio signal, an antenna needs to protrude above the soil surface. This is designed to be easily laid down on the soil surface to permit spraying operations and easily disconnected and re-connected at sowing and harvest.

Radio communication

The radio signal from the logger is transmitted through the antenna protruding 2 to 3 m above the soil surface, to a similar antenna connected to a receiver located at some distance away (up to 10 km under ideal conditions).

Telephone link

The radio receiver is connected to a pc-EPhone[®], a combined cdma telephone and personal digital assistance running the Microsoft Windows CE operating system. Custom software running on the pc-EPhone receives and stores the measurements sent by the microloggers. At a pre-programmed time each day, the pc-EPhone connects to the internet and uploads the data to a CSIRO ftp site. Should a cdma connection not be able to be established, the data is kept in protected storage to be sent the next day. If the cdma link fails completely, the stored data can be downloaded to a PC or to a compact flash card.

Loading the data to the web page

Each morning, software running on a CSIRO server automatically copies any incoming data files from the ftp site, processes them, and adds them to an excel spreadsheet. This spreadsheet updates charts of the data and saves them as "gif" images, which are uploaded to the web page and are immediately available for viewing. While the quality of the charts is not extremely high, they are small files (< 15 kB) that can be downloaded quickly even on slow dial-up lines.

Appendix B. Interpreting the measurements

The measurements reported were made with Watermark[®] gypsum blocks, as described in Appendix A. Gypsum blocks measure soil water potential, not soil water content. The two are related, but not uniquely; the relationship is not linear (it is in fact close to logarithmic) and varies with soil type and from place to place within a given soil type as individual soil properties vary.

Unlike soil water content measurement, water potential measurements cannot, by themselves, indicate how much water is stored in the soil and available for crops. Soil water potential measurements are, however, much easier and cheaper to make than soil water content measurements and still provide much useful information.

Soil water potential provides an absolute measure of how wet or dry the soil is:

- a value of zero indicates that the soil is saturated - ie. water will ooze from the soil;
- a value of ~10 to 20 kPa indicates that the soil is at field capacity or drained upper limit - this is the practical upper limit of wetness; a well-drained soil, would rarely spend more than a day or two wetter than this
- a value of 1,500 kPa indicates that the soil is at wilting point - ie. so dry that plants cannot extract more water from it.

In contrast, a measurement of soil water content can only be interpreted in this way if the values of water content at these three limits (saturation, drained upper limit, and wilting point) are known in advance, which is usually not the case.

Temperature effects

A complication in interpreting measurements from gypsum blocks, and most other soil water sensors (including the very expensive ones), is that they are temperature dependent. Their output is affected not only by water content, but also by the soil temperature at the time of the measurement. Soil temperature changes in response to air temperature, although the magnitude of the change in soil temperature decreases with depth.

At shallow depths (less than about 200 mm), soil temperature reaches a peak in early afternoon and a low around dawn. Because of the time it takes for the soil to heat up and cool down, these daily variations are not seen below 200 mm, and so aren't a concern for the measurements reported here, the shallowest of which is at 200 mm. However, the seasonal oscillation in air temperature shows up at much greater depths, because in 6 months heat can travel down as far as 2 meters into the soil and cause a temperature rise. The seasonal oscillation of the Watermark gypsum block output caused by temperature is illustrated in Fig. B1.

The consequence of the temperature effect on gypsum block measurements is that some extra care is required when interpreting their output:

- in spring and summer, a gradual wetting in gypsum block output is more likely to be a result of increasing soil temperature than an increase in soil wetness
- in autumn and winter, a gradual drying in the gypsum block output is more likely to be a result of decreasing soil temperature than a decrease in soil wetness

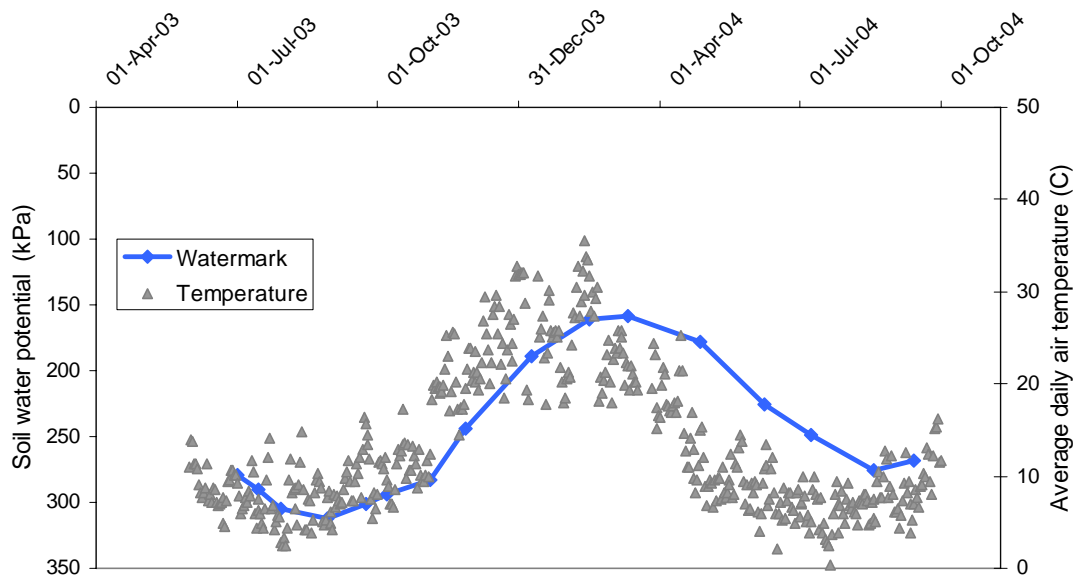
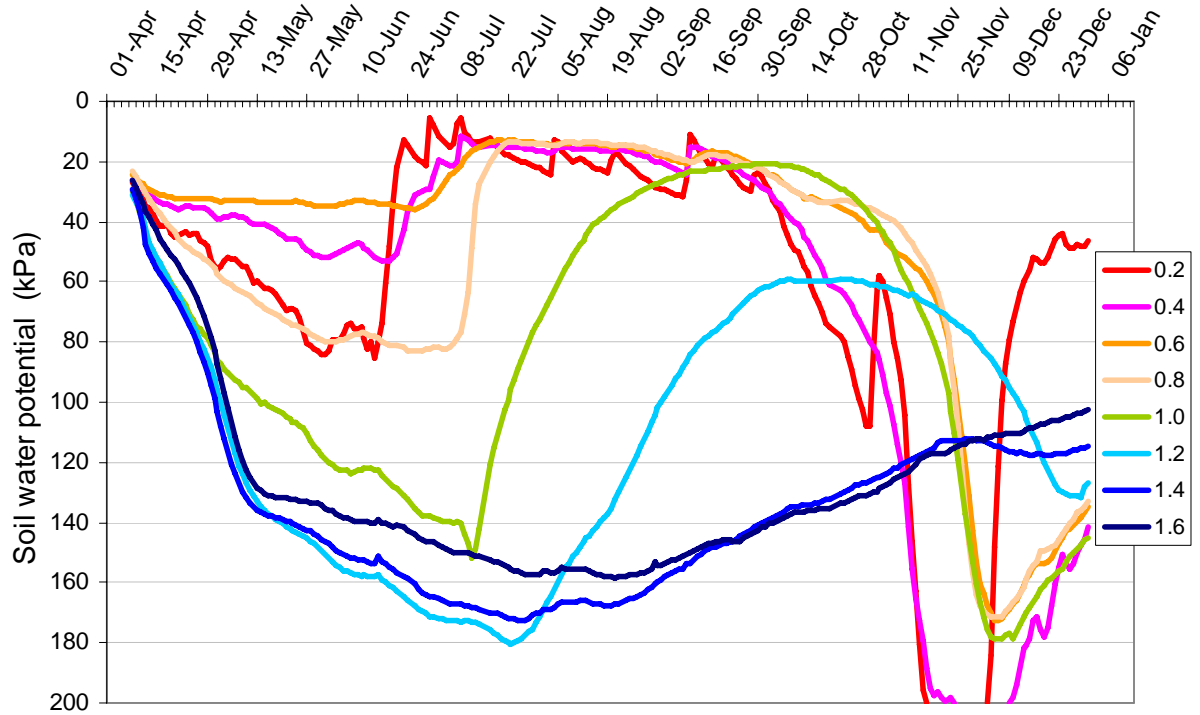


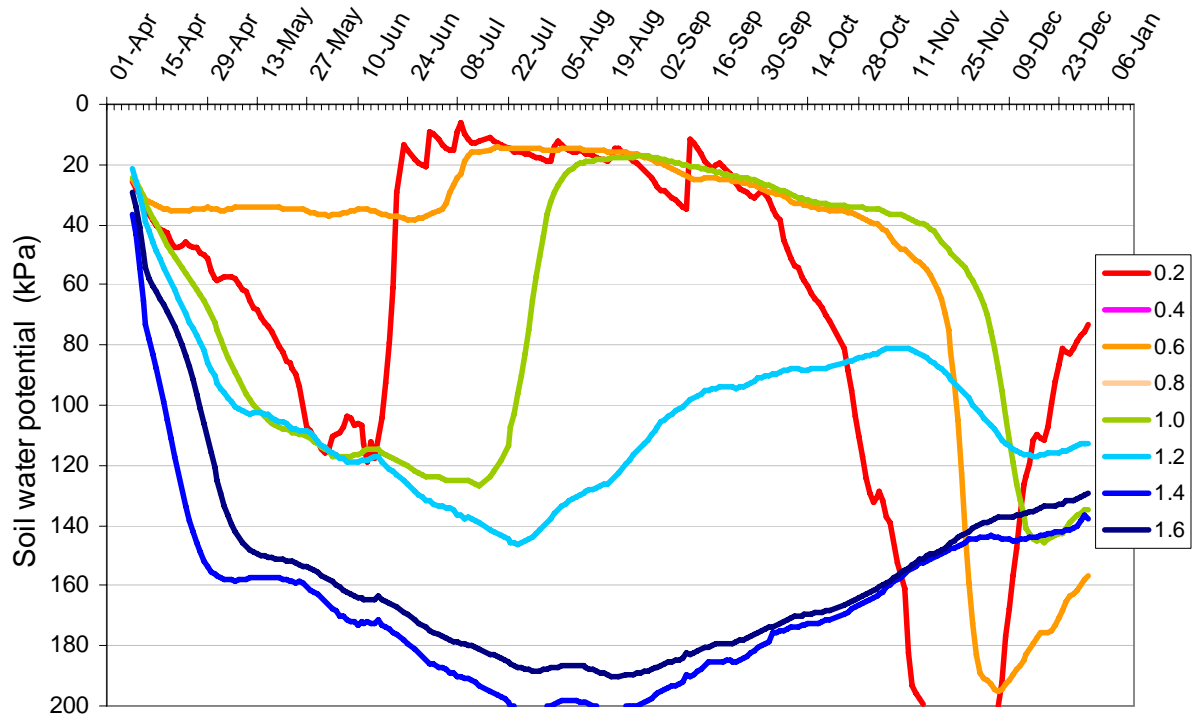
Figure B1 Soil water potential measured by a Watermark[®] gypsum block for a 12 month period at a depth of 1.7 m in a paddock at Charles Sturt University, Wagga Wagga. Independent measurements of soil water content with a neutron probe showed no variation during this period, because the soil had been previously dried by lucerne and there was insufficient rainfall to rewet it. The oscillation correlates with observed air temperature, subject to a lag of about 1 month.

Appendix C. Data Summary

Whistler (grazed)



Wedgetail (ungrazed)



Diamondbird

