MANAGING WATER USE EFFICIENCY ON FARMS

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Maximising water use efficiency (WUE) means maximum returns from a scarce resource. In addition, increasing public debate about water use adds a political imperative to get it right. A survey of current performance shows that while some growers are performing well, others have aspects that require attention.

The first step toward managing WUE is to measure current performance. Proper measurement will provide a comparison against the performance of other producers in your area and against industry standards. It will also help identify where losses are occurring.

Introduction

Water use has become an important issue locally and globally. There is increasing competition between agricultural, industrial, domestic and environmental sectors. Concurrent with this increase in competition, there has been increasing public debate about water and environmental issues. This imposes additional pressure on irrigators, including cotton growers, to be accountable for the way water is used.

Even without these external pressures, water use efficiency (WUE) is a key issue for producers. If water is a limiting resource, optimising production per unit of available water is clearly an important component of maximising returns. Further, inefficiencies in water use may indicate losses from the system which can cause additional difficulties on the property: excessive run-off leading to erosion, seepage leading to localised ground water rise and possibly salinisation.

To assess the current water use efficiency within the cotton industry we calculated water use efficiency at the crop and the farm level using producers' historical water management data. A whole farm water use efficiency was calculated and then two components of this: the efficiency with which water was supplied to the crop (irrigation efficiency) and the efficiency with which the crop converted the water it actually used into lint (crop water use efficiency). Our results indicate significant opportunities for improving water use. Using this simple technique, producers can assess their own water use efficiency and compare their performance to others in their area or to industry benchmarks.

Indices of Water Use Efficiency

The overall efficiency of production of a cotton farm can be characterised using a whole farm water use efficiency (FWUE); calculated as the lint production (bales) per unit of water supplied for crop production.

FWUE (total water)=total yield (bales)/total seasonal water supply (ML).

This index takes into account all available sources of water including rainfall, irrigation water from rivers or bores and possibly overland flow. When assessed over a growing season the depletion of stored soil moisture may also be considered an input. FWUE can be simply transformed into an economic efficiency by multiplying yield by market price.

For irrigated production, FWUE can also be calculated on the basis of irrigation water inputs alone:

FWUE (irrigation water)=total yield (bales)/applied irrigation water (ML).

While this approach has a certain appeal for gauging the efficiency with which irrigation water is used, the efficiency figure obtained is heavily dependent on the initial soil moisture storage, and the amount of rainfall the crop receives. It is therefore less useful for comparing efficiency between seasons or locations or for evaluating water savings than FWUE based on total water.

The water inputs for crop production are dissipated through a number of mechanisms. Non-beneficial losses include surface run off, deep drainage, and application and storage losses. Evapotranspiration can be considered to be the water that is productively used by the crop. This is the water transpired during the course of the season, together with a certain amount of water which is inevitably evaporated from the soil surface and free water surfaces within a cropped field. Evapotranspiration can be used to divide FWUE into its two primary components: irrigation efficiency and crop water use efficiency as described below.

Irrigation efficiency (IE) can be calculated at the whole farm level by calculating the percentage of irrigation water actually used by the crop (as evapotranspiration) relative to the total irrigation water inputs at the farm level available during the growing season.

$$IE = \frac{ET - RI - SM_D}{\text{Total water supplied from rivers, bores and storages}}$$

ET = Evapotranspiration over the growing season, RI = Rainfall that infiltrates in the crop, SM_D = Soil moisture depleted over the growing season.

This is different from the efficiency of a single irrigation event at the field level. IE based on single events cannot be used to make assessments and recommendations at the whole farm level. The harvesting and reuse of tail water means that the water is not lost from the farm system, although it is generally assessed as a loss when considering a single irrigation event. Thus, it is possible for the irrigation system of the whole farm to be more efficient than a single irrigation.

The ratio of water inputs and water outputs at different points of the irrigation system can be calculated to reflect the efficiency of different components of the farm system. Storage, conveyance, application and distribution efficiencies are commonly used indices. The index for whole farm irrigation efficiency used in this paper groups all these components.

Crop water use efficiency (CWUE) is the lint yield (kg/ha) produced per millimetre of evapotranspiration used over the growing season. This index quantifies how efficiently the crop produces lint yield from the amount of water actually consumed by the crop.

CWUE (kg/ha/mm) = lint yield (kg per ha) / seasonal evapotranspiration (mm).

It should be noted that since CWUE and FWUE are ratios that include the yield of the crop, they can be effected by any factor which alters yield, not only those relating to water management.

Assessing Current WUE in the Cotton Industry

To assess the current water use efficiency within the cotton industry we calculated the above indices using producers' historical water management data. Data were collected from approximately 25 farmers across the major cotton growing areas. The following information was collected for the last few years depending on availability.

<u>Field level</u> (3-4 fields per farm per season): Neutron probe readings, date of sowing and harvesting, dates of irrigation, lint yield, previous crop, and soil type

Farm level: On farm daily rainfall data, total cotton area, total water pumped (for cotton) from the rivers (ML), total water pumped (for cotton) from bores (ML), total water harvested on farm and stored water used (ML)

Other than daily rainfall, the climatic information required for the analysis was obtained from the nearest meteorological station.

Firstly, FWUE was calculated. We then calculated actual crop water use (evapotranspiration) and thence CWUE and IE. All efficiencies were calculated across the whole growing season: from sowing to harvest. Water losses occurring in storage outside the growing season were not included in the calculation.

Since evapotranspiration was needed for calculating both CWUE and IE, a good estimate was needed to allow us to partition FWUE into its components. Evapotranspiration was calculated from a combination of observed soil moisture changes (from neutron probes) and a daily soil moisture balance. Probe data were used when possible to allow a direct calculation of water use. When probe data were unavailable or were interspersed with unmeasured rainfall, evapotranspiration was calculated from meteorological data using the modified Ritchie (1972) model. In this model, deep drainage losses are considered negligible.

Measured Water Use Efficiency

Farm water use efficiency

The average yields across the participating farms are given in Table 1 along with the evapotranspiration and the water use efficiencies derived. Farm water use efficiency varied from 0.38 bales/ML to 1.27 bales/ML when based on total water input and from 0.43 bales/ML to 3.28 bales/ML when based on irrigation water inputs. Examining the components of FWUE (CWUE and IE) allows us to explore the sources of this variation.

Table 1. The average yield from participating farms (bales/ha), evapotranspiration and the water use efficiency indices calculated. Numbers in parentheses indicate the observed range.

	1996-1997	1997-98	1998-99
Yield (bales/ha)	8.14	8.38	7.66
Evapotranspiration	760 *(670-698)*	755 *(626-888)*	694 *(623-737)*
Farm WUE (bales/ML):			
Total water	**0.73**	**0.76**	**0.88**
Irrigation water	1.18	1.19	1.86
Crop WUE (kg/mm)	**2.49** *(2.06-2.62)*	**2.52** *(2.03-2.95)*	**2.52** *(2.34-3.17)*
Irrigation efficiency (%)	**54** *(0.20-0.80)*	**55** *(0.29-0.86)*	**66** *(0.36-0.76)*

Crop water use efficiency

The average CWUE observed was 2.5 kg/ha/mm. There was a high degree of variability between producers but the average was very similar for the three seasons of the study. The maximum CWUE observed for a farm was 3.2 kg/ha/mm and the lowest was 2.0 kg/ha/mm (Table 1).

To examine the effect of crop water use on lint yield, the yield from individual fields were plotted against seasonal evapotranspiration by the crop. There was a positive relationship between evapotranspiration and yield up to about 700 mm. However, beyond this, additional water consumption did not increase yield (Fig. 1). This relationship has been demonstrated previously in experimental data. The broken line in the figure is the relationship derived by Orgaz and co-workers (1992) who studied water use by cotton when managed with different irrigation deficits. Our results demonstrate that the relationship applies in the commercial situation also. The yield plateau results from a decline in the proportion of lint produced relative to the whole plant weight (Orgaz et al. 1992). The total dry weight produced continues to rise above an evapotranspiration of 700 mm but, while there is more vegetative growth, there is no increase in reproductive output.

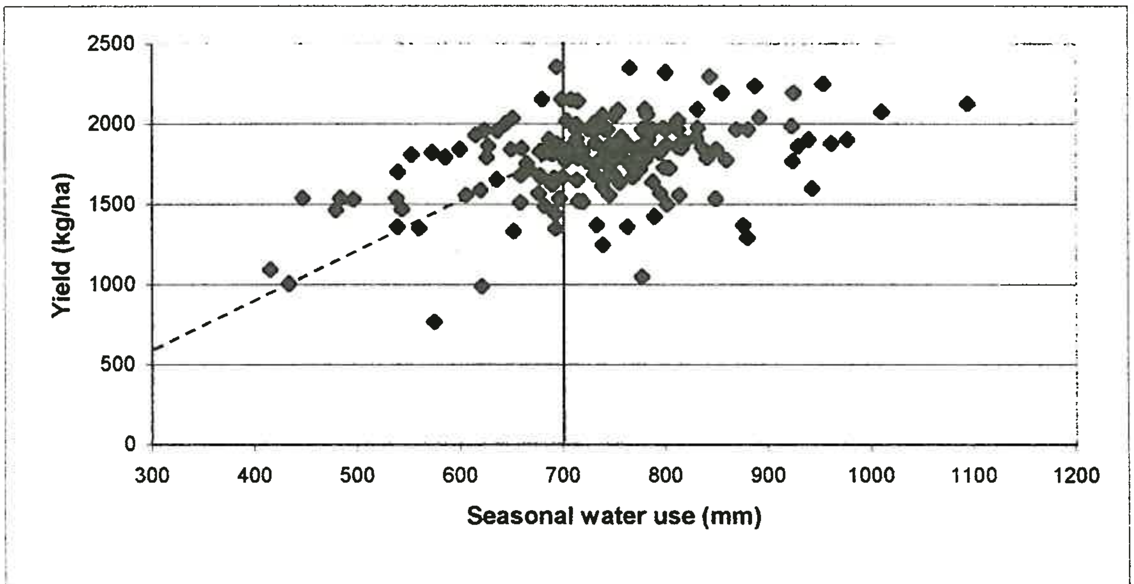

Figure 1. Relationship between lint yield (kg/ha) and seasonal evapotranspiration (mm) obtained from producer's data. The broken line shows the relationship found by Orgaz and co-workers (1992) from experimental studies.

As a result of the relationship between evapotranspiration and yield, CWUE was relatively constant up to 700 mm and then declined (Fig 2). The average CWUE for crops using up to 700 mm was 2.7 kg/ha/mm, indicated by the broken line. Combining the responses for CWUE and yield, the target evapotranspiration for a crop should be taken to be around 700 to 800 mm. Below this level, yield is being sacrificed. Above this, water is being wasted with no advantage in yield being achieved. Further, the risk of waterlogging is increased (Hearn and Constable 1984).

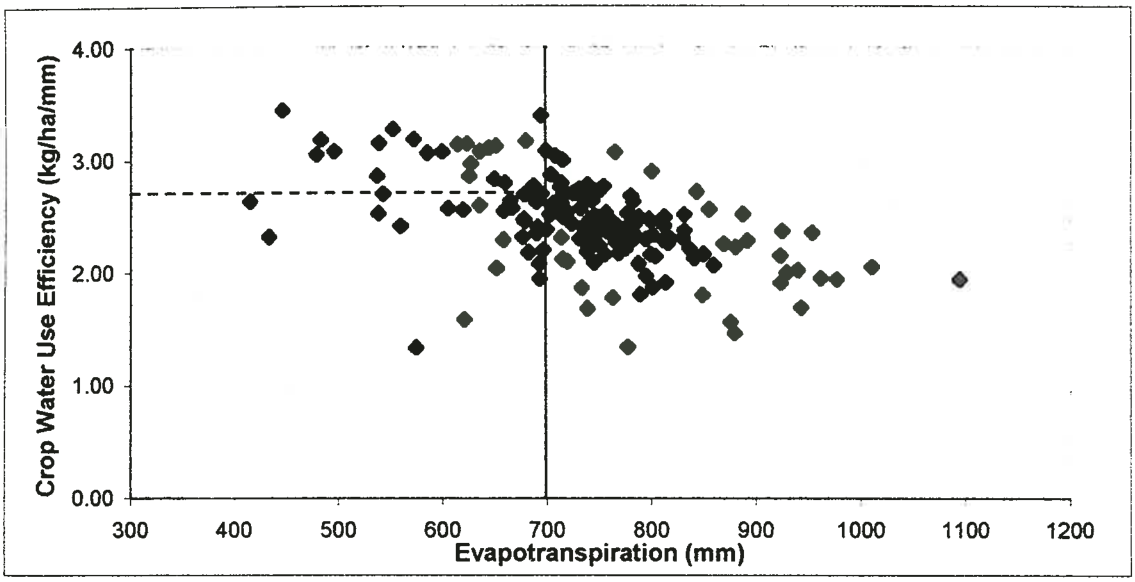

Figure 2. Relationship between crop water use efficiency and evapotranspiration for individual fields in this study. The broken line indicates the average CWUE (2.7 kg/ha/mm) for fields where evapotranspiration was less than 700 mm.

There are a number of management options which can be manipulated to help achieve evapotranspiration in the target range. In situations of excessive evapotranspiration, the most apparent factor to consider is irrigation strategy. Excessively frequent irrigation is known to promote vegetative growth at the expense of fruit. This in turn increases the crop water demand further. Mild water stress prevents excessive vegetative growth and promotes yield development. Optimal irrigation strategies have been explored in the past by a number of authors including Constable and Hearn (1981) and Hearn and Constable (1984).

High nitrogen predisposes a crop to excessive leaf development. Clearly, a proportionately high water supply is also needed, but if this should become available through rainfall or over irrigation, excessive nitrogen will promote luxuriant growth. Nitrogen application rates based on soil testing will prevent over application. Whether high levels of nitrogen or water are anticipated or not, monitoring crop vigour will allow timely application of Pix if excessive vegetative growth begins.

If evapotranspiration is too low, again the first management factor to examine is irrigation strategy. Irrigation interval and the timing of the first irrigation are obviously basic to developing a plant of adequate size. The impact of inadequate water supply is to reduce evapotranspiration and yield proportionately. The result is a low yielding crop but with

CWUE not effected. Inadequate nitrogen has the same impact. Leaf area is very sensitive to low nitrogen. Low leaf area in turn reduces evapotranspiration and yield.

Variation in CWUE can occur not only through water supply but it is also influenced by any management factors affecting yield such as nutrient, insect, weed and soil management. This causes the vertical scatter of points in Figures 1 and 2, seen at all evapotranspiration levels. Some of these factors may act through reducing plant size and hence cause a commensurate reduction in yield and evapotranspiration. However, if the development of the fruit is effected disproportionately compared to vegetative growth, the result can be a reduction in yield with little reduction in water use; and hence a reduced CWUE. Insect damage can suppress yield directly through the loss of fruit and hence depress CWUE. It is also possible that if there is sufficient time and resources available to the crop it may promote excessive growth due to the removal of the fruit demand on resources.

Hearn (1997) proposed a target for CWUE of 3 kg/ha/mm. This is a high but achievable objective for commercial properties; being exceeded in a number of the commercial crops in our study (Fig 1). However, the wide variability in CWUE as seen in Fig 1 and the predominance of CWUE values below 3 kg/ha/mm, indicate that there is considerable room for improvement on some farms. A CWUE of 3 kg/ha/mm can be achieved by yielding 9.3 bales per hectare with 700 mm seasonal evapotranspiration. Improving CWUE from 2.5 to 3 kg/ha/mm with 700 mm seasonal evapotranspiration will result in producing an additional 1.25 bales per hectare with the same water use or a saving of about 17% of water which could be used for the production of additional irrigated crops.

Irrigation efficiency

Whole farm irrigation efficiency in our study averaged 57% (Table 1) but there was a large variability. The observed irrigation efficiencies for individual properties varied from around 25% to 80%. The results indicate that the irrigated cotton crop actually uses just over half of the irrigation water supplied at the farm level. Around 40 to 45% is lost within the farm system through conveyance, storage and application losses or improper scheduling. Clearly, with some properties having figures as low as 25%, identifying where these losses are occurring and rectifying the problems presents significant opportunity to improve the efficiency with which irrigation water is used. Paul Dalton and Steve Raine of The University of Southern Queensland are currently conducting research to develop methods that can be used by producers to identify where irrigation water is being lost during storage, distribution and application and to improve application techniques. Evaporative losses have been shown to be a large factor in IE.

As for the CWUE, Hearn's (1997) proposed target for IE of 75%, is a high value but achievable. It was achieved in 10% of the year x season combinations in this study. Because of the constraints of location, farm design and soil type not all producers will be able to approach this objective without significant capital investment. However, if very low IE is indicated, there are clearly grounds for further investigation using some of the techniques being developed by The University of Southern Queensland.

Recommendations

The most important step toward managing water use efficiency on farm is to start measuring your water use. The wide variation in both CWUE and IE indicates that there is significant potential for many producers to increase their efficiency. The data requirements for the type of analysis conducted here are relatively simple and are already collected by many producers, although the full set is rarely recorded on any one farm. In collaboration with the CottonLOGIC team, a software tool is being developed to assist producers to record the appropriate data and analyse their water use efficiencies at the field and farm level. It will allow proper comparisons to be made against benchmarks or other local producers. It will also assist in identifying ways of increasing efficiency specific to a producer's property.

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