

Getting the Most From Every Megalitre/Millimetre of Available Water

Dallas Gibb, Cotton Development Officer, CRC, Moree

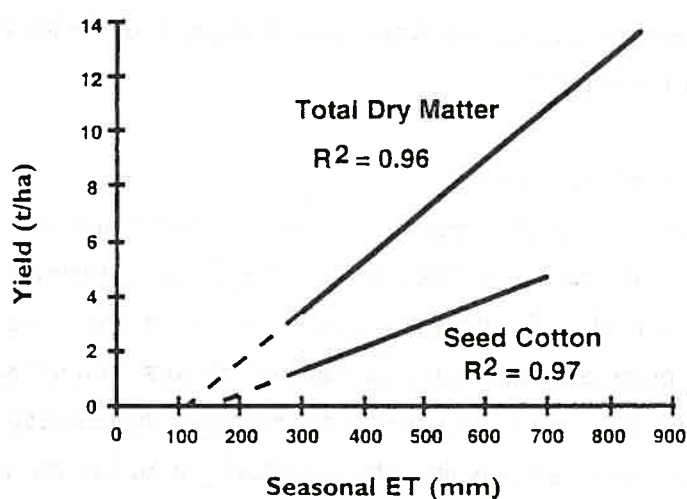
Farm management must be geared towards maximising on-farm water supplies and minimising any water loss. If this is achieved, maximum water use efficiency and returns per megalitre or millimetre of stored water will be achieved. The key to getting the most from every megalitre of water available is developing a water management plan.

In developing a water management plan, farm water use efficiency can be broken down into three segments - plant, agronomic and irrigation efficiency. This paper will briefly discuss important aspects which can effect plant water use but mainly concentrate on water management efficiencies (agronomic and irrigation fallow efficiency). Topics relevant to both irrigation and dryland cotton production are discussed.

Plant Water Use Efficiency

Plant water use efficiency (WUE) can be defined as that amount of plant growth produced per unit of water consumed by the plant (kg/mm). It is important to accept the idea that in isolation plant WUE (biological efficiency) remains constant, independent of the amount of water available for growth. This is shown in figure 1, which illustrates the relationship between evapotranspiration (ET - total crop water use) and vegetative and seed cotton yield, (evaporation is assumed to be constant) (Hearn 1995).

Figure 1 Cotton Yield as a function of seasonal evapotranspiration (ET) (Hearn, 1995)



For growers, this means that for every extra amount of water that can be made available for plant consumption, a consistent harvest index may be achieved. Accepting this implies that farm and crop management are the major factors effecting water use efficiency.

Crop water use efficiency for irrigated cotton has been measured around 1.3 bales/megalitre. For dryland crops this may be reduced to 1.0 bales/MI or 2.2 Kg lint/mm of plant available water. These values can be used as benchmarks. Growers should assess their own level of water use efficiency and if significantly lower than the above values, farm and/or crop management may need to be altered in the future so as to lift WUE values. The value of every extra millimetre of water made available for crop growth for different crops is shown in Table 1.

Table 1 Crop water use efficiency
(kg/mm and \$/mm produced per mm of available water)

Crop	Water Use Efficiency	Price/T	Value of Stored Moisture \$/mm
Wheat	9.5 kg/mm	180	1.71
Sorghum	8.4 kg/mm	180	1.51
Sunflower	4.0 kg/mm	350	1.40
Chickpea	5.0 kg/mm	320	1.60
Mungbean	5.5 kg/mm	430	2.48
Cotton	2.2 kg/mm	1988*	4.36

* \$450 per bale (QDPI Ref. Q 194039)

The minimum water requirement before any yield can be expected to be produced is estimated to be between 125 and 150 mm. Evaporation may contribute 80% of this water requirement.

Developing Water Use Efficient Varieties

Plant breeders utilise the fact that crop WUE remains constant by measuring the ratio between photosynthesis and transpiration. This measurement indicates how much carbon dioxide (CO₂) is being fixed by the plant per unit of water transpired (CO₂/H₂O). The greater this ratio, the more WUE the plant. The objective is to screen different cultivars with the hope to combine better WUE characteristics into adapted cultivars. (Refer to paper by Stiller and Constable in these proceedings for further details).

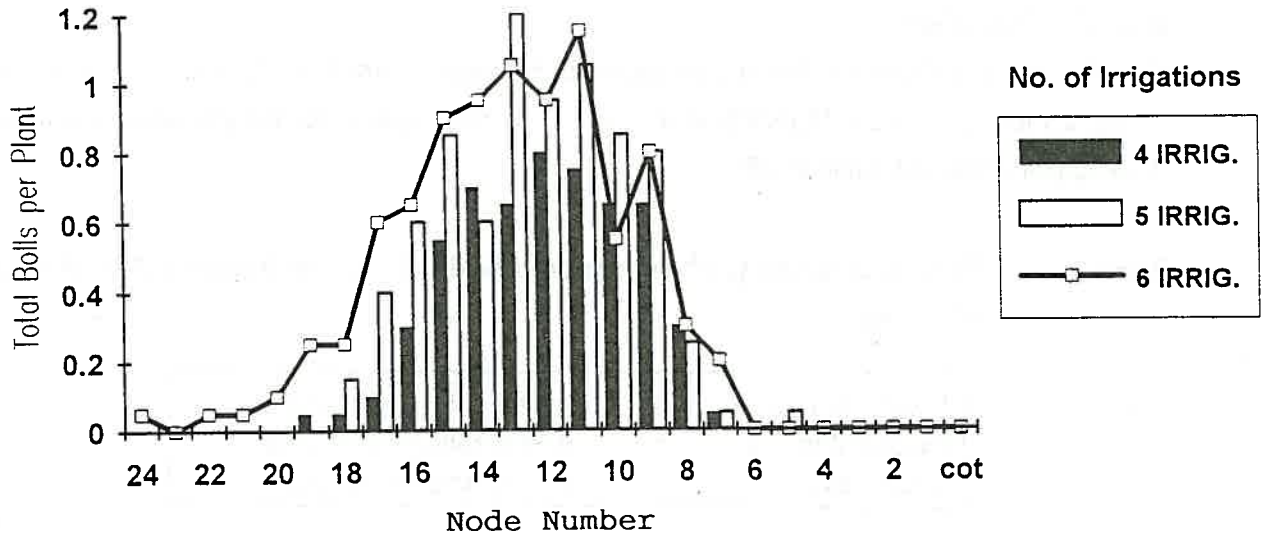
Water Allocation With Limited Water

Accepting that a constant relationship exists between crop water use and yield, one can appreciate that to maximise returns per hectare growers should reduce their area of production so that the crop can be produced as if under full irrigation. Such a strategy is a low risk option and is correct, provided other crop and water management factors do not restrict either crop growth or total water supply (e.g. soil compaction and evaporation from storages). Restricting the total area of production obviously may limit the opportunity to utilise any increase in water allocation throughout the season. In selecting to spread available water over a larger area, yield risk assessments need to be completed prior to planting and again at first irrigation. Details of yield expectation across various regions for different levels of water allocation were discussed in a recent article in *The Cotton Grower* by Brian Hearn, (Sept/Oct 1995, Vol 16 No. 5).

Irrigation Scheduling - Should I Apply Early or Late Stress?

The optimum timing of the last irrigation is when the crop is around 20% open. Figure 2 demonstrates changes in boll retention throughout the plant as effected by end of season water stress during a season where little effective rainfall occurred. In this trial, denying the crop it's last irrigation caused little reduction in overall crop WUE. However, denying the crop it's last two irrigations reduced crop WUE by some 50% to 0.6 bales/Ml.

Figure 2 Late season water stress and boll retention (boll number by node)



Taking into account the potential yield reductions from late season stress, the broad conclusion can be made that if water allocation will limit normal irrigation numbers by two or more, then delaying the timing of the first irrigation may be the better option. It must be remembered that any significant increase in water deficits early in the season will reduce yield potential from the early plant growth stage, thus if extra water becomes available later in the season, some damage has already been done.

The length of time by which first irrigation should be delayed will depend on yield expectations. In situations where adequate water supply is available, first crop irrigations should occur prior to first flower, around 60 days after planting. As a general rule, for each day the first irrigation is delayed beyond flowering, a 1% yield reduction could be expected (based on well structured clay soils - yield losses would be expected to be greater in poor structured and lighter textured soils).

Timing of Subsequent Irrigations

The timing of subsequent irrigations throughout the season should be maintained close to normal irrigation deficits. Increases in water stress during peak demand periods will have the greatest impact on crop yields. Delays in the timing of first irrigation will aim to reduce plant vigour and

fruit load to such a level that meets yield expectations. Subsequent irrigations are used to mature those bolls which have already set. Extra stress will reduce fruit retention and yield further and impact on fibre development.

Irrigation deficits will vary from field to field and will change throughout the growing season. Soil type and structure not only effects the total amount of plant available water but also the capacity of a plant's root system to extract water. It is therefore important to prioritise field water requirements on a regular basis. A flexible irrigation system is essential.

Row Configuration

Correlations have been established to estimate the yield comparison between different row configurations (Table 2) (Marshall, et.al. 1994). Recent trials in the Gwydir have confirmed these correlations, (D. Gibb 1995).

Table 2 Row spacing and yield conversions (yield in bales per hectare) (Marshall et. al. 1994)

Single skip yield	=	0.82 x solid yield + 0.36
Double skip yield	=	0.58 x solid yield + 0.79
Double skip yield	=	0.71 x single skip yield + 0.46

The option to allocate water to skip row can prove to be a worthwhile risk minimisation strategy if limited water is available and the crop can be managed to exploit the cost saving potential of skip row. The benefits gained from growing skip row, particularly double skip relative to solid, declines as more water becomes available. If yield expectations are greater than 4.0 bales per hectare then solid plant is the preferred option.

Water Use and Skip Row

Recent studies of water use patterns throughout different row configurations has indicated that both the rate and total amount of water extracted across the skip, within skip row cotton, may be less compared to that amount extracted under the plant line. The difference in water use is exacerbated within double skip and where irrigation is applied to skip row. Root development is increased under the plant line within skip row cotton and thus water extraction under the plant line may be increased compared to solid plant cotton.

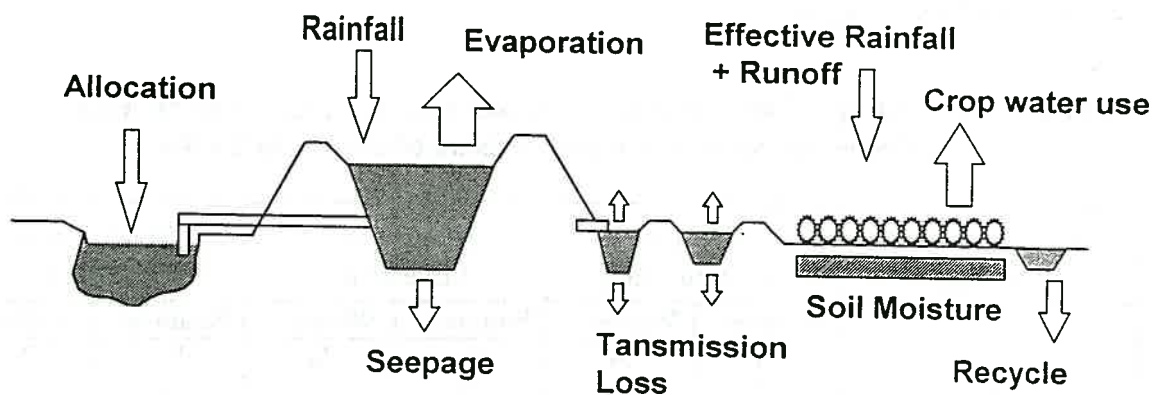
Cyclic water use patterns may also occur within skip row cotton. Water which is readily available is first extracted under the plant line and then across into the skip. After this has occurred the plant will concentrate on extracting water at lower deficits and at depth, back under the plant line before once again utilising water within the skip. (Goynes Pers. Comm.)

These water extraction patterns, in combination with increased water loss from soil surface evaporation may reduce overall WUE from skip row compared to solid plant. In practice, reduced WUE can be accepted where the risk of crop failure is high. During years of high rainfall or where irrigation is applied to skip row, reduction in WUE will be further increased compared to solid plant cotton.

Farm Water Use Efficiency - Irrigation

Farm WUE is measured by the total number of bales produced per megalitre of water supplied to the farm for crop consumption. In measuring farm WUE, establishing a water budget is essential. This budget will include total water supply and water loss throughout the season. Figure 3 illustrates major inflow and outflow elements which need to be considered in developing a water budget.

Figure 3 Water flow across the farm



Irrigation efficiency at the farm level is a measure of the percentage of water on the farm which is actually consumed by the plant. Irrigation efficiency is therefore a combination of field, supply system (channels, head ditch, etc.) and storage efficiencies. Estimates of irrigation efficiency, excluding water loss from farm storages, have been estimated to be 75% of total available water. Thus, using crop WUE values previously discussed as benchmarks, overall farm WUE should be around 1.0 bale/Ml (crop WUE x 0.75).

In situations where on-farm water storages supply the major proportion of water for the crop, maximising storage efficiency is vital. The major losses that occur from a storage are through evaporation and seepage. The rate of evaporation from a storage is around 75% of measured pan evaporation. Seepage losses have been estimated to average 1.5 mm/day. In considering these values during the cropping season (September to February), it is estimated on average that 1,150 mm of water will be lost from a storage. This represents 11.5 megalitres per hectare of storage area. In other words per unit area, a storage will lose more water than that required for

the crop itself.

In terms of farm water management, this means that every effort should be made to reduce the surface area of total farm water storage and where river allocation is available, storage water should be used prior to using any allocated water. Farm irrigation systems need to be flexible so that water can be shifted from shallow to deeper storages. This is particularly important when water is to be stored for any length of time. If the number of storages is limited, division of storages into cells or increasing their depth needs to be considered to improve total storage efficiency.

Table 3 demonstrates the percentage of water loss that can occur across different depths of storage throughout the summer and winter months. The overall percentage of water loss is also calculated for examples where a storage is divided into either two or three even sized cells. The table is independent of storage size and can be used on the basis of depth of water at the start and end of the season. The table clearly shows the benefits of dividing shallow storages into cells and building deep storages.

Table 3 Percentage of storage water loss over summer and winter months as affected by water depth and division of storage into cells

Storage Depth (metres)	Single Storage (without cells)		Divided into 2 Even Cells		Divided into 3 Even Cells	
	Summer	Winter	Summer	Winter	Summer	Winter
	%	%	%	%	%	%
5	23	13	17	10	15	9
3	38	22	29	17	26	15
2	58	33	43	25	39	22
1.5	77	44	58	33	52	30

Values based on average evaporation of 875mm in summer (Sept - Feb) and 390mm in winter (Mar - Aug)
Includes estimated seepage losses of 1.5mm/day

Should I Store Water in the Ground or Leave it in Storage?

If storages represent an inefficient method of holding water, is it better at the end of the season to store water in the soil rather than the storage? This question may be applicable where storage efficiency is low and water cannot be transferred to another deeper, more efficient storage.

Evaporation still occurs from the soil, however this loss is expected to be only 10% of the rate of evaporation occurring from a storage. Taking into account storage seepage losses, storing water in the soil during the winter fallow (May 1 to September 1) is much more efficient than leaving the water in the storage.

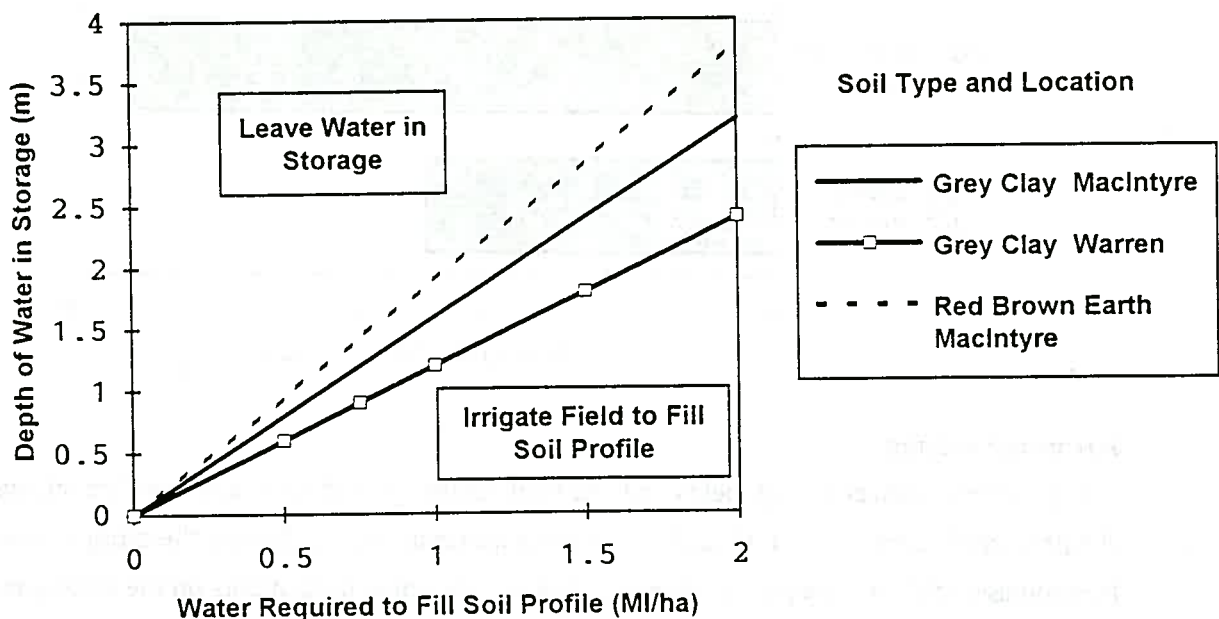
The major factors which will impact on the decision of whether or not to store the water in the soil are, depth of water in the storage, amount of water required to fill the soil profile and the level of evaporation. As the water requirement to fill the soil profile increases the total area irrigated, will be reduced, thus reducing total soil water evaporation. Soil type is another factor affecting soil water evaporation.

To provide a guide on the option to store water in the soil versus leave it in storage, a simple chart has been developed (Figure 4). The chart relates both the water requirement to fill the soil and the depth of water in storage. Storage evaporation is based on 80% rainfall data (i.e. rain that occurs eight years out of ten). For a grey clay soil in the MacIntyre, if the depth of storage (metres) is less than 1.6 times the amount of water required to fill the soil profile (megalitres), then irrigating fields at the end of the season (May) may be an option. Storage evaporation is less in Warren, thus the benefits of storing water in the soil are reduced.

In the event of winter rainfall, runoff will be increased from any field which has been irrigated. It is important that the capacity exists to harvest this runoff. In deciding to store water in the field over winter, effective weed control is essential. Obviously weed growth and cultivation will reduce fallow efficiency.

Figure 4 Winter water storage guide

If depth of water in storage is above appropriate line - leave water in storage



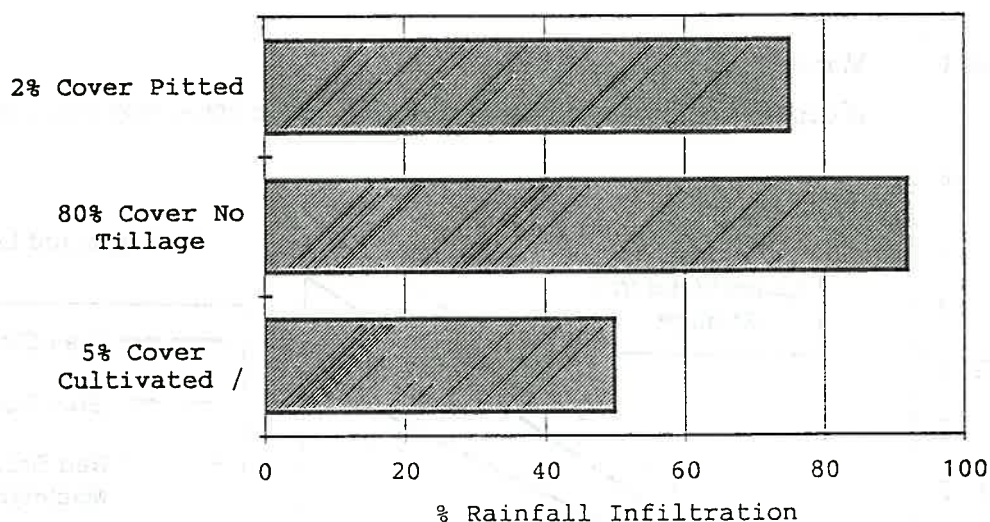
Farm Water Use Efficiency - Dryland

Within a dryland system, irrigation efficiency is replaced by fallow and rainfall efficiency. Reduced tillage and stubble retention are obviously methods of improving overall WUE in a dryland (and irrigated) system.

Figure 5 demonstrates the effect of tillage and stubble cover on storm rainfall infiltration. Measured on a black cracking clay soil for a storm of 75mm of rain at a rate of 100mm/hour, (Huf and Agnew, 1994). Within this trial nearly 50% of the rainfall was lost as runoff when the soil surface was finely cultivated and had no stubble cover. Pitting, similar to that achieved when using an implement such as the Conservation King, decreased the amount of runoff to 25%. The most effective treatment at getting rainfall in was zero tillage with stubble cover. Less than 10% of the rainfall ran off.

Recent studies by Bruce Radford in central Queensland has shown that there are clear benefits from adopting a minimum tillage controlled traffic (tramlining) cropping system. Soil compaction from a single wheel pass was shown to reduce fallow efficiency by 60% compared to an uncompacted soil (13% compacted versus 35% uncompacted). This reduction in fallow efficiency represented 107 mm of stored water over the 11 month fallow period. Similar results were observed comparing conventional and minimum tillage.

Figure 5 The effect of tillage and stubble cover on rainfall infiltration
(Huf and Agnew, 1994)



Farming Systems

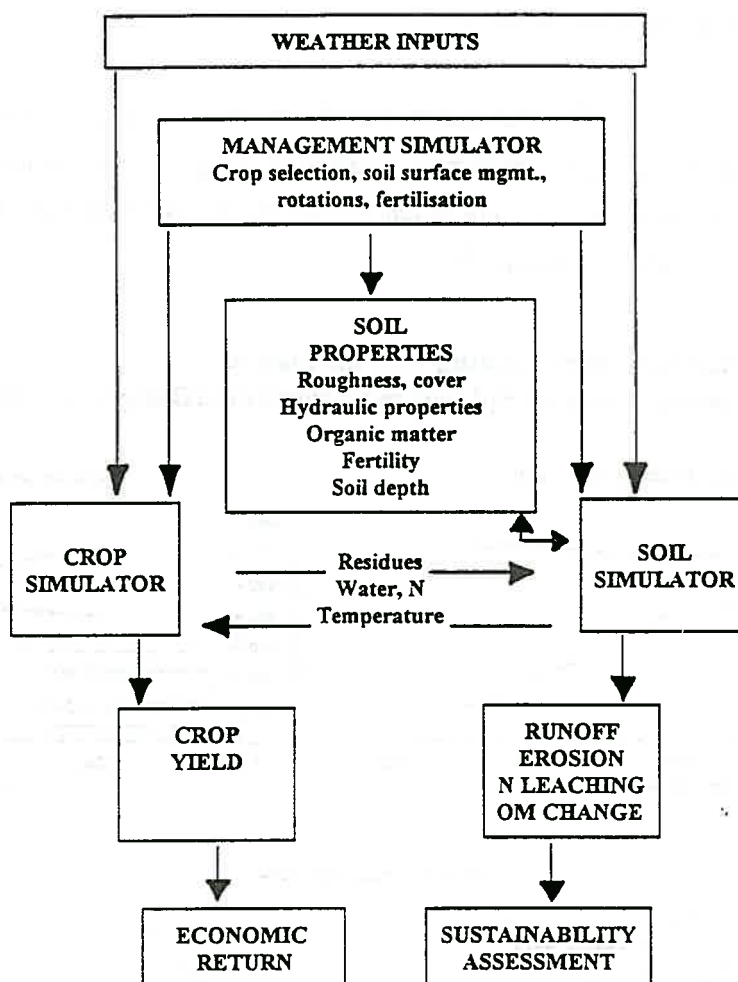
Many factors influence crop yields and the final returns gained from any one farming system. Weather conditions are undoubtedly the most important factor affecting the cropping system. In recognising this, growers are continually making risk value judgements on the strategies they employ within their cropping system.

Computer models can be used to consider variability in weather conditions and their impact on the cropping system. The objective of using models is to predict the risks and benefits of any one cropping system over another.

Together, the Australian Cotton Research Institute (ACRI) and the Agricultural Production System Research Unit (APSRU) are developing a farming system model which will allow growers to make more informed decisions regarding their cropping system (irrigated and dryland).

To assess the farming system as a whole, the model is broken into three core segments. These are, crop growth, soil properties and farm management. Over the top of these segments is a long term weather database (Figure 6). Perhaps in the future over the top of the weather will be State and Federal politics??

Figure 6 Components of farming system model



To date the model has been used in comparing dryland farming systems. Yield prediction has proved to be very accurate and growers are currently using the model to make value judgements on cropping options. Table 4 indicates average predicted versus actual yields for three crops, across a number of locations and seasons.

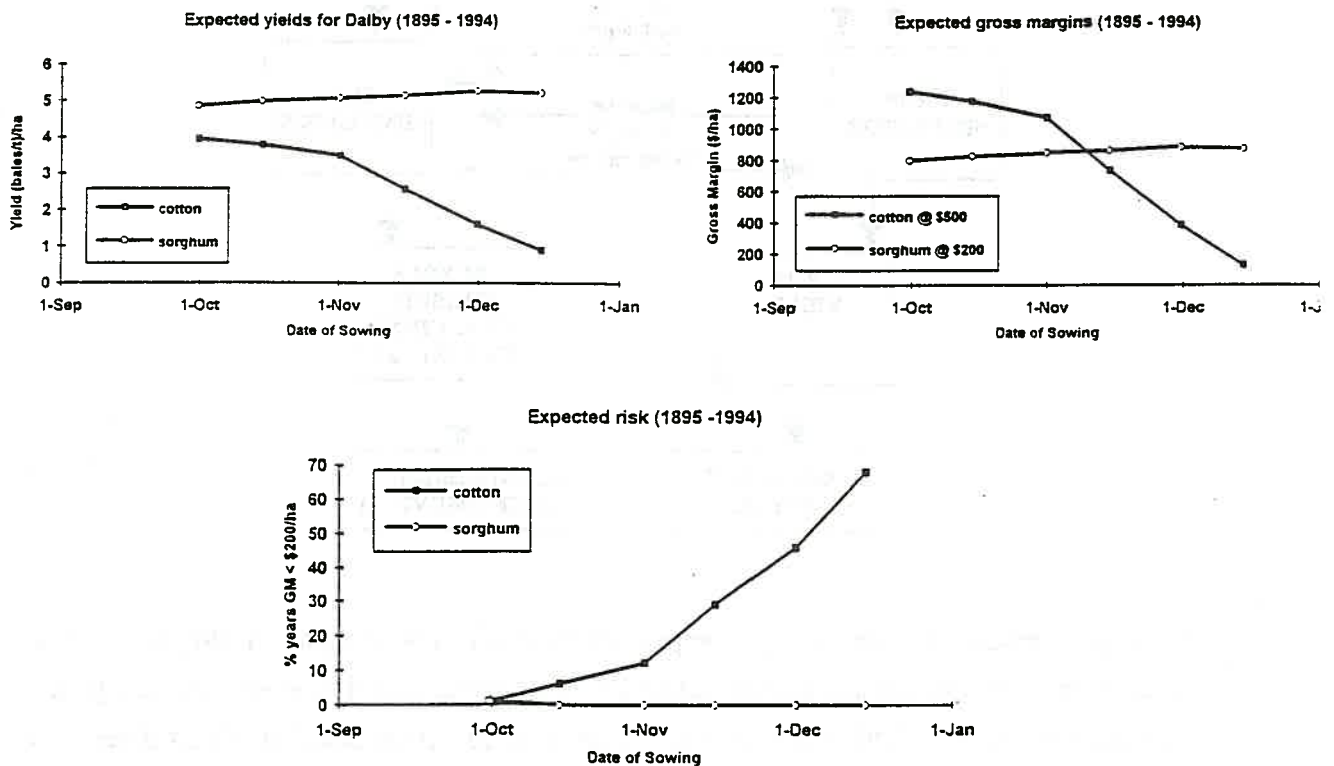
Table 4 Cropping system - crop yield predictions versus actual yield (Carberry, Pers. Comm.)

Crop	Years (Seasons)	Locations	Crop Yield		
			Predicted	Actual	Difference %
Sorghum	4	18	4.0 (t/ha)	4.1	98
Cotton	3	7	2.8 (b/ha)	2.9	97
Mungbean	1	9	0.89	0.97	92

As well as direct benefits for growers in the future, such farming system models may also be used to assess the implications of different farming practices and/or Government policy on the long term sustainability of cropping regions. Sustainability may be measured from both an economic and environmental perspective (figure 6).

A simple example of how a farming system model can be used by a grower is to compare the effect of sowing date on yield and gross margin (\$/ha) of sorghum versus cotton. It can be seen that the risk of poor returns from late sown cotton (later than mid-November in Dalby) are greater than that for sorghum (figure 7).

Figure 7 Prediction from farming systems model. Planting date dryland cotton vs sorghum (Dalby). Carberry (Pers. Comm.)



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