

2.2 Crop and management decisions in limited water situations

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Key points

- Limited water supplies may be a result of reduced surface runoff, restricted groundwater allocations or low capacity irrigation bores and/or pumping systems
- When water is limited, profit may be maximised by adjusting cropping systems, agronomic strategies and irrigation systems and management
- There are several support tools available to assist irrigators dealing with limited water scenarios – these include Irrigation Optimiser, CropWaterUse, CottBase, HydroLOGIC and WaterSched2
- The Bureau of Meteorology also provide weather data and forecasts which can assist irrigators manage limited water availability
- No one single strategy is the best to manage limited water – usually a combination of approaches is needed

Most irrigated farms in Australian cotton growing regions are water limited, as the amount of irrigable land is greater than the typical water supply. However some farms may face additional water pressures when:

1. Low rainfall or drought conditions cause reduced surface water availability
2. Groundwater allocations are restricted, for example due to declining aquifer levels
3. Irrigation bores and/or pumping systems are of low capacity, so that the available supply of irrigation water is insufficient to meet the peak demand of the crop.

Under normal water availability scenarios, most farms will practice **full irrigation**. In other words, irrigation water is applied to completely meet crop water demand or evapotranspiration (ET_c) that is not supplied by rainfall or stored soil water

However when water supplies are severely limited, irrigators and their consultants can use a number of strategies to maximise their return on the water available. These strategies relate to:

- the cropping system
- individual crop management
- the irrigation system and its management
- the farm business

Cropping System

There are several cropping system strategies that irrigators can use to manage limited water situations.

For example, reduced tillage and stubble retention, often combined with controlled traffic layouts, can result in better infiltration and use of in-crop rainfall. These techniques are increasingly favoured by growers to increase available soil water, even under conditions of typical water availability. Information on stubble retention is available at the GRDC website [here](#) and [here](#).

Similarly, irrigators can use particular crop sequences to enhance soil water storage in fallows. An example of this can be found on the Darling Downs where a sorghum-chickpea- summer fallow-winter fallow- cotton-winter fallow to sorghum sequence has been used in response to limited water supplies. Sorghum is relatively water stress tolerant and chickpeas fix more nitrogen following the sorghum crop. Rainfall over the long-fallow provides a full profile for cotton, which is the most profitable crop in the sequence.

Reduced water availability may also lead to the consideration of alternative crops. Different crops have different seasonal ET_c requirements, and these differ between locations in response to growing season length, planting

Table 2.2.1. Average seasonal crop evapotranspiration (mm) for a range of irrigated crops.

| Season | Narrabri | | | Dalby | | | Emerald | | |
|-------------------|----------|---------|-----|-------|---------|-----|---------|---------|-----|
| | Dry | Average | Wet | Dry | Average | Wet | Dry | Average | Wet |
| Barley | 383 | 352 | 332 | 410 | 387 | 363 | 420 | 405 | 375 |
| Chickpea | 424 | 396 | 364 | 449 | 419 | 398 | 292 | 280 | 260 |
| Corn - Spring | 636 | 598 | 569 | 599 | 565 | 548 | 685 | 659 | 623 |
| Corn - Summer | 624 | 600 | 564 | 534 | 529 | 500 | 605 | 575 | 537 |
| Cotton | 821 | 780 | 744 | 758 | 739 | 717 | 784 | 748 | 729 |
| Mungbean - Spring | 523 | 493 | 467 | 486 | 456 | 443 | 448 | 420 | 396 |
| Mungbean - Summer | 524 | 501 | 470 | 453 | 435 | 417 | 412 | 387 | 363 |
| Sorghum - Spring | 625 | 572 | 552 | 578 | 528 | 520 | 583 | 549 | 519 |
| Sorghum - Summer | 673 | 650 | 612 | 565 | 561 | 530 | 518 | 484 | 458 |
| Soybean | 759 | 726 | 691 | 671 | 633 | 622 | 697 | 657 | 614 |
| Wheat | 356 | 328 | 310 | 383 | 362 | 339 | 405 | 389 | 366 |

Source: [CropWaterUse](#)

time and weather conditions (Table 2.2.1). Therefore, the choice of crop, maturity length and planting time can be used to adjust to the limited water supply.

Crop yields generally increase linearly with crop evapotranspiration (Figure 2.2.1). Some crops (for example corn) are more responsive to every mm of ET_c than others (for example wheat). However, to achieve high yield, corn requires more water in total than wheat.

The choice between crops comes down to the profitability per mm of applied water for each crop and the total area that can be grown with the water available.

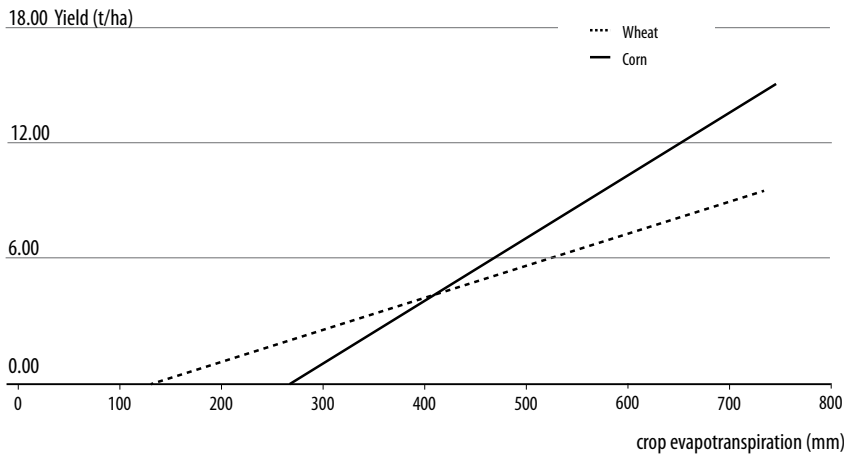
Strategies for reduced allocation

When water supply is limited growers have three management options available:

1. Fully irrigate a reduced area of irrigation
2. Deficit irrigate a larger crop area
3. Include different crops that require less irrigation

As previously mentioned, **full irrigation** occurs when irrigation water is applied to completely meet crop water demand or evapotranspiration (ET_c) that is not supplied by rainfall or stored soil water, with the typical aim of maximising yield. In contrast, **deficit irrigation** occurs when less irrigation water is applied than that required to fully satisfy ET_c . In this case, water stress occurs at some time(s) during the growing season, and irrigation applications should be timed to the most yield sensitive growth periods.

Deficit irrigation - should not be confused with soil moisture deficit. Deficit irrigation occurs when the crop receives less water than required for ET_c . Soil moisture deficit is a measure of soil moisture status as compared to field capacity (see WATERpak Chapter 2.1).

Figure 2.2.1. Indicative grain yield vs. ET_c relationship for corn and wheat

Source: Steiner et al, 1985; Payero, 2006.

Deficit irrigated crops will have lower yields and crop returns compared with fully irrigated crops, with the aim to maximise crop water productivity (returns per mm of applied water).

The decision to fully irrigate a reduced area minimises farm input costs and maximises the yield and return from the reduced area. The irrigator needs to know the amount of water available for the season and the likely crop water requirement. If the season turns out more favourable than expected this option can result in a lost opportunity with less total crop production than if a greater area had been planted.

The decision to reduce the supply of irrigation water to the normal cropping area runs the risk of low yields and failing to break-even if the area is not reduced sufficiently.

In reality, irrigators will choose an option somewhere between these approaches. This “best-bet” approach should be based on available seasonal forecasts (www.bom.gov.au/wat/ and www.longpaddock.qld.gov.au) and past experience.

Free online tools such as DAFF Queensland’s [CropWaterUse](#) and [Irrigation Optimiser](#) can assist in making this decision. In addition, cotton irrigators can access the CottBase Tool through the CottASIST website (www.cottassist.cottoncrc.org.au). These tools are explained in further detail in WATERpak Chapter 2.3.

The third choice of growing different crops requiring less irrigation is often used in combination with the “best-bet” approach. For example, grain sorghum is less impacted by water stress compared to corn. It can be grown as dryland crop or with only a single irrigation applied prior to flowering. Some of the shorter-season crops are also grown when irrigation supplies are limited – for example mungbeans which use less irrigation than other summer crops because of the short growing season.

Winter crops generally use less water than summer crops due to lower evaporative demand in winter. This is one reason for including them in rotation with summer crops. Crop price and likely gross margin per ML of irrigation water should also be considered when comparing winter and summer crops.

Strategies for Low System Capacity

If irrigation system capacity is less than that required to meet crop water requirements during peak water use periods, yields will be reduced under average seasonal conditions.

Sometimes such situations can occur when irrigation systems have been poorly designed. However, low system capacity is more often due to supply constraints, such as limited bore discharge.

Management strategies for low capacity systems may aim to ensure a reasonable supply of soil moisture when peak crop water demand is experienced, for example through pre-irrigation and earlier in-crop irrigation at higher starting soil moisture levels. Then when plant demand rises above the system capacity, plants can draw on stored soil moisture to maintain yield potential.

However, with low rainfall, soil moisture levels may fall below the critical refill point during the reproductive growth stage and yields will be reduced. Similarly, if rainfall is greater than anticipated and the soil is already moist, precious rainfall may run off.

To manage this, it is possible to split irrigation fields into two or more cropping units that have different peak water needs, thus reducing the water required during both peak demand periods. This might be achieved by rotating crops to spread the irrigation season over a greater period. Similarly, staggering planting dates can offset periods of peak irrigation demand.

Crop management

Net Water Requirement

Crops use water for a range of processes including cooling, photosynthesis, cell expansion and maintaining turgor pressure. The amount of water used by a crop at any time is influenced by weather conditions, crop stage and water availability.

Furthermore, the effect of moisture stress varies between crop types and crop growth stages. Understanding crop water requirements is therefore crucial for planning your mix of crops, the area to be planted, and how irrigation is managed.

The average net crop water use by a crop (see Table 1) is the amount the crop will use in an average year, assuming soil moisture doesn't fall below critical levels. Ideally this net water requirement is reduced by effective rainfall. For example, for an average 15 October planted cotton crop at Dalby, the average net ET_c is 739mm. The average effective in-crop rainfall is 284mm. So the average net demand is 455mm (739mm-284mm).

To maximise yield, this demand has to be supplied by stored water and irrigation. If the root zone profile was full at planting (200mm of total available water) then the net irrigation required would be 255mm (455mm-200mm).

The gross irrigation requirement for a lateral move with an 85 per cent irrigation efficiency in an average year will be 300mm or 3ML/ha (255/0.85).

Similarly, the gross irrigation requirement for dry and wet seasons is 384mm and 220mm respectively (given the same assumptions).

These values can be compared with the available water to help make planting area decisions. The [CropWaterUse](#) tool can be used to make these same calculations for your particular situation.

Agronomic Practices

Agronomic practices to manage limited water scenarios differ between crop types. Detail for cotton can be found in WATERpak chapters 3.1, 3.2 and 3.3 and for other crops in WATERpak chapters 4.1 (wheat), 4.2(sorghum), 4.3(corn), 4.4(chickpeas) and 4.5(soybeans).

Choice of crop is an important consideration in managing with limited water. Some crops are more tolerant of water stress than others. It is also possible to use particular agronomic practices to manage limited water. Plant populations and row configurations have been used to manage limited water availability.

Reducing plant populations has been a strategy used by irrigators to maintain yields with limited water.

For corn, fully irrigated populations are generally in the order of 55,000 to 75,000 plants per ha (the optimal established population varies with variety). For limited water situations irrigators have opted for lower populations. On the Darling Downs, consultants have recommended plant populations of 35,000 plants per ha where there is only sufficient water for one irrigation of 100 mm, and 50,000 plants per ha if

two such irrigations are possible, and there is a full moisture profile at planting. Research by Peake (2008) demonstrated that optimal populations under limited water at Dalby are around 50,000 plants per ha (see Figure 2.2.2).

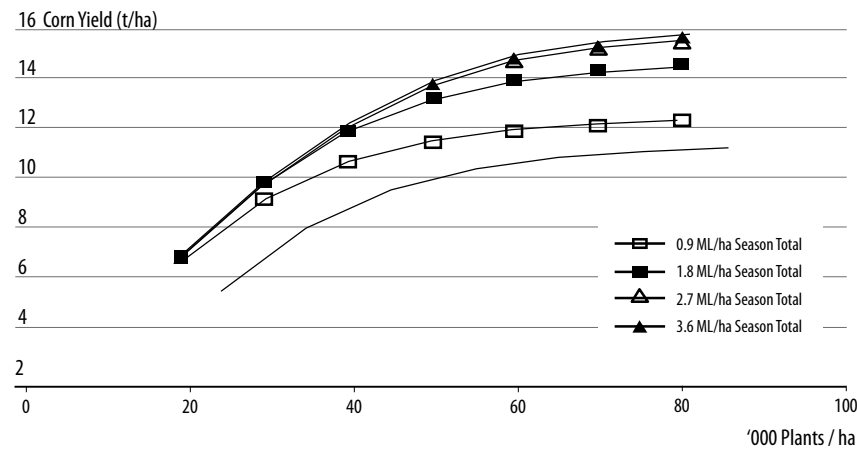
Plant row configurations are also used in response to limited water. In cotton and sorghum, a range of skip-row configurations have been used to maximise yield with limited water. Whilst yield potential generally declines as row spacing increases, in more favourable environments like the Darling Downs the yield penalty from single-skip configurations has been relatively minor. The reasons for using skip-row include:

- Reduced risk of crop failure
- Buy time to get rainfall or irrigations
- Spread the irrigation interval.
- Make better use of in-crop rainfall
- Reduce Bollgard II costs

Further information on row spacing in cotton crops is contained in WATERpak Chapter 3.3.



Figure 2.2.2. Corn grain yield for plant population x seasonal irrigation allocation for long-term simulation experiments at Dalby for a range of plant population densities grown on a 220 mm PAWC soil



Source: Allan Peake, 2008

Irrigation

Irrigation System

Optimising irrigation application efficiency – the amount of water delivered to the crop root zone divided by the gross irrigation water applied to a field – is important in any water limited irrigation situation. Given that ET_c is the main driver of crop yield, minimising irrigation water losses so that as much water as possible is delivered to the root zone (and therefore available to meet ET_c) is critical to maximise water productivity. Losses can occur from distribution to fields, runoff, deep drainage and evaporation.

Surface irrigation remains the dominant irrigation system within cotton-grain farming systems. Irrigators can achieve high application efficiencies with surface irrigation by:

- Shortening excessive row length
- Optimising flow rate and set times – this may include increasing furrow flow rate and cutting back on set time

These practices minimise losses from deep drainage and excessive runoff. They should be combined with tailwater return systems. Further information on surface irrigation system performance can be found in WATERpak Chapter 5.3.

Losses from distribution systems can be minimised by sealing leaking sections of channel and using fields closest to on-farm storages when water is limited.

In some circumstances, alternative irrigation systems such as overhead (centre pivot and lateral move) and drip can be used. On soils less suited to surface irrigation these systems are inherently more efficient.

However, they have higher capital cost and require greater management skill.

With ringtank storages there is the potential for seepage and evaporation losses. Recent investigations have shown that the average losses from seepage are minimal. However, some individual storages may have very high seepage losses. If unsure of the losses have them assessed using a seepage meter. Seepage assessments can also provide a measure of typical evaporation losses.

Even if seepage losses are low, small errors in assumed seepage can quickly multiply into significant water volumes in seasonal water budgets. Similarly, accurate storage surveys are absolutely critical when managing small water volumes. It is not uncommon for actual storage volumes to differ by more than 20% over the design.

Once storages have been surveyed and losses have been quantified, the irrigator can decide on the most appropriate course of remediation or management, and can be sure that seasonal budgets will be accurate. Further information on storage management is included in WATERpak Chapter 1.6.

Irrigation Management

Historically pre-irrigation is used with surface irrigation in cotton-grain farming systems. Under conditions of limited water supply irrigators have opted to move away from pre-irrigation because of the high volumes of water required. Crop residue management, crop sequencing and use of fallows have been used to increase soil water storage and negate the need for pre-irrigation during extended periods of limited water availability.

Crop establishment is a distinct area of advantage of overhead (CPLM) irrigation systems, as they have the ability to establish crops with limited water and make better use of in-crop rainfall. These systems have limited the need for pre-irrigation when combined with soil water storage practices. Reduced reliance on pre-irrigation is the main reason for lower irrigation water use with these systems compared with surface irrigation (often reported to provide at least a 20 per cent water saving). This can be seasonally dependent and also depends on the efficiency of the surface system it is being compared with.

When water is limited, greater care is needed with irrigation scheduling. The aim is to supply the right amount of water at the right time. In-field soil moisture monitoring equipment used by crop consultants is invaluable in making irrigation decisions between fields and crops. This information can also be combined with decision support tools like [WaterSched2](#) and [HydroLOGIC](#).

WaterSched2 has been developed by DAFF Queensland to assist irrigators make real-time irrigation scheduling decisions at the farm scale. It enables irrigators to manage their available water supply and all the crops they grow on their farm at any one time. It uses local weather data and includes economic analysis to assist them to allocate a limited water resource most appropriately as weather conditions change.

HydroLOGIC is a specific cotton irrigation scheduling tool to assist irrigators manage irrigation for a single field. It combines seasonal weather data and historical data to assist cotton growers make best-bet irrigation decisions for their crop.

Irrigators can also access records and forecast information to assist their irrigation decisions from the Bureau of Meteorology. This includes:

- [evapotranspiration](#) ;
- [rainfall](#);
- [ENSO](#); and
- [seasonal streamflow](#).

More information on decision support tools and data sources can be found in WATERpak Chapter 2.3

Farm Business

There are many farm business strategies that have been used by irrigators in response to ongoing limited water situations. During the Millennium Drought, strategies reported by irrigators included:

- Purchase of additional land and water.
- New technologies to minimise labour demand – overhead systems and Roundup Ready cotton varieties.
- Retaining highly skilled labour.
- Broadening income base using shares and contract harvesting.
- Growing dryland crops using water conservation strategies and use irrigation for opportunity crops.
- Careful use of forward selling for cotton.



Case Study

During the past decade, irrigators have been implementing a number of strategies to deal with limited water availability. The mix of strategies is determined by soil type, farming system, available capital and cropping alternatives. This case study is based on an actual irrigated cotton-grain farm at Dalby in Southern Queensland.

Traditionally this farm furrow irrigated solid plant cotton, corn and sorghum in a rotation outlined in Figure 2.2.3. In response to limited water, a new cropping sequence has been implemented (Figure 2.2.4). In this sequence, wheat has been added to the system and soybean has replaced the second cotton crop.

The planting rules for these two systems are outlined in Table 2.2.2.

It can be seen that available water is a critical factor in the choice between crops, and that sorghum and wheat are grown as opportunity crops depending on the occurrence of planting rainfall during the most appropriate planting window. Corn is preferred to sorghum when there is better soil moisture and on-farm water in storage.

Figure 2.2.3. Traditional crop sequence

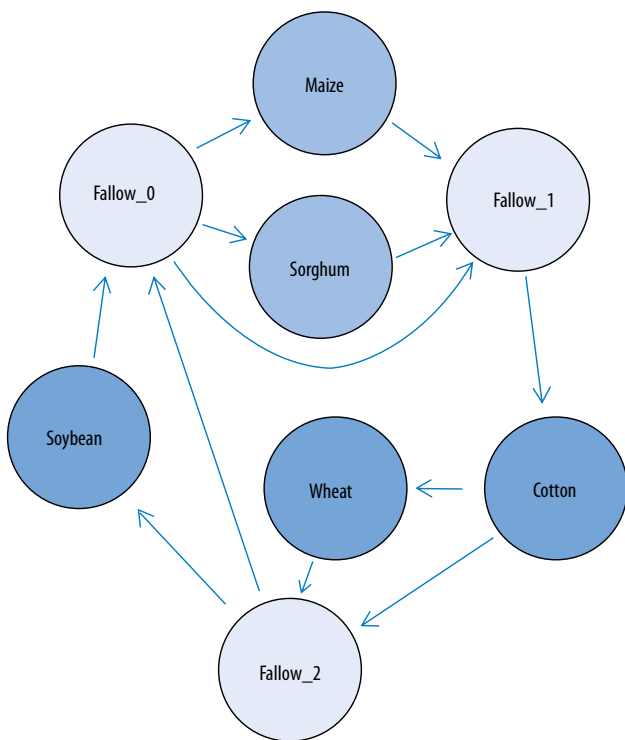


Figure 2.2.4. New crop sequence

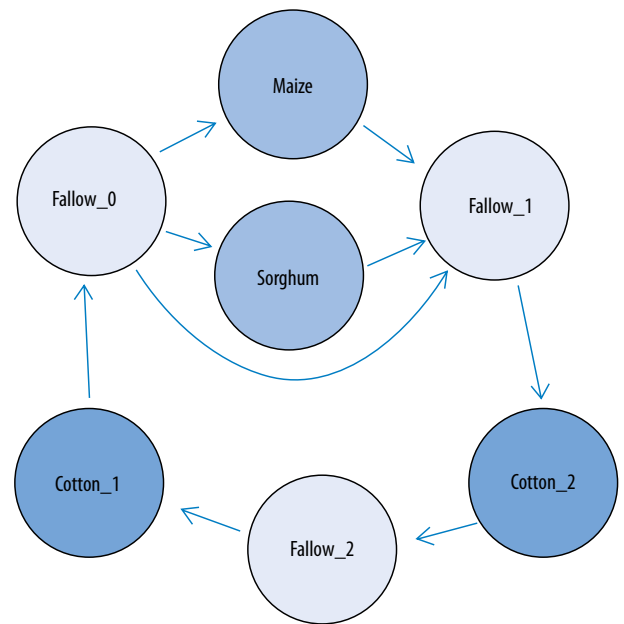


Table 2.2.2. Planting rules for each crop

| Crop | Planting Dates | Available Water | Area Restriction |
|---------|-------------------|-----------------|------------------|
| Corn | 15 Sept to 15 Oct | ≥ 4 ML/ha | 410 ha |
| Sorghum | 16 Oct to 14 Jan | ≥ 0 ML/ha | 449 ha |
| Cotton | 16 Oct to 15 Nov | ≥ 0 ML/ha | 599 ha |
| Wheat | 16 Apr to 1 Jul | ≥ 0 ML/ha | 534 ha |
| Soybean | 1 Dec to 15 Jan | ≥ 3 ML/ha | 758 ha |

Figure 2.2.5. Simulated applied irrigation (ML/ha) for each crop in the traditional (a) and new (b) crop rotation. The wheat crop in the new rotation is dryland.

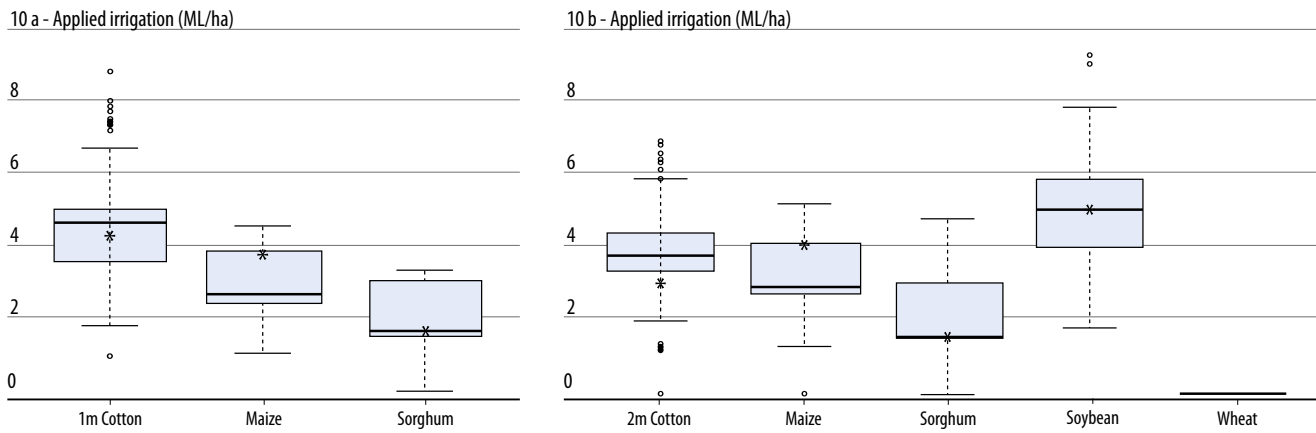


Figure 2.2.6. Simulated yields for each crop in the traditional (a) and new (b) crop rotation. The wheat crop in the new rotation is dryland.

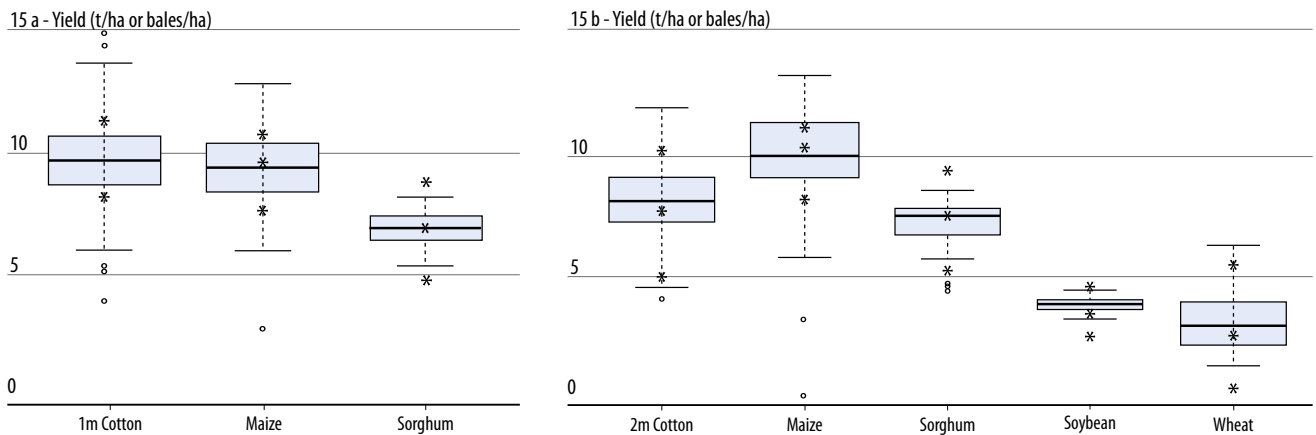


Figure 2.2.7. Simulated gross margins (\$/ha) for each crop for the traditional (a) and new (b) rotations.

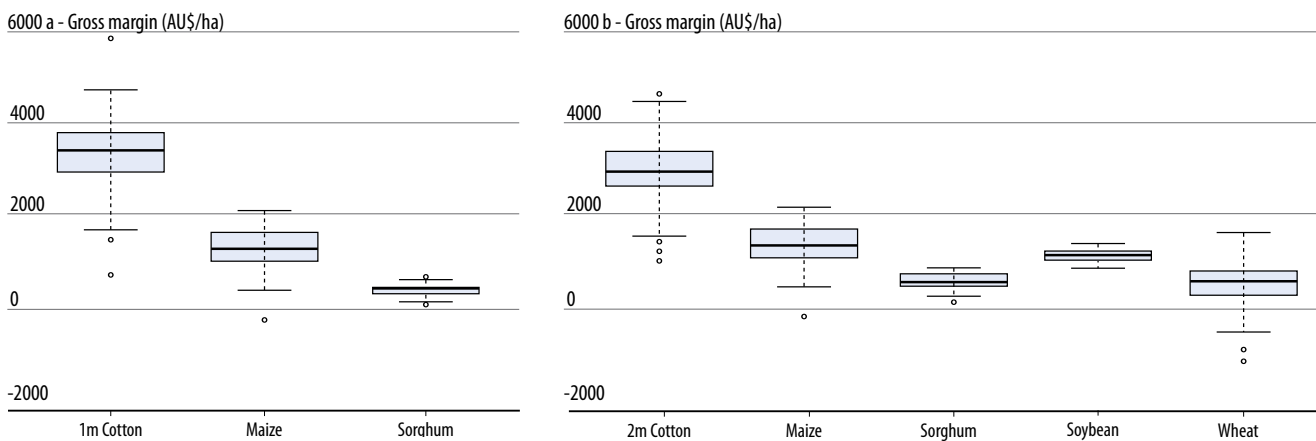
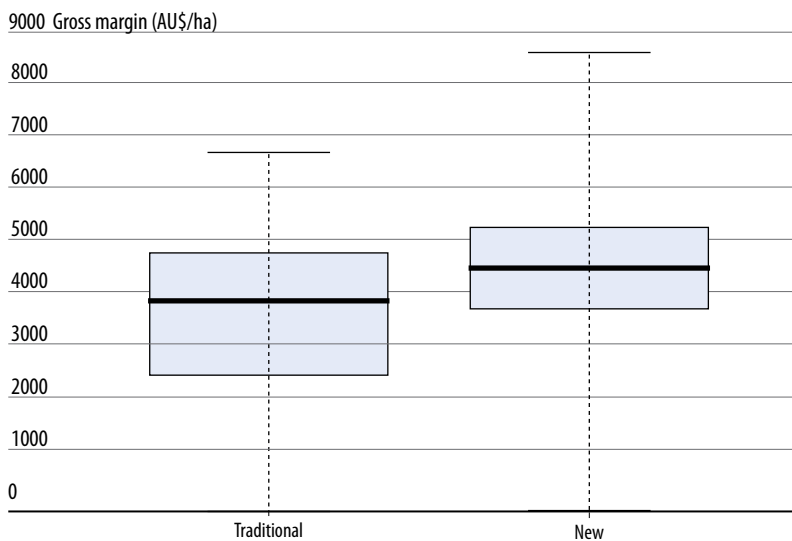


Figure 2.2.8. Simulated whole farm gross margins for the traditional and new rotations



Dryland wheat is also grown when there is planting rain after cotton – it provides a benefit in fallow by protecting the soil surface and aiding soil water infiltration.

Cotton grown in the new system is planted in a 2m row configuration (one in, one out) which uses less water than 1m cotton but limits yield potential. WATERpak Chapter 3.3 contains further information on row configurations in cotton.

APSFarm (a multi-field configuration of the APSIM model – the Agricultural Production Systems Simulator) was used to analyse the performance of the traditional and new cropping sequence for Dalby over the 119 year climate record.

This analysis revealed the following:

- The new system reduced the cotton area by 16%.
- There was a 34% increase in the area of corn.
- There was a 145% increase in the area of sorghum.
- On average 46ha of soybeans was introduced to the farming system.

- On average the new sequence increased the cropping intensity from 41% to 50%.
- 2m cotton uses less water than 1m cotton (Figure 2.2.5.), although also produces slightly less yield (Figure 2.2.6.).
- Cotton is the most profitable crop in both rotations, followed by corn and soybeans (Figure 2.2.7.).
- Wheat is the least profitable crop (Figure 2.2.7.).
- At the whole farm scale the new rotation was more profitable than the traditional system (Figure 2.2.8.). There was no increase in downside risk with the new rotation.
- The new rotation used 12% less nitrogen than the traditional rotation.

This case study demonstrates some of strategies that irrigators have used to manage with limited water. It shows that profitable outcomes can be achieved when irrigators implement these strategies.

Further Reading

[GRDC 2011 Stubble Management Fact Sheet](#)

[GRDC 2011 Managing Stubble](#)

[Cotton CRC 2011 Modifying storages to save water: the cost of water saved through storage structural modifications](#)

[Cotton CRC 2011 Storages Seepage & Evaporation – Final Summary of Results](#)

Payero, J.O., Melvin, S.R., Irmak, S. and Tarkalson, D. 2006 Yield response of corn to deficit irrigation in a semiarid climate, *Agricultural Water Management* 84: 101-112

Peake, A.S., Robertson, M.J. and Bidstrup, R.J. 2008 Optimising maize plant population and irrigation strategies on the Darling Downs using the APSIM crop simulation model. *AJEA* 48:313-325

Power, B., Rodriguez, D., deVoil, P., Harris, G. and Payero, J. 2011 A multi-field bio-economic model for irrigated grain-cotton farming systems. *Field Crop Research* 124: 171-179

Steiner, J.L., Smith, R.C.G., Meyer, W.S. and Adeney, J.A. 1985 Water use, foliage temperature and yield of irrigated wheat in south-eastern Australia. *Australian Journal of Agricultural Research*, vol. 36, pp.1-11.