Accounting for cotton water use and productivity: A tool to estimate on-farm water use efficiencies

Sunil Tennakoon, Scott Johnston and Stephen Milroy

CSIRO Cotton Research Unit, Australian Cotton Cooperative Research Centre, Narrabri, NSW, http://cotton.pi.csiro.au Email sunil.tennakoon@csiro.au , scott.johnston@csiro.au , steve.milroy@csiro.au

Abstract

Cotton farmers need strategies and tools to assist in monitoring water use with a view to improving efficiency. Simple water accounting can be used for analysing the use, loss and productivity of water on a whole farm basis. This is important for assessing the impact of farm and field level management on the water use, identifying areas of potential water savings. For this, a standard method for measuring, recording and analysing water use is necessary to make a valid comparison of water use efficiencies between fields, properties and seasons.

A user-friendly software tool was developed to assist cotton growers to record, analyse and assess the performance of individual fields and whole farm water use efficiency using readily collected on-farm data. Both production and quantitative water use efficiencies are considered, including the overall irrigation water losses within the farm. Irrigation efficiency is calculated as the proportion of water input to the farm used by the crop as evapotranspiration (ET). Crop water use efficiency is calculated as the efficiency with which water used as ET is converted to lint yield. Crop water use is estimated using observed soil moisture data and simulated daily ET values. This system enables irrigators to identify the fate of water within the farm, identifying points of loss and potential areas for improvement. The terminology and framework presented here have been developed for general use on a typical Australian cotton farm. The beta version of the tool is currently being evaluated under field conditions by Cotton CRC extension personnel in Queensland. The primary limitation to the tool's use is the availability of appropriate data. The most common limitations are information on water use from on-farm storages and water harvesting. Where more than one field is irrigated at a time, the proportion of water going to each crop is also generally unknown. The software does not account for losses from farm storages outside the growing season, which can be considerable. This is an area for future development.

Key words

Irrigation scheduling, irrigation efficiency

Introduction

Recent reductions in water allocations to irrigators have increased the need to improve on farm management of water resources. Effective strategies need to be formulated to increase productivity while reducing any environmental impact. Losses and non-productive uses must be carefully scrutinized to identify potential savings. To achieve this, procedures for accounting for water use and productivity need to be developed and implemented. Water accounting is a procedure for analysing the use, loss and productivity of water on a whole farm basis. This is important for assessing the impact of farm and field level management, on water use and to identify areas of potential water savings. For this process a common framework is required to describe water use and water use efficiency (WUE) on the farm. Further, use of a standard method for measuring, recording and analysing is necessary to allow valid comparison of WUE between fields, properties and years. Therefore, a user-friendly software tool was designed for cotton farmers to assess the performance of individual fields and the whole farm using a minimum set of measurements.

The accounting procedures and standards described here are tailored to the needs of an irrigated cotton farm. Many Australian cotton farmers collect and record on farm water use and weather data for the purpose of water management (1). However the data are under utilised. Standard procedures to measure, record and analyse the information are required. Therefore, a desktop methodology was designed and developed, based on a water balance approach, to utilise the types of measurements made by the growers to derive estimates of the efficiency of water usage. A number of different sources of water inputs (surface water, ground water, in-season rainfall and moisture stored in the soil profile) are available. These inputs need to be separately estimated and recorded along with water outputs such as evapotranspiration and surface and subsurface drainage.

Methodology

Crop water use efficiency (CWUE) is defined as the lint yield (kg/ha) produced per millimetre of water evapotranspired from a cotton field during the growing season. Farm water use efficiency is defined as the number of bales (227kg) produced per unit of total water input or per unit of irrigation water input at the farm level. The farm level irrigation efficiency was calculated as the percentage of irrigation inputs at the farm gate that were used in evapotranspiration during the growing season. The time scale used in these definitions was the growing season from sowing to harvest (October to March) which thus excludes the water losses from farm storages that occur outside the growing season. The required data include neutron probe soil moisture readings, date of sowing, harvesting and irrigation, lint yield, total cotton area, irrigation inputs and weather data (rainfall, max & min temperatures, wet bulb temperature and total solar radiation). The actual crop water use (ET) is estimated by means of moisture changes in the soil profile during the growing season. Daily basis volumetric moisture content in the soil profile is estimated for the whole season using measured and simulated data (2).

A user-friendly interface has been developed for easy operation of the system. This can be used to assess performance of individual fields and whole farm water use efficiencies with a minimum data set. The program requires the basic details of the farm such as elevation and latitude. For a particular season, the production and water-input data required are the total area of irrigated cotton, total number of bales produced, total water pumped, total amount of water used for other crops during the season, amount of water used from storage and the on-farm harvested water. Daily basis weather data is also required. This data can be accessed from an on-farm weather station or from the nearest Bureau of Meteorology weather station via the SILO web site. It is important to use on-farm rainfall data because of its high spatial variability.

Minimum system requirements for this program are: IBM PC or compatible (Pentium 100 MHz or faster), CD-ROM drive, Windows 95 / 98 / NT / 2000 /XP, 16 MB RAM, 10 MB free hard disk space and 640 x 480 display or better. The software can be easily installed using the CD Rom and the user-friendly interface helps to run the program with minimum computer knowledge.

Table 1. Sample output from software showing the water use summary for the whole farm.

Season	**98/99**
Total water pumped (bore) ML	0
Total water pumped (river) ML	7447
?	
On farm storage at planting ML	6250

On farm harvested during the season ML	3710
On farm storage at harvesting ML	3975
Used from farm storage ML	5985
Water used for other crops ML	2300
?	
Total irrigation applied on cotton mm	363
Rainfall	
Growing season rainfall mm	518
Total effective rainfall mm	347
Used Soil reserve mm	119
?	
Total seasonal water usage mm	830

Field level analysis

At the field level, CWUE is lint yield produced per millimetre of water depleted as evapotranspiration. Components of the water balance are a function of crop and cultural practice. Practices such as mulching, crop spacing, rotation and tillage affect the amount of water stored in the soil, runoff and deep percolation in addition to final yield.

Planting, harvest and irrigation dates (and quantities if available) yield and measured soil moisture information are entered. The software estimates daily ET and hence a daily soil water balance. Soil moisture is adjusted for observed values. From the water balance, the total seasonal crop evapotranspiration is derived. The contributions to ET from irrigation, in-season rainfall and the soil moisture reserves are estimated. CWUE is then calculated from the derived ET and the observed yield.

Farm level assessment

At the farm level, the focus is on irrigation inputs at the farm gate and beneficial output as crop ET. As compare to field level, there are more opportunities for water losses such as evaporation from free water surface and conveyance losses. The water use summary (Table 1) for the farm is calculated. The rainfall and soil reserve depletion are average values computed from individual fields. Table 2 shows the amount of water used from different sources during the season, the amount of irrigation water used in ET and the seasonal evapotranspiration.

Table 2. Sample output from software showing the water use summary for the farm over the growing season on a per area basis.

Water use summary	
ML/ha pumped	2.42
ML/ha effective rainfall	3.47
ML/ha harvested	1.21
ML/ha used soil reserve	1.19
ML/ha total water usage	8.30
Irrigation water used in ET mm	226
Total seasonal crop water use (ET) mm	690

An example of water use efficiencies calculated for a farm is given in Table 3. The total seasonal farm water usage includes pumped water from river and bores, amount of water used from storage, the amount of in-season rainfall infiltrated into the soil profile, the amount of harvested water and the depleted soil reserves during the growing season.

Table 3. Sample output from software showing details of water use efficiency for the farm.

Crop water use efficiency	
kg/ha/mm	2.06
ton/ML	0.21
Farm water use efficiency	
ton/ML (Total water)	0.17
ton/ML (Irrigation water)	0.39

Irrigation efficiency	
Overall farm Irrigation efficiency	0.62

Discussion

The output from the software can be used to compare a grower's performance with industry benchmarks or with neighbours' performance to suggest areas for improvement. An analysis of whole farm water use efficiency in the cotton industry (3) has indicated that, in general, there is most potential for improving efficiency via irrigation efficiency. However some properties perform well in this aspect. It, therefore, becomes necessary to assess an individual property to see if potential for improvement exists. The software is well suited to this application. At the field level, there is a trend for some producers to over irrigate and so depress CWUE. The software can also be used to suggest whether this is likely to be occurring. A key application will be to monitor changes in efficiency between years.

The primary limitation to the tool's use is the availability of appropriate data. The most common limitations are information on water use from on-farm storages and water harvesting. This can be over come by monitoring the level of water in the storage and converting this to volume. Apparatus to automatically monitoring water levels is available, but manual measurements before and after major run off events and extractions would suffice. An alternative approach is to meter extraction directly at the pump. Where more than one field is irrigated at a time, the proportion of water going to each crop is also generally unknown. This is somewhat difficult to resolve. The proportion of water flowing into the different supply channels could be monitored and applied to the total water pumped from the source. This begins to move away from the farmer-friendly philosophy on which the software was developed, although more growers are installing flow metres in their reticulation systems.

The software does not account for losses from farm storages outside the growing season, which can be considerable (P. Dalton, University of Southern Queensland, personal communication). This is an area for future development. Estimations of deep drainage and surface runoff will be included. If the trend toward more monitoring of flows in the reticulation continues, the program could also be modified to derive storage, conveyance and application efficiencies.

Acknowledgements

The Cotton Research and Development Corporation provided partial financial support for this project. Feedback from the water use efficiency officers of the Australian Cotton CRC is appreciated.

References

(1) Tennakoon, S.B. 2000. Final Project Report to CRDC and CSIRO, Australian Cotton Research Institute, Narrabri, NSW.

(2) Ritchie, J.T. 1972. Water Resource Res., 8: 1204-1213.

(3) Tennakoon, S.B. and Milroy, S.P. 2000. Proc. Irrigation Australia 2000 Conf., Melbourne.