

Agronomic and Economic Aspects of Water Use  
Efficiency in the Australian Cotton Industry

Cotton Research and Development Corporation

Prepared by:

Cameron Agriculture Pty Ltd  
in association with  
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## Section 1

### Executive Summary

#### Agronomic and Economic Aspects of Water Use Efficiency in the Australian Cotton Industry

##### Introduction

In 1995 the Cotton Research and Development Corporation (CRDC) commissioned a study entitled *The Australian Cotton Industry: An Economic Assessment* (CIE 1995). The report identified supply of irrigation water as a major limit to production, and as one of the major issues for the industry. The project described in this report extended the CIE assessment to include a specific agronomic and economic assessment of the efficiency with which the cotton industry uses irrigation water in Australia.

Terms of reference agreed between the CRDC and the authors were to achieve the following objectives:

1. Document current knowledge on the water use efficiency of Australian cotton and comment on potential for improvement.
2. Compare Australian cotton with other irrigated crops in Australia and cotton in other countries and determine the comparative economic efficiency.
3. Determine overall water use of cotton in Australia and relate it to its economic efficiency.
4. Calculate the efficiency of use of other assets in the Australian cotton industry.
5. if possible, estimate the spin-off effects of water research and development in the Australian cotton industry on other irrigation industries in Australia.
6. Prepare an economic analysis which shows the actual cost of water to cotton producers.

Because of the skill requirements needed for the preparation of this report it has been prepared by two separate groups of authors. Brian Hearn prepared Section 2, the agronomic section, and John Cameron and Bridget Jackson prepared Section 3, the economic assessment. Section 1, this section, provides an overall summary of Sections 2 and 3. Because each section was prepared by two different authors there are slight style differences between the sections. No attempt has been made to eliminate these differences as it was felt that to do so may jeopardise the impact of each section.

## Section 2- Agronomic Aspects

### Overall summary

The aim of Section 2 was to document how efficiently the cotton industry uses irrigation water. To this end data on the amounts of irrigation water used and cotton produced were collected at three levels- region, farm, and field. The regional data were obtained from various sources. The amounts of irrigation water used on cotton at a regional level are not in the public domain; great difficulty was encountered in obtaining them, and in matching them with crop area and production data. Fifteen farms were asked to supply farm and field data.

Between 1988 and 1994 the cotton industry used an average of 1261 GL per annum of irrigation water from all sources (regulated rivers, unregulated rivers, and ground water), representing 9% of all irrigation water used in Australia. Groundwater accounted for 13% of irrigation on cotton. In the Murray Darling Basin, cotton also used 9% of irrigation water from surface sources. In the northern rivers of the basin where cotton is produced, the crop takes 63% of surface water released for irrigation. The mean area of irrigated cotton was 199,263 hectares giving a mean application rate of 7 ML per ha, ranging from 3.9 ML per ha in the Gwydir Valley to 11.7 ML per ha in the Macintyre Valley. Variation among valleys reflected effects of both drought and losses from on farm storage of harvested water. The farm data, collected to cross check the regional data, confirmed these rates, though the farms surveyed applied slightly less water.

The efficiency with which the cotton industry uses water has two components: the engineering component is **irrigation efficiency (IE)**, which is the percentage of the water input actually used by crops in evapotranspiration (ET), and takes into account delivery or conveyancing losses; the agronomic component is **crop water use efficiency (CWUE)**, which is the amount of cotton produced per unit of water used in ET, and it takes into account agronomic deficiencies. On the three farms with measured ET, IE averaged 75% and CWUE averaged 294 kgs of lint per ML. These values are identical (for IE) or very close (for CWUE) to previous independent estimates, and can be accepted as provisional benchmarks for the industry.

Measurements of ET were not available for the regions, nor for most farms, although all use the neutron probe for scheduling from which ET can be determined using software supplied with the probe. Alternative procedures were devised. By assuming a value of 300 kgs of lint per ML for CWUE, IE can be estimated for regions and farms that did not measure ET. The overall mean for all regions and years was 58%. The mean IE for individual regions ranged from 41% for the Macintyre and Emerald to 94% for the Gwydir. The mean for farms was 63%, ranging from 49 to 78%.

A benchmark for production per unit of water input is the product of the benchmarks for IE and CWUE- 225 kgs of lint per ML or 1 bale per ML. Where ET is not measured, this value cannot be calculated directly. An alternative is farm WUE (FWUE) at the farm level, and is production per unit of water input including rainfall. The regional alternative is marginal production WUE (MP\_WUE), which is how much a region produces for each ML of water delivered to the farm gate, over

and above what would have been produced from rainfall alone. Mean FWUE was 186 kgs of lint per ML with a range of 140 to 214, and a mean MP\_WUE was 172 kgs of lint per ML with a range among regions of 124 to 222, both of which can be compared with the benchmark of 225 kgs of lint per ML.

National and international comparisons indicate that the Australian cotton industry uses water more efficiently than foreign industries, and other irrigation industries in Australia. However, comparisons with the provisional benchmarks suggest there is scope for both agronomic and engineering improvement.

### Recommendations

In view of the lessons learned during this study on availability of information and the importance irrigation the following recommendations are made.

- Standardise on-farm water record keeping and accounting in order to determine CWUE, FWUE, and IE, making better use of farm information, particularly probe readings to calculate ET.
- Convene regional working parties of growers to facilitate standardised record keeping and establish benchmarks, coordinated across industry.
- Encourage individual farms to use water accounting and by comparison with benchmarks identify whether there is scope to improve engineering or agronomic water use efficiency.
- Place regional volumes of water usage in the public domain with breakdown by crops, and same detail and format for all states, thus making better use of information already collected.

### Section 3- Economic Aspects

As with the agronomic section, paucity of information on water use was a major restraint of this study. Nevertheless, data was used from Section 2 and from other sources which did enable an assessment of the economic efficiency with which cotton in Australia uses irrigation water. This data was compared to rice and other irrigated crops in Australia and to cotton in other producing countries. The main conclusions of Section 3 are summarised below.

- Worldwide, cotton production has doubled in the last 30 years although the area under production has remained relatively static. Effectively, yields have about doubled. Information on changes in water use per hectare over this time is not available.
- Australian production has increased over those thirty years (a steep trend) as a result of increasing area under production and of a doubling of per hectare yields.

- Rice production has shown similar trends except that rice yields in Australia have only increased by 30% in the period.
- The deflated (constant) prices of cotton and rice have declined by around 50% in the last 20 years.
- Australia's cotton industry has invested, on average, seven times more capital per farm than the national average. However, their total assets per unit of production is 60% less than the average of all farms.
- Further confirmation of the efficiency of Australian cotton farms is their value of assets to produce \$1 of value added: \$7.9 compared with all of agriculture of \$12.2.
- The absolute level of debt of Australian cotton farms is about seven times that for all agriculture and average equity is lower, so the issues of water availability and reliability and water use efficiency are vital to this industry.
- The yield efficiency of water use of Australian cotton has increased by around 89% in the last 30 years. This has occurred at the same time as yields have doubled.
- By comparison, the yield efficiency of water use of rice increased in the same period by only about 25%.
- International data indicate that Australia's cotton yields are highest in the world after Israel and about 60% higher than the world average. This disparity in yields has increased in the last 30 years. Additionally all evidence points to Australia having amongst the highest yield efficiency of water use in the world, being perhaps double that of the average of seven other producing countries.
- In terms of return per hectare, an international survey notes that returns in Australia from irrigated cotton production are the highest of the countries surveyed and over three times the average of all countries surveyed.
- An economic assessment of the marginal return from irrigation for cotton production showed that on average, about \$600 million per annum could be attributed to irrigation with about \$250 million being attributed to rainfall. Even the rainfall component of the crop is higher than the total production value of the rice crop which uses about the same amount of water as cotton.
- Average marginal returns per ML from cotton production were calculated for regions and these varied from \$242 per ML in the Border Rivers to \$914 per ML in the St George Region. The national average was calculated to be about \$450 per ML.
- The average marginal return from irrigation per ML of water from farms surveyed in the project was \$488 with a range (of the eleven farms) of \$102 to \$792 per ML.

- The output value efficiency of water use of cotton is estimated to be around four times that of rice. Its value of production is about four times that of rice for around the same total water use.
- A comparison of gross margin budgets and water use also places cotton highest in Australian broadacre irrigation in terms of both output value efficiency of water use and also gross margin value per ML of water used.
- An analysis of the cost of water and its application indicates that this is comparatively high in the cotton growing valleys of Australia, and should not be ignored in assessing the importance of water use efficiency to the Australian cotton industry.

## Section 2

### Agronomic Aspects of Water Use Efficiency in the Australian Cotton Industry

#### Introduction

The aim of the agronomic section of this project was to find out how much water the Australian cotton industry uses, how efficiently it uses that water, and how that use compares with other irrigation industries. The efficiency of water use encompasses agronomic, engineering and economic components. Public debate about use of the country's water resources, characterised by rhetoric rather than fact, focuses on the competing claims of irrigation and the environment. One outcome of this project may be to inject some fact into the debate.

#### Rhetoric

- "You and I know this [6ML/ha] is not enough to water a successful cotton crop." - Dr Brian Button, "The Button Transcripts", 1985.
- "The cotton industry has a voracious appetite for water." - Dr Peter Crabb, ABC TV Documentary "Running the Rivers", October, 1993.
- "...water-ravenous cottonfields..." - Douglas Nicholas, quoted by Siobhan McHugh, "Cottoning On", 1996.

#### Strategy for the Study

The study was done at three levels - region, farm and field. Data were sought for each level. Efficiency indices were calculated at each level in order to evaluate irrigation practices.

#### Data Collection

*Regional Data.* The area and production of cotton and other crops were obtained from the Australian Bureau of Statistics (ABS) supplemented by statistics published by *The Australian Cotton Grower* magazine (ACG). In NSW water usage data were obtained from the Department of Land and Water Conservation (DLWC) and from the recently privatised bodies - Murrumbidgee Irrigation, Coleambally Irrigation and Murray Irrigation. In Queensland water usage data were obtained from the Annual Reports of the Department of Natural Resources (DNR, previously DPI Water Resources). More detail on sources of data will be found in Annex 2.1.

*Farm Data.* Fifteen farms in the Macquarie, Namoi, Gwydir and Macintyre valleys were asked to provide information. The information requested was the area and production of cotton, the amount of irrigation water used to grow the crop broken down by sources, and rainfall from October to February. The information was requested for several years, including 1991-92 if possible, as for most it was the last year when there was not a shortage of irrigation water. The sample is probably biased as farms were selected because they were thought to keep good records. The farm data were collected to cross check with regional data, and to check that the conclusions drawn from regional level data were plausible.

*Field Data.* The farms were also asked to provide data for selected fields consisting of evapotranspiration estimated with the neutron probe and associated software (Cull 1986) and yield per hectare .

### Water Inputs

Water inputs for cotton production consist of irrigation and rainfall. In this study the primary concern is the efficiency of use of one component - irrigation. The components are dealt with differently at the farm and regional levels.

*Farm Water Inputs.* At the farm level water inputs for cotton production are considered to consist of *all* irrigation water received and *all* rainfall, which differs from the way most farms account for these inputs when efficiencies are calculated. Water from off-allocation and unregulated flows, water harvested on-farm from rainfall run-off and recycled tailwater is held in on-farm storages, and subject to large losses, particularly evaporation. Some farms estimate losses from on-farm storage and deduct these before calculating water use efficiency. The objective of this study is to determine the total amount of water drawn from off-farm surface water sources and groundwater sources, referred to as water delivered to or received at the farm gate, and determine how efficiently it is used. Therefore for this purposes storage losses are not deducted, and such losses will be reflected in the efficiencies calculated.

Accounting for rainfall varies among farms. Some count effective rainfall as falls greater than 10mm or 20mm, others as 75% of total rainfall. In this study all rainfall in the season is counted as an input. Light falls of rain are effective, provided a crop is not water stressed and is still growing actively, and should be included. Even if these falls do not enter the soil, energy is used to evaporate the water from the leaves and soil surface. That energy would otherwise be used to draw water from the soil profile. Such falls therefore substitute for water that otherwise would be drawn out of the profile, and therefore constitute water saved. Consequently all rainfall is counted as a water input.

Rainfall run-off is harvested on some farms for irrigation. Water harvested on-farm, though used for irrigation, is not counted as an irrigation input. If the run-off is from cotton fields it is already accounted for in the rainfall. However some of the water harvested on-farm may come from other fields, and will not therefore be accounted for in the rainfall on cotton fields. In this study half the water harvested is assumed to come from other fields, and is therefore counted as a water input additional to rainfall on the cotton fields, but is not counted as part of the water delivered to the farm-gate.

Harvested water is excluded from the irrigation input in order to achieve the objective of determining how much water is received at the farm gate, and how efficiently it is used. Use of harvested water will be reflected in the efficiency with which the rainfall input is used, which is assessed in the efficiency with which total water input is used (irrigation plus rainfall).

Change in soil water storage during the season is another input. On average it is likely that the soil profile contains less water at the end of the season than at the beginning, the difference representing an input from rain falling prior to the season. This input is ignored at the whole farm level, but could amount to 1 ML per ha.

*Regional Water Inputs.* At the regional level it is not possible to deal with rainfall in the same way as at the farm level, because rainfall varies across a valley and because there are no records of the amount of rainfall harvested in a region. In regions where there is rainfed production an alternative way to account for the contribution of rainfall is to use the yields of rainfed crops to estimate what production would have been without irrigation. This estimate is deducted from the gross irrigated production, in order to determine the marginal production resulting from irrigation. Change in soil water storage during the season is accounted for at the regional level when rainfed yield is used to estimate marginal production.

#### Efficiency of Water Use

In order to evaluate how the cotton industry uses the water inputs it receives from the country's water resources, a number of efficiency indices have been calculated. These indices fall into two groups - water use efficiency (WUE) and irrigation efficiency (IE). Detailed derivation of the indices is given in Annex 2.2.

The term water use efficiency is used in different ways. It is important to distinguish them, and only to compare like with like. All are derived from physiological WUE which is described in Annex 2.2. Water use efficiency is production per unit of water used. Water used can be on the basis of either crop evapotranspiration (ET) giving crop WUE (CWUE), or water input to the farm to give farm WUE (FWUE). Both include the contribution of rainfall, either to ET (for CWUE) or to water input (for FWUE). Irrigation efficiency expresses how much of the water input is used in crop evapotranspiration. CWUE, FWUE and IE are related thus:

$$\begin{aligned} \text{CWUE} &= \text{lint} / \text{ET} \\ \text{FWUE} &= \text{lint} / \text{water\_input} \\ \text{IE} &= \text{ET} / \text{water\_input} \end{aligned}$$

If any two are known, the third can be estimated. In this case CWUE is calculated at the field level, and FWUE at the farm level, and IE is estimated from the ratio FWUE: CWUE. Calculated this way IE estimates how much of the total water input of a farm (irrigation delivered to the farm gate plus) is used for crop ET.

At the regional level two additional WUE indices are calculated. Gross production WUE (GP\_WUE) is how much a region, or the industry as a whole, puts into the economy in relation to the amount of water it takes from the country's water resources. GP\_WUE is also calculated at the farm level to cross check with the regional data. At the regional level rainfall is taken into account in a different way in the marginal production WUE (MP\_WUE), which is how much a region puts into the economy for each ML delivered to the farm gate, over and above what would have been produced from rainfall alone. MP\_WUE is a better index than GP\_WUE for comparing seasons and regions with different rainfall. However without the irrigated cotton industry there would be very little if any dryland production. Consequently GP\_WUE is most appropriate for evaluating irrigation from a national perspective.

FWUE and MP\_WUE both account for rainfall, though in different ways, are not strictly comparable. FWUE is total production divided by total water input (irrigation plus rainfall), whereas MP\_WUE is the marginal increase in production attributed to irrigation. The ratio MP\_WUE: CWUE is an estimate of regional IE -

how much of the irrigation water delivered to the farm gate in a region is used for crop ET. In contrast to farm IE it does not incorporate the efficiency of using rainfall.

Some farms estimate WUE, but not all are comparable with those used in the study. Some farms calculate what in this study is called GP\_WUE from production and irrigation water input. These may be validly compared. Other farms deduct losses, estimated in various ways, from the total water input (irrigation plus rainfall) and divide this into total production. Such estimates lie somewhere between CWUE and FWUE.

## Results

Assembling the data was much more difficult than anticipated. It had been assumed that all the information would be readily available in the public domain, which was true for Queensland but not NSW. A further difficulty was matching data from the water supplying agencies with crop production data from the ABS; the geographical units for recording statistics were not the same.

### Regional Level

Cotton production and water usage for each year for the regions included in the study is given in Annex 2.3, which is summarised in Table 2.1. Six years (NSW) or seven years (Queensland) data were obtained starting from 1988-89. Production and area were greatest in 1991-92, but the volume of water used was largest in 1990-91. All major regions producing cotton are included.

Table 2.1  
Summary of Cotton Water Use in Regions

	% of cotton irrig. area	Irrigated area ha	Irrigated production tonnes	Irrigated yield kg/ha	Irrigation water ML	Irrigation water ML/ha	GPWUE kg/ML	MPWUE kg/ML	Irrigation efficiency
<b>Means for regions.</b>									
Macquarie	99.6%	28444	41519	1444	226129	8.51	184	209	70%
Namoi	93%	43606	65255	1492	321995	7.45	203	125	42%
Gwydir	81%	52364	73442	1336	239623	3.92	394	282	94%
Macintyre	80%	17557	30692	1748	171544	11.73	183	124	41%
Bourke	100%	8649	13356	1549	75677	10.04	168		
St George	100%	12712	18610	1510	60149	4.75	331		
Darling Downs	49%	18477	27713	1493	60445	3.94	404	222	74%
Biloela/Theodore	65%	4608	6483	1411	27681	6.06	235	180	60%
Emerald	98%	12641	19493	1514	98792	7.76	199	124	41%
<b>Totals and Means for years.</b>									
1988-89	91%	162403	248349	1529	1205341	8.30	195	124	47%
1989-90	88%	187775	246020	1310	1321772	8.43	211	139	46%
1990-91	86%	208672	330773	1585	1497688	7.38	244	135	45%
1991-92	85%	243807	394940	1620	1451033	6.41	270	174	58%
1992-93	82%	203782	303605	1490	1025701	5.48	321	257	86%
1993-94	76%	189139	244852	1295	1065168	6.32	270	204	68%
1994-95									
Mean	85%	199263	294756	1471	1261117	7.05	252	172	58%

The total area of cotton in these regions averaged 232,867 ha over the six years, representing 97% of the Australian crop. An average of 84.6% of this area, 199,263 ha, was irrigated with 1,261 GL of irrigation water delivered to the farm gate, applied at 7.05 ML/ha and yielding 1471 kg/ha lint (6.6 bales/ha). The

average GP\_WUE was 252 kg of lint produced for each ML of irrigation water delivered. The MP\_WUE was 172 kg/ML.

Groundwater averaged 13% of the irrigation water for cotton, but increased during the drought from 9% in 1989-90 to 25% in 1993-94. This use of ground water was not distributed regularly among the regions. All regions except three used none or negligible amounts. Namoi used 115,918 ML (36% of total use), and Darling Downs 22345 ML (37%); in 1993-94 more than 50% of irrigation was done with ground water in both regions. All irrigation in the Callide valley was with groundwater but this only amounted to 4% of the total for Biloela/Theodore.

There was a decline in the amount of water used per ha from 8.30 ML in 1988-89 to 5.48 in 1993-94, reflecting the increasing severity of drought. Yields declined but not to the same degree, so that production per megalitre (GP\_WUE and MP\_WUE) increased. This reflects improving water use efficiency.

There was a range among regions in the volume of water used per ha (ML/ha). This variation depended on local factors. Bourke (10 ML/ha) and the Macintyre valley (11.7 ML/ha) used most water per ha, reflecting greater dependence on harvesting of off-allocation and unregulated flows with large evaporation losses during subsequent on-farm storage. Drought reduced the amount of water per ha, with the severest effect in the Gwydir valley where applications fell from 6.49 ML/ha in 1990-91 to 1.43 ML/ha in 1993-94. Application rates were consistently low on the Darling Downs averaging 3.9 ML/ha, but for reason given in Annex 2.1 the Darling Downs data must be treated with caution.

Variation in the GP\_WUE (cotton produced per ML water delivered) and in the MP\_WUE (cotton production attributed to irrigation per ML water delivered) was associated with the amount of water delivered per ha. Bourke and the Macintyre valley with large volumes per ha (a result of on-farm storage losses) had low values of GP\_WUE and MP\_WUE, while high values were obtained for the Gwydir valley and the Darling Downs.

#### Farm Level

Eleven farms out of 15 asked supplied data which is presented in Annex 2.4. The number of years of data ranged from 2 to 7. The mean rate of irrigation with water delivered to the farm gate was 5.37 ML per ha and the mean yield was 1528 kg per ha. The range was from one farm with a means of 3.81 ML/ha and 1449 kg/ha to another with 8.0 ML per ha and 1836 kg per ha. The amount of water per ha fluctuated widely on some farms (Farms 5 and 7 for example), while others (numbers 6 and 10) were more consistent. This difference results from both different supply situations and different attitudes to risk.

Production from water delivered to the farm gate (GP\_WUE) averaged 335 kg per ML delivered, ranging from 222 to 444 kg/ML. Farm WUE (FWUE), which takes into account rainfall, was less variable and averaged 186 kg per ML, ranging from 140 to 214 kg per ML.

#### Comparison of Regional and Farm Results

When the regional data is compared with the selected farms, the farms yielded more per ha, used less water per hectare and consequently produced more cotton per ML delivered (higher GP\_WUE). However the regional and farm data cover different ranges of years, and the farms are drawn mainly from the Namoi,

Gwydir and Macintyre valleys. Table 2.2 compares the same years and regions (Namoi, Gwydir and Macintyre for 1991-2, 1992-3 and 1993-4).

Table 2.2  
Comparison of Regional and Farm Cotton Water Use  
for Namoi, Gwydir and Macintyre Valleys

	Irrigated yield kg/ha	Irrigation water ML/ha	GPWUE kg/ML	Rainfall acctd for kg/ML	Irrigation efficiency
<b>Valley Data</b>				<b>MPWUE</b>	
1991-92	1662	5.65	308	170	57%
1992-93	1458	5.20	346	276	92%
1993-94	1146	5.84	305	263	88%
<b>Mean</b>	<b>1422</b>	<b>5.57</b>	<b>320</b>	<b>236</b>	<b>79%</b>
<b>Farm Data</b>				<b>FWUE</b>	
1991-92	1820	5.24	374	215	69%
1992-93	1377	3.80	443	218	74%
1993-94	981	3.92	312	137	46%
<b>Mean</b>	<b>1393</b>	<b>4.32</b>	<b>377</b>	<b>190</b>	<b>63%</b>

When compared this way, farm yields were more than valley yields in a year of full water allocations (1991-92) but less in a drought year, giving similar means overall (1393 and 1422 kg/ha). Delivered water per ha is less every year (4.32 vs 5.57 ML/ha), while GP\_WUE is greater (377 vs 320 kg/ML). As water becomes scarcer the selected farms spread what water they had over a larger area, or reduced area of crop to a lesser extent than the regions' average. MP\_WUE of the regions is appreciably more than FWUE of the selected farms, precisely because MP\_WUE is a marginal efficiency whereas FWUE is an overall efficiency that includes water required to get the crop to the fruiting stage.

#### Field Level

Only three farms, out of the 11 that responded, also supplied the required field level data (Farms 3, 7 and 11). The data needed is the ET for the field for the season measured by the neutron probe, as well as yield. The data for the farms that responded are given in Annex 2.5. Crop WUE (CWUE) for selected fields ranged from 151 to 822 kg/ML, with a mean of 344, 280 and 258 kg/ha for the three farms. The average of 294 kg/ML for the three farms is consistent with the value of 308 kg/ML cited by Cull and Robson (1994) based on experience with the neutron probe throughout the Australian cotton industry. A value of 300 kg/ML is considered a reasonable average for fully irrigated crops. However these values may overestimate CWUE because the neutron probe does not measure water from the surface layers accurately, and may underestimate ET. This possibility is supported by a CWUE of 227 kg/ML from Australian research in which extraction of soil water from the surface layers was measured gravimetrically (see data of Hodgson et al 1990 in Table 2.6). Partially irrigated and rainfed crops that receive less than 4

ML/ha usually have lower values for CWUE (< 150 kg/ML), because water use prior to fruiting, which constitutes an unavoidable overhead, is spread over a shorter period of effective fruiting.

### Irrigation Efficiency

*Farms with Field Data.* For the three farms with measured ET (Farms 3, 7 and 11), irrigation efficiency is estimated by the ratio FWUE: CWUE. Irrigation efficiency (IE) indicates the magnitude of the losses incurred, but without any indication of where the losses occur in the system. Estimates range from 25% to 92%, with an average of 66% on the three farms. Two of the values appear to be aberrant (Farm 3 1994-95 with 25% and Farm 7 1989-90 with 30%). With these excluded the average is 75%, which is identical with the irrigation efficiency determined by Cull et al (1986) for a farm in 1984-85. It is also the figure accepted by engineers and assumed throughout the cotton industry. One of the aberrations, Farm 3 1994-95 with 25%, appears to be caused by low yields rather than poor irrigation, and the other by exceptionally high values of CWUE.

*Farms without Field Data.* Farm irrigation efficiency for the farms without measured ET, and therefore without CWUE estimates, can be estimated using the value of 300 kg/ML for CWUE. This assumption gave an average IE of 63%. However there is a very wide range from 13% to 101%. Unlike the three farms with field data, there were no clearly aberrant values that could be reasonably excluded. Calculation of FWUE does not include water stored in soil and depleted during the season, which amounts to up to 1 ML per ha. Adjusting water inputs by this amount affects high values of IE more than low values. All the high values are decreased to plausible values over 60% (for example IE of Farm 5 in 1992-93 would decrease from 101% to 67%), accounting for about one third of the data, leaving the long tail of low values unchanged. There are a number of reasons which could account for low values: losses by evaporation when large volumes of water have been stored on-farm for long periods; rainfall poorly utilised; yields depressed for agronomic reasons; underestimation by the probe of ET. If either of the first two apply (evaporation or poorly utilised rainfall) the IE values are a genuine expression of losses and inefficiency. If either of the latter two apply the assumed value of CWUE (300 kg/ML) is inappropriate. There is not enough information to determine which if any of these reasons apply in any particular case.

*Regional Irrigation Efficiency.* Irrigation efficiency at the regional level has been estimated for all regions and included in Annex 2.3, except where there was no rainfed production (Bourke and St George and most years in the Macquarie valley). Marginal production WUE (MP\_WUE) replaced FWUE and was divided by the assumed CWUE value (300 kg/ML). The range in IE values is even wider than at the farm level. In this case changes in soil water storage can not account for the high values (three greater than 100%), as it is already accounted for in production attributed to rainfall, which was deducted from irrigated production in estimating MP\_WUE. As with the farm level estimates the following reasons may apply: water stored for long periods; rainfall poorly utilised; or an inappropriate value of CWUE. A further reason might be inaccuracy in the regional crop and water usage data.

*Discussion of Irrigation Efficiency.* These estimates of irrigation efficiency must be accepted with extreme caution in view of the indirect way they were calculated. They are the best possible with the data available. There is insufficient information to determine which of the possible reasons account for the variation at either the farm or the regional level. Even if 225 kg/ML is assumed as a more reasonable estimate of CWUE, approximately half the resultant values of IE would be unacceptably low. There is clearly scope for improving the irrigation efficiency of the irrigation systems used in the Australian cotton industry.

The sugar industry generally believes its irrigation is efficient. It is noteworthy that Raine and Bakker (1996) found application efficiencies in sugar ranging from 14-90% for single irrigations and 31-62% for the season. This range is very similar to that for cotton found in this study making the values more credible.

Jennelle Douglas' (personal communication) results for the first year of a field level study indicate IE in the range 90 to 95%. Most of the loss is run-off rather than deep drainage, and at the farm level the run-off would be re-cycled as tailwater. If this figure is confirmed by future work that she and others have planned in various locations, then the major losses are evaporation and seepage from storages and channels. Evaporation losses can be estimated from the area of storages and channels, how long they carry water and the evaporation rate, and seepage losses estimated by difference. Thus with more resources these factors could be further investigated and the inefficiencies identified with confidence.

### **National Perspective**

The volume of water used to irrigate cotton in Australia ranged from 1026 GL in 1992-93 to 1498 GL in 1990-91. The mean annual volume from 1988-89 to 1992-93 was 1261 GL, which was 74 % of irrigation water received at the farm gate in cotton growing regions, but only 9% of irrigation water used in Australia (estimated from Wood & Banks 1991). Most irrigated cotton is grown in the Murray-Darling Basin, accounting for 90% of all irrigation water used on cotton. The surface water component accounts for 9% of water released for irrigation in the whole basin, and 63% of the water in the northern valleys, where cotton is grown. These percentages are based on an average annual release of 10648 GL from 1988 to 1993 (Murray-Darling Basin Ministerial Council, 1995).

The cotton industry takes a similar amount of water as rice (Table 2.3), applies it to twice the area (and therefore at half the ML per ha) for about 4 times the gross value of produce per ML. Because of differences among water supply bodies in breakdown of water use, it has not so far been possible to do this for other crops. As far as is known this report is the first study based on actual historical volumes of water used rather than a notional budget. It is interesting to note that both cotton and rice use less water per hectare than that assumed in published gross margin data.

Table 2.3  
Comparison of Cotton and Rice Water Use

		Irrigation water total MI	Irrigation water MI/ha	Yield kg/ha	GPWUE kg/MI
<b>Cotton</b>					
	1992-93	1025701	5.48	1490	321
	1993-94	1065168	6.32	1295	270
	Mean	<b>1045435</b>	<b>5.90</b>	<b>1392</b>	<b>295</b>
<b>Rice</b>					
	1992-93	1184687	11.33	8087	714
	1993-94	1411219	11.30	9900	876
	Mean	<b>1297953</b>	<b>11.31</b>	<b>8993</b>	<b>795</b>

### International Perspective

Factual information from commercial production in other countries, comparable to that gathered in this study, is meagre. Table 2.4 contains information collected by Gillham et al (1995) and Garcia and Cameron (1996). The accuracy of the data is uncertain because it was not gathered with the rigour used in this study. Differences in seasonal ET among countries mainly reflect differences in the amount of advective energy (energy in hot dry winds) available to the crops. Where IE apparently exceeds 100%, the water table is shallow enough for crops to draw water from it. Compared with Australia, many other countries use more water per ha, all have lower yields and lower values of GP\_WUE and CWUE. Many research papers report crop WUE with values range from 132 to 376 kg per ML of ET (Table 2.5), with a clear difference between high and low advection environments. The latter average 275 kg per ML, slightly less than the values reported in Australian commercial crops in this and other studies. The difference may reflect an underestimate of ET by the probe in Australian commercial crops.

Table 2.4  
Water Use of Foreign Irrigated Cotton Crops

	Yield kg/ha	ET MI/ha	Irrigation MI/ha	GPWUE kg/ML	CWUE kg/ML	IE %
<b>Gillham et al 1995</b>						
Egypt lower	920	9.7	6.2	149	95	155%
Egypt middle	945	10.4	7.6	124	91	136%
Egypt upper	923	13.9	10.7	86	66	130%
Uzbekistan N&W	830	8.2	13.7	61	101	53%
Uzbekistan S&E	830	12.3	25.0	33	67	49%
China NW	930	8.6	6.8	138	108	107%
Pakistan	647	8.3	11.0	59	78	56%
<b>Garcia &amp; Cameron 1996</b>						
Uzbekistan	830		12.8	65		
Greece	830		2.7	310		
Syria	830		7.4	112		
Egypt	930		8.5	109		
Pakistan	470		19.0	25		
USA (Calif)	1230		8.9	138		
Australia	1370		7.0	196		

Table 2.5  
Measurements of Crop WUE in International Research (Hearn 1996)

	Country	CWUE-kg/ML
<b>Low advection environments</b>		
Sammis 1981	California	249
Howell et al 1984	California	194
Mein et al 1992	Israel	367
Orgaz et al 1992	Spain	265
Plaut et al 1992	Israel	376
Hodgson et al 1990	Australia	227
Mateos et al 1991	Spain	248
<b>Mean</b>		<b>275</b>
<b>High advection environments</b>		
Sammis 1981	New Mexico	153
Radin et al 1992	Arizona	132
<b>Mean</b>		<b>143</b>

Australian cotton growers use irrigation water more efficiently than growers in other countries and achieve a crop WUE equal to the potential measured in research studies. However there is scope to reduce storage and conveyancing losses.

### Options for Action

#### Water Supply Authorities

Public concern over the use and management of the country's water resources has resulted in a number of recent initiatives. In the Murray-Darling Basin authorities have recently announced caps on extraction of water for irrigation. The difficulty encountered in assembling the data for this study is disturbing, and is of itself an important finding. Water resources used for irrigation are not being adequately measured, and the data are not readily accessible. At a recent CRDC workshop on irrigation water use efficiency, in introducing the application of Total Quality Management to irrigation, Richard Clarke said "If you can't measure it, you can't manage it". It is therefore arguable that the country's water resources are not being managed, because they are not being adequately measured.

If the country's water resources are to be responsibly managed, and if debate on the issue is to be informed, the information must be readily available in the public domain, as accessible as, or part of, ABS data. Only then will regulating authorities be able to make informed decisions on the competing claims of irrigation and the environment for water. It is doubtful if current decisions are informed. Only when fact replaces rhetoric will public debate be informed. If the country is serious about responsible management and use of water resources, then full use must be made of the information being collected.

#### Research

*Irrigation Practices.* The Australian Cotton Foundation has commissioned an audit of the Barwon-Darling River catchment (Brewster et al 1996). The CRDC is considering a project to measure the components of the water balance of a whole farm. The Co-operative Research Centre for Sustainable Cotton Production has a

project in Sub-Program 1.5 entitled "*Managing the hydrologic cycle in relation to cotton*" in which Jennelle Douglas is measuring the components of the water balance of a single field. These three projects correspond to the three levels addressed in this study - region, farm and field. Information on deep drainage at a field level is also being obtained in other work assessing the risk of salinity (Willis & Jenkins 1994, Ben Wilshire & Ian Gordon in CRC sub-program 1.5).

In Queensland, Greg Claydon and Brian Venz are doing a project in the National Landcare Program entitled "*Best Practice Irrigation Systems - Northern Murray-Darling Basin*" which aims to identify specific best management practices to increase the efficiency and sustainability of on-farm irrigation systems. In September LWRRDC called for projects on "*Development of Irrigation Water Use Efficiency Practices to improve resource sustainability*".

*Evaporation Losses.* Sainty & Scott (1996) report that floating plastic covered rings show great potential in reducing evaporation losses. The reduction amounted to 65% giving a payback period of 3 years. Further testing is being done.

*Varieties.* Genotypes with improved physiological WUE have been the aim of research for a number of years. The CRDC previously funded an investigation of carbon isotope discrimination as a technique for identifying genotypes with higher WUE (Hubick & Farquar 1987). The CRDC is supporting Warwick Stiller in the CRC for Sustainable Cotton Production in a project to identify genotypes with superior performance with a limited water supply (project CSP55C). Similar work is being done in Texas and elsewhere, and genotypic variation has been found in physiological WUE but as yet no superior commercial varieties have been produced. The use of parameters like physiological WUE, based on a ratio of two measurements, carries a very real danger of coming to spurious conclusions. WUE is a description, and an increase in WUE may be a result of improved performance, not a cause of improved performance. A genotype may have a higher yield for a large number of reasons. If the higher yield is not accompanied by a commensurate increase in transpiration, then WUE will be higher, but it does not mean that genotype has specific genes for higher WUE.

It is often suggested that short season varieties should be grown to save water (CIE 1995, Gibb Environmental Sciences & Arbour International 1991), particularly when irrigation water is in short supply, the implication being that yield would be maintained resulting in an increase in WUE. Under Australian conditions this suggestion does not stand up to analysis, nor is it supported by experience. Because, as already noted, CO<sub>2</sub> assimilation and loss of water share a common pathway and are both driven by solar radiation, reducing the duration of water use in short season varieties will also reduce the duration of CO<sub>2</sub> assimilation which will reduce yield unless harvest index (the proportion of assimilated carbon ending up in the agronomic yield) is increased.

The several sources of earliness in cotton that potentially can be the basis of short season varieties fall into three groups: (i) earlier onset of fruiting; (ii) more rapid fruiting so that the boll load builds up faster and the crop cuts out earlier; and (iii) faster development of individual fruit (a shorter boll period). Most short season varieties depend on (ii) and to a lesser extent (iii), both of which result in reducing water use at the expense of also reducing CO<sub>2</sub> assimilation, as already described.

In such varieties the period prior to fruiting is unchanged and water use during that period is also unchanged and represents an overhead which is spread over a shorter productive fruiting period. The result is reduced WUE overall. Short season varieties utilising (i) would have a reduced pre-fruiting overhead which might increase WUE overall, but the indications are that the crop would cut out earlier with a less effective root system less able to utilise water in the profile during the terminal drought, as described above. A limited water supply disadvantages short season varieties more than full season varieties, because the root system is less able to utilise water remaining in the profile after the last irrigation, probably because early cutout stopped the root system expanding (Hearn 1996).

The value of short season varieties is in environments where temperature not water supply shortens the season. In such situations short season varieties may have a higher WUE than long season varieties, not because they intrinsically have a higher WUE, but because they yield more in a thermal short season without increasing ET.

### On Farm Options

*Water Accounting.* At a farm level full use is not being made of the information collected. It is recommended that farms make more use of information currently collected in order to evaluate the efficiency of their practices. Several growers made unsolicited comments (see box below) which indicate an increasing awareness of the need to do this.

#### Unsolicited Comments from Growers

- *"My records are not that good."*
- *"As you can see we are slowly learning the value of better measurement and recording of WUE."*
- *"Our records of water use are very poor."*

It is recommended that growers standardise book-keeping and accounting for water inputs (including rainfall), estimation of storage losses and carryover of water in storage from one season to the next. It is recommended that farms use the neutron probe and associated software to estimate seasonal ET in order to calculate IE and CWUE. It is noteworthy that all the farms except one use the neutron probe for irrigation scheduling, but few use the software to estimate seasonal ET. The only satisfactory way to determine how much rainfall contributes to ET is to use the neutron probe and associated software. The "total gain" calculated for the season includes rainfall effective at the time of the fall, and any rainfall subsequently recycled as irrigation with harvested water.

An appropriate way forward would be to convene local farmers' groups to develop and promote a system. If an acceptable system could be standardised across the industry, it could be implemented as computer software integrated in

*hydroLOGIC*<sup>1</sup> or in the proposed user-friendly version of OZCOT<sup>2</sup> or CERCOT<sup>3</sup> for water management, employing record keeping analogous to that in *entomoLOGIC*<sup>4</sup>. A water accounting software package could include calculation of IE, CWUE, FWUE and GP\_WUE.

As noted earlier in defining water use efficiency, some farms estimate CWUE but not all values are comparable with those reported here, or with each other, because of the differences in accounting for rainfall and losses. The results are not true CWUE, though they may be of value for year to year comparisons within farm, but not between farms. It would be better to calculate the true CWUE, FWUE and GP\_WUE.

The ratio between ET and total water inputs is IE. The difference between ET and total water inputs is the magnitude of the losses which contribute to inefficiency indicated by a low value of IE. It is possible to partition these losses into evaporation, seepage (from channels and storages) and deep drainage. Evaporation losses can be calculated from the area of storages and channels, how long they contain water and the evaporation rate. If Janelle Douglas' work confirms that deep drainage is small and relatively constant amount for a given soil type per irrigation or per saturating rainfall event, it can be estimated. Seepage losses can then be estimated by difference. By accounting for water in this way growers will know the relative magnitude of various losses.

*Strategies with Limited Water.* When irrigation supplies are restricted, growers can reduce the area of crop in proportion to the reduced allocation in order to have the same ML per ha, or maintain the area of crop with less ML per ha, or something in between. These strategies have been evaluated using long term weather data (Hearn 1992, 1995). For most regions the strategy which maximised gross margins per ML was a water supply of 5 to 6 ML per ha. In the drier south west this increased to 7 ML per ha, and in the wetter north decreased to 3 or 4 ML per ha. There are risks with these options, and these risks have been assessed. The strategy at which crops break-even nine years out of ten increased from of 2 ML per ha at Emerald to 4 ML per ha in the Macquarie Valley.

This evaluation was done using the OZCOT computer model with general assumptions for growing costs and cotton price. It would be preferable for growers to be able to do the analyses themselves using their own assumptions. It is therefore recommended that the OZCOT model or the CERCOT model be put in a user-friendly form for this purpose.

*Water application technology.* Critics of the cotton industry cite its use of furrow irrigation as inefficient, and advocate increasing efficiency by using various systems that have been developed during the last 25 years such as drip irrigation. Globally, 94% of irrigated cotton is flood or furrow irrigated (ICAC 1993) and only

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<sup>1</sup> HydroLOGIC is an irrigation scheduling package developed by CSIRO at the ACRI, based on the OZCOT model with the facility to do "what if" analysis on the outcome of irrigation decisions under various scenarios.

<sup>2</sup> OZCOT is a cotton crop simulation model developed by CSIRO at the ACRI, and is used for risk analysis of irrigation strategies, amongst other things.

<sup>3</sup> CERCOT is a more robust replacement for OZCOT, shortly to be released.

<sup>4</sup> *EntomoLOGIC* is a computer based decision support and record system for pest management of cotton developed by CSIRO at the ACRI.

0.2% drip irrigated. Israel stands in stark contrast to the rest of the world with 60% of cotton drip irrigated. Apart from Israel, drip has made no impact on the irrigation of cotton, although there has been a lot of research recently summarised by Hearn (1996) who noted drip irrigation saved water in 7 cases out of 9, and increased yield in 5 cases out of 9. Savings in water result from reduced conveyancing and application losses, reduced soil evaporation (E component of ET) and reduced deep drainage. CWUE data was given in only three cases. Drip irrigation increased CWUE in only one case out of the three, and was the result of increased yield, not reduced ET. However CWUE presumably increased in the other experiments where water was saved and/or yield increased.

Australian research showed no saving in water nor increase in yield (Hodgson et al 1990) This finding has been confirmed in a number commercial of attempts in Australia to use drip irrigation which were not sustainable.

The degree to which introduction of drip irrigation will result in water savings depends on where losses occur in current commercial practice, which in turn depend on soil type and water source. If, as suggested in this report, the losses in the Australian cotton industry are mainly evaporation from storage and conveyancing losses and not deep drainage in the field, then introduction of drip irrigation is unlikely to result in savings of water, as confirmed by research and commercial experience. Drip irrigation on Australia's heavy clay vertisols with low saturated hydraulic conductivity offers little scope to reduce loss of water by deep percolation. Where water is conveyed to farms in open channels and in some cases is stored in on farm storages, drip irrigation will likewise not reduce losses.

In Israel yields have been raised and water saved with drip irrigation on lighter soils of variable slope and depth, and the potential of such marginal soils has been raised to that of better soils. Having to pay a full economic cost for water is also a contributory factor. As water costs rise, and drip costs fall there may be wider adoption. Low cost, low pressure drip systems are being developed (Miller 1990). Meanwhile large scale commercial trials are continuing.

## Section 3

### Economic Aspects of Water Use Efficiency in the Australian Cotton Industry

#### Introduction

This section provides an assessment of some of the economic aspects of cotton production and the economic efficiency with which the industry utilises its available water. Key input into this section was the material presented in Section 2 relating to the physical water usage of irrigated cotton and other crops. As noted in that section the collection of data was difficult and as a result it was only possible to assess water use for cotton and rice in any detail. Apart from data from Section 2, substantial data came from the Australian Bureau of Statistics (ABS), Australian Bureau of Agriculture and Resource Economics (ABARE), The Australian Cotton Grower journals, numerous state government departments, irrigation organisations, private farmers, and other published and unpublished material.

Because of the lack of hard data specifically relating to irrigated crops, departmental gross margin budgets were used in some of the analyses. There was little alternative. Water use data in the gross margins was adjusted to be in line with the cotton and rice water use data in Section 2. Where possible, cotton production (and irrigated cotton production) was compared to rice production.

ABS does not collect data specifically relating to irrigation or irrigated crops with the exception of cotton production in Queensland for several years and in NSW starting recently. There is an important and continuing need to have objective material available which assesses water use of major crops and other major users of water such as the numerous "environment" sites throughout the country. ABS and ABARE are urged to collect relevant crop water usage and efficiency data so more informed decisions can be made on the allocation of the country's scarce water resources.

This section has been divided into a number of parts. The first provides a background of the Australian cotton industry in terms of its relative size within the world industry; the second reviews world prices for cotton and other crops; and the following parts assess cotton's relative efficiency in converting water into output and export income compared to rice and other irrigated crops. The final section assesses the real cost of applying water on a typical cotton farm in northern NSW and southern Queensland. The Annexes at the end provide the detailed tables used in each of the assessments.

#### The Australian Cotton Industry in Perspective

##### World Cotton Production

World cotton production for 1995/96 is estimated by ABARE at 20 million tonnes or about 89 million (225 kg) bales. Of this, Australia produced 0.421 million tonnes or about 2.1%. World production of cotton has increased dramatically over the 35 years from 1960. In the year 1960-61 total world production was estimated by ABARE at 9.8 million tonnes and it steadily increased and peaked in 1991/92 at

20.8 million tonnes (93 million 225 kg bales). Since then world production has fluctuated between 16.7 and 20 million tonnes. It is of interest to note that during the period of rapid world growth in cotton production (1960/61 to 1984/85) when the size of the crop increased by about 100%, the area harvested only increased by 5% to about 33.7 million hectares. It is also of interest to note that of the three largest world producers, USA, China, and the former Soviet Union, only China showed any significant production growth during this period. ABARE estimates that the 1996/97 world crop will be 19 million tonnes.

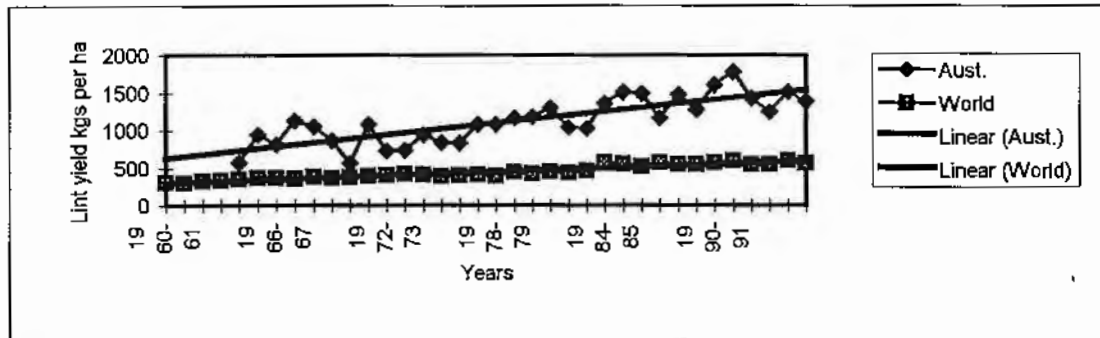
#### Australian Cotton Production

Cotton production in Australia was negligible up until the mid 1960s and from then until 1980 it averaged about 36,000 hectares per year. After the early 1980s the area planted increased dramatically peaking at 300,000 ha in the most recently completed crop year- 1995-96. About 70% of the 300,000 ha was irrigated and this produced an estimated 0.32 million tonnes of lint or about 80% of the crop. In 1991/92, which was the last national crop largely unaffected by irrigation water shortages, total production was about 0.5 million tonnes of lint (over 2 million bales) from 280,000 ha. About 85% of the cropped area was irrigated and this produced about 93% of the crop. Data on average world and Australian production and yields is located in Annex 3.1 and data irrigated Australian production and yields by location is in Annex 2.3.

#### World and Australian Cotton Yields

Average world and Australian yields have improved significantly over the 35 years from 1960. From a global perspective the area planted to cotton has remained relatively static; falling between a range of 30 million ha and 35 million ha (1995/96). As noted above, world production has more than doubled. Average yields have increased from an estimated low of 300 kgs per ha in 1961/62 to 600 kgs in 1991/92. Hearn (1996) estimates that about 53% of the world's cotton crop is irrigated and that this produces some 73% of the world crop. On this basis, world irrigated yields have increased from 418 kgs per ha in 1961/62 to 837 kgs per ha in 1991/92; a doubling. It highlights the very significant improvement in world productivity over a relatively short period. Yield improvements in Australia have been equally impressive improving from a ten year average (1964-65 to 1973-74) of 850 kgs per ha to 1,435 kgs (1986-87 to 1995-96). This data includes rainfed and irrigated cotton. As noted in Section 2, if rainfed cotton is excluded the average yield of irrigated cotton in Australia over the period 1988-89 to 1995-96 was an estimated 1,508 kgs per ha (See Annex 2.3). Chart 3.1 below shows average world and Australian yields over the period 1960-61 to 1995-96. A trend line is also included in the graph which helps overcome the fluctuations caused by water shortages in Australia.

Chart 3.1  
Average cotton yields- Australia and the World 1960-61 to 1995-96  
(Source- ABS)



### Irrigated Cotton Yield Variation in Australia

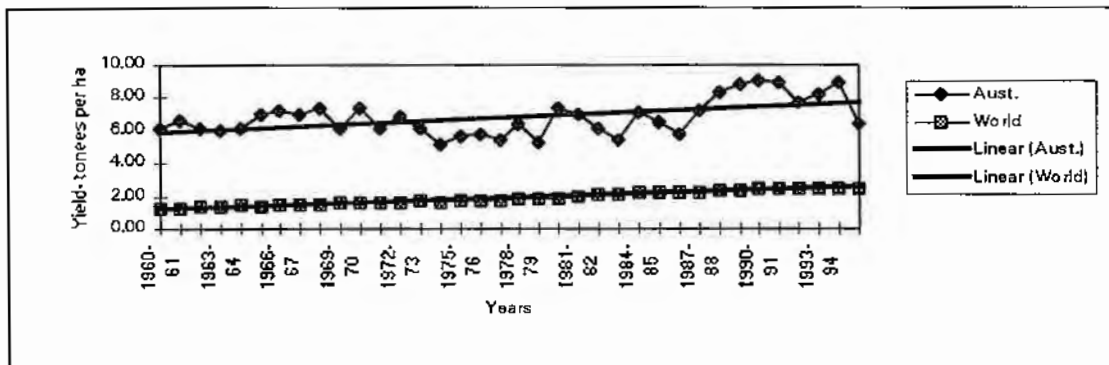
Whilst Section 2 indicates a wide variation in irrigation efficiency (i.e., 41% to 94%) and in water use (11.73ML per ha to 3.92 ML) per ha between valleys, average per hectare yields for irrigated cotton vary little. For the 8 years 1988-89 to 1995-96 the simple average yield for NSW and Queensland was estimated to be virtually the same at 1,508 and 1516 kgs per ha respectively. In the 8 years over which the analysis was undertaken the average yield for all NSW river valleys (Macquarie, Bourke, Namoi, Gwydir, and Macintyre) was within the range of 95% to 115% of the NSW average. The highest comparative average in NSW was the Border Rivers at 115% and the lowest average was the Gwydir Valley at 95% of the state's average. Data for Queensland were similarly consistent with the major sites (St George, Darling Downs, Biloela/Theodore, and Emerald) falling within the range of 92% of the state's average (Biloela/Theodore) to 103% (Emerald). This relative stability in per yields between states and valleys tends to suggest good management of all inputs where water is one of many.

### Rice Worldwide and in Australia

World rice production has followed a similar trend to world cotton production in that average yields have increased significantly while the average area planted has only increased relatively slightly. Between 1960 and 1995 the average world yield doubled from about 1.25 tonnes per ha to 2.5 tonnes per ha and the average area harvested increased by 23% to 148 million ha. The result, over the 35 years, is an increase in production greater than 100% to 370 million tonnes.

Rice production in Australia has shown similar trends as Australian cotton production when compared to international data although average rice yields in Australia have not increased nearly as fast as have cotton yields. This is illustrated in the trend lines of Chart 3.2 below. This trend line shows that average Australian yields have increased from around 6 tonnes per ha to between 7.5 and 8.0 tonnes per hectare- an increase of about 30%. When compared to world yields, Australian yields are much higher- in 1994-95 they were higher by a factor of about 3.6 times.

Chart 3.2  
Average rice yields- Australia and the World 1960-61 to 1995-96  
(Source ABS)



Details of yields and total production of rice for the world and Australia are shown in Annex 3.2.

## International Trade and Price

### Cotton

World exports of raw cotton equal about 30% of production with the balance being processed into goods in the producing countries. As the bulk of Australia's crop is exported, the Australian crop makes up a sizeable portion of the total internationally traded crop at between 5 and 6%. Australia is ranked fourth in the world as a cotton exporter behind USA, Uzbekistan, and Francophone Africa. The international price of cotton is largely determined on the New York cotton futures contract as traded on the New York Cotton Exchange and Australia's relatively small level of production has little if any impact on this price.

### Cotton Compared to Other Commodities

As with most internationally traded agricultural commodities the price of cotton has fluctuated considerably over the years. Annex 3.3 shows nominal world indicator prices for cotton, wheat, rice, sugar, wool and beef for the 25 year period 1971-72 to 1995-96. An accompanying table also shows these data converted to Australian dollars and shown as an index based on 1971-72 prices.

These data show, in nominal US\$ terms, that 1971-72 recorded the lowest prices for cotton, wheat, and rice over the 25 year period. The price of sugar fluctuated significantly during the period. In Australian dollar terms a similar picture is seen for cotton, wheat, rice, sugar and wool. The lowest nominal beef prices were recorded in 1974-75. The table below shows the prices for the six commodities deflated to 1971-72 values for two five year periods and the average prices for the five years. The purpose of the table is an attempt to determine the relative strength of prices for each of the commodities.

Table 3.1  
Commodity price comparison for two five year periods  
using deflated prices

Year	Cotton (Ac/lb)	Wheat (A\$/t)	Rice (A\$/t)	Sugar (Ac/lb)	Wool <sup>a</sup> (Ac/kg)	Beef (Ac/kg)
1970-71	32	50	120	5.3	167	61
1972-73	29	67	137	6.4	167	65
1973-74	43	110	336	10.5	189	66
1974-75	28	87	229	15.8	175	24
1975-76	31	74	152	6.8	179	22
<b>Average (1)</b>	<b>32.6</b>	<b>77.6</b>	<b>194.8</b>	<b>9.0</b>	<b>175.4</b>	<b>47.6</b>
1991-92	15	38	72	2.1	107	36
1992-93	15	40	70	2.4	92	39
1993-94	18	39	99	2.8	96	39
1994-95	21	40	78	3.2	133	34
1995-96	19	50	84	2.6	101	25
<b>Average (2)</b>	<b>17.6</b>	<b>41.4</b>	<b>80.6</b>	<b>2.6</b>	<b>105.8</b>	<b>34.8</b>
<b>Av 2/Av1 %</b>	<b>54</b>	<b>53</b>	<b>41</b>	<b>32</b>	<b>60</b>	<b>73</b>

Note: (a) Wool is for years 1974-75 to 1978-79 and 1991-92 to 1995-96  
Source: ABARE

Of the four crop products reviewed, sugar has declined the most in real terms in Australian dollars followed by rice. Cotton and wheat have declined by about the same amount. But, all crops have declined by a greater amount than livestock products.

Even though the deflated price of cotton is approximately half of what it was in the early 1970s, cotton producers have been able to sustain their businesses because of a significant improvement in their operational, marketing and financial efficiency. In particular; (i) yields of seed cotton have increased through improved varieties and better management; (ii) ginning efficiency and turnout has improved; and (iii) production systems have been improved which have allowed costs to be somewhat contained.

#### Relative Size, Productivity and Economic Efficiency Ratios of the Australian Cotton Industry

Data showing financial statistics for a variety of different farm types is shown in Annex 3.4. This data is for the period 1991-92 to 1994/95. In Table 3.2 below they have been averaged to help overcome any particular seasonal bias and summarised. It should be noted that the material is the average for the ABS classification of farm types. In other words, a cotton farm may have income from livestock sales but cotton is considered the main enterprise. Similarly, a livestock farm may have income from cotton. It should also be noted that the data for cotton production would include data relating to rainfed cotton production. Because rainfed cotton makes up only a relatively small percentage of cotton production its impact on the financial data would be minimal. Regardless of these shortcomings, the data does provide an excellent profile of the financial position of cotton farms and their relative size and level of investment when compared to other farming enterprises. It should also be noted that the period reviewed covered a period in which some cotton growing areas were adversely affected by irrigation water shortages. For example, in the Gwydir (the largest cotton producing valley when

adequate water is available), the total production in 1994/95 was only 10% of 0.55 million bales produced in 1991/92.

Table 3.2  
Key financial and performance indicators  
various agricultural enterprises four year average data  
1991-92 to 1994-95

Enterprise	Income (\$'000)	Value added (\$'000)	Capital spent (\$'000)	Total assets (\$'000)	Total debt (\$'000)	Net worth (\$'000)	Equity %	Ret. on assets %	Ret. on equity %	Assets to prod. \$1 t'over <sup>1</sup> \$	Assets to prod. \$1 Val add. <sup>2</sup> \$
Cotton	1261.3	522.7	113.9	4014.7	1049.9	2964.9	73.8	8.3	8.1	3.2	7.7
Poultry	495.0	188.2	41.0	1271.1	293.7	977.4	76.9	8.2	7.9	2.6	6.8
Grain	245.7	106.4	27.1	1012.3	170.6	841.8	83.2	7.8	7.5	4.1	9.5
Grain/stk	183.7	80.8	17.4	1037.3	152.9	884.4	85.3	4.9	4.0	5.6	12.8
Shp/beef	150.0	68.4	10.6	1341.2	146.9	1194.4	89.1	2.5	1.6	8.9	19.6
Sheep	120.1	56.2	7.7	968.0	128.0	840.0	86.8	3.0	1.9	8.1	17.2
Beef	168.7	65.2	13.8	1440.8	154.0	1286.8	89.3	2.7	2.0	8.5	22.1
Dairy	184.0	91.1	16.9	923.8	124.2	799.6	86.6	6.4	5.9	5.0	10.1
Pigs	420.5	117.5	22.1	1003.7	190.0	813.7	81.1	6.1	5.4	2.4	8.5
Sugar	212.2	105.4	21.2	995.0	133.4	861.6	86.6	8.0	8.1	4.7	9.4
All ag.	194.6	87.1	16.6	1065.1	149.7	915.4	85.9	4.9	4.2	5.5	12.2

Notes: 1. Assets to produce \$1 turnover is a measure of efficiency of the use of assets. It is calculated by dividing total assets by total income. 2. Assets to produce \$1 value added is also a measure of efficiency of the use of assets. It is calculated by dividing total assets by total value added

Source: ABS

Average income from the average cotton farm in the four years was \$1.26 million or about 6.5 times the average of all agriculture. The data also shows that cotton farms spent on capital items, on average, about seven times more than the average farm. A significant portion of this expenditure is incurred locally as identified by Powell and others<sup>1</sup> in the numerous reports they have prepared on the impact of the irrigated cotton industry.

Table 3.2 shows that cotton farms needed only \$3.2 in capital assets to produce \$1 in turnover. This is less than 60% of the average for all reported agriculture of \$5.5. The only farms which needed fewer assets, on average, were poultry farms. The relative efficiency of the cotton industry is maintained in the industry assessment of assets required to produce \$1 value added. For cotton, \$7.9 in capital was needed, on average, to produce \$1 in value added, while the average for all agriculture was \$12.2. Again, the only reported agricultural industry to show greater efficiency was the poultry industry which needed \$6.8 in capital to produce \$1 in value added. These data indicate that the cotton industry is a far more efficient user of capital than other broad-acre agricultural enterprises for which data are available. This helps to explain why the cotton industry has grown so rapidly and successfully in Australia.

<sup>1</sup> for example, Powell, R., Chalmers, L. and Fisher, S. 1993, *The Economic Impact of the Cotton Industry in the Macintyre Valley*, Centre for Agricultural and Resource Economics, University of New England, and Powell, R., Chalmers, L. 1995, *Gwydir Valley Cotton Drought Study*, Centre for Agricultural and Resource Economics, University of New England

Table 3.2 also shows that cotton farms have a lower average equity than the average for all agriculture and for all the industries included in analysis above. The comparatively high debt of the cotton industry means that productivity of the industry is vital if debt commitments are to be serviced. The data also highlights the absolute level of debt carried by the average cotton business. Even though the average equity for cotton farms is only 12% below the average for all agriculture (73.8% compared to 85.9%), the average absolute level of debt is about seven times that for all agriculture.

In the four years of the analysis the average total asset value of cotton farms was about \$4 million compared to the \$1.1 million average for all agriculture. Overall, cotton farms are shown to be efficient in terms of asset use when compared to other farms.

### Yield Efficiency of Water Use- Cotton and Rice

#### Cotton and Rice in Australia

Table 3.3 below shows yields for the five years 1964-65 to 1968-69 and for the five years 1991-92 to 1995-96 for cotton and rice. Rice data is from ABS, irrigated cotton yield for 1991-92 to 1995-96 is from Annex 2.3 and the cotton yield 1964-65 to 1968-69 is from ABS but adjusted to irrigation yields. The table also shows the water usage data determined in Section 2 for each crop and the average yield per ML of water. This simple analysis assumes that the volume of water applied to both crops has declined by 10% per hectare over the 25 year period. In view of the significant advances in water management techniques, farm layout design and crop hygiene, this assumption is considered conservative.

Table 3.3  
Yield and water use efficiency- irrigated cotton & rice

	Cotton	Rice
1964-65 (kg/ha)	630	6140
1965-66 (kg/ha)	1030	6960
1966-67 (kg/ha)	895	7190
1967-68 (kg/ha)	1240	6990
1968-69 (kg/ha)	1160	7360
Average (kg/ha)	990 lint	6928
Average (kg/ha)	1400 seed <sup>1</sup>	
Total pdn (kgs/ha)	2390	6928
Water use (ML/ha)	6.56	12.57
Production (kg/ML)	151 lint	551
Production (kg/ML)	213 seed	
1991-92 (kg/ha)	1620	8890
1992-93 (kg/ha)	1490	7670
1993-94 (kg/ha)	1295	8200
1994-95 (kg/ha)	1574	8880
1995-96 (kg/ha)	1624	6380
Average (kg/ha)	1520 lint	8004
Average (kgs/ha)	2200 seed <sup>1</sup>	
Total pdn (kgs/ha)	3720	8004
Water use (ML/ha)	5.90	11.31
Production (kg/ML)	258 lint	707
Production (kg/ML)	373 seed	

Note: Seed estimated on the basis of 1.45 tonnes of seed produced per 1 tonne of lint

This analysis shows that the productivity of cotton has increased, on average, from 151 kgs of lint per ML to 258 kgs per ML- an increase of 71% or in the case of cotton seed by 75%. The corresponding data for rice shows an increase from 0.55 tonnes of rice per ML to 0.7 tonnes per ML- an increase of 25%. These data clearly indicate that cotton producers have achieved far greater productivity gains in water usage than rice farmers over the thirty year period.

### **Estimate of Marginal Return from Irrigation for Cotton Production**

Two methods are used below to assess the economic marginal return from irrigation water for irrigated cotton production. Both methods deduct the estimated value of rainfall from the value of the crop. The analysis is simplistic because it assumes that irrigated fields, had they not been irrigated, would have yielded the same as rainfed fields which is not necessarily true.

#### Method 1- Marginal return using the regional level MPWUE (Table 2.1, Section 2)

Table 2.1 in Section 2 shows that the mean marginal production WUE is 172 kgs/ML and the mean irrigation water use is 7.05 ML/ha over a total area of 199,263 ha. Based on an average price of \$2370/tonne for lint and \$175/tonne for seed<sup>2</sup>, the average annual marginal return from irrigation from cotton production is \$634 million or an average national marginal production WUE of \$451 per ML.

Annex 2.4 shows FWUE by farm (surveyed in this project) and for the average of the eleven farms. The average marginal return based on Annex 2.4 was \$488 per ML with a range of \$102 per ML to \$792 per ML. This range indicates that there is significant variability in the national data which determined the average marginal production WUE.

#### Method 2- Marginal return using irrigated and dryland total production data

Annex 3.5 provides an economic assessment of the benefits of irrigation for each of the main cotton growing areas in Australia over the period 1990/91 to 1995/96. The assessment was prepared using data from Annex 2.3 and data on rainfed yields from various sources and it was made by deducting achieved rainfed yield in each valley from the achieved irrigated yield.

Table 3.4 below summarises the results of the analysis by providing the average data for the six years of the analysis.

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<sup>2</sup> The simple average of the actual value of lint and seed used in Method 2

Table 3.4  
Estimate of Average Benefit of Irrigation for Cotton Production  
For the years 1990/91 to 1995/96

	Macq. Valley	Namoi Valley	Gwydir Valley	Border Rivers	Other NSW	Emld Region	Biloela Region	Darling Downs	St Geo Region	Australia
Ha of irrigated cotton	27784	46096	48940	21469	13904	13492	4669	19321	11744	207416
Yield irrig. Cotton (t/ha)	1.522	1.552	1.394	1.731	1.506	1.614	1.537	1.507	1.647	
Yield rainfed cott. (t/ha)	0.255	0.636	0.609	0.624		0.460	0.461	0.660		
Benefit from irrig. (t/ha)	1.268	0.916	0.786	1.107	1.506	1.154	1.076	0.847	1.647	
Tonnes of lint from irr.	35221	42225	38448	23770	20943	15573	5024	16361	19345	216909
Tonnes of seed from irr.	51202	61384	55893	34555	30445	22639	7304	23785	28122	315330
Val attrib. to irrig (\$mill)	94	110	97	61	56	41	13	43	51	567
Val attrib. Rain (\$mill)	19	77	75	35		16	6	34		261
Val of total crop (\$mill)	113	187	172	96	56	57	19	77	51	828
% Pdn. Attrib to irrigation	83	59	56	63	100	72	68	56	100	68
Val. Attrib. To irr. \$/ha	3383	2386	1982	2841	4028	3039	2784	2226	4343	
ML/ha (Annex 2.3)	8.51	7.45	3.92	11.73	10.04	7.76	6.06	3.94	4.75	
Attrib. To irr. \$/ML	398	320	506	242	401	392	459	565	914	466

This analysis estimates that the average annual marginal return from irrigation in the cotton industry for the years 1990/91 to 1995/96 was \$567 million or about 68% of the total value of the irrigated cotton crop. It is of interest to note the variability of the average benefit between major producing regions. Three regions did not attempt to grow any rainfed cotton and were assessed as being totally dependent on irrigation (Bourke, Tandou, and St George) with the least dependence being the two largest producing valleys the Namoi and Gwydir each with 59% and 56% respectively.

Section 2 notes that "without the irrigated cotton industry there would be very little if any dryland production". This is assessed because of the large infra-structural requirements of the industry and the benefits that inputs such as research and development have contributed to the industry. Without irrigated cotton industry this research would not have occurred. This assessment is probably true but, nevertheless, the data in the table above demonstrates, in pure financial terms, the direct calculated economic effect of irrigation on the output of the industry.

One further point worthy of note is the estimated value of rainfed cotton on irrigated land. In this analysis it is estimated to have averaged \$261 million over the six years of the analysis. Over the same period the average total output of rice (which used approximately the same amount of irrigation water as irrigated cotton) was \$206 million or only some 80% of the attributed rainfed output of cotton from irrigation land.

Table 3.4 also assesses the marginal returns per ML on a regional basis. These vary from a low of \$242 per ML in the Border Rivers to a high of \$914 in the St George Region. The national average using this methodology is \$466 per ML which is remarkably close to the \$451 per ML calculated in Method 1 above.

Generally, within the limitations of the data available the results of the Method 1 and 2 analysis are remarkably similar.

## Cotton Compared Internationally

As noted in Section 2, information on international cotton production and water use efficiency is particularly scarce and that which is available may not be totally reliable. Nevertheless, data from one source is presented below. The purpose of presenting this data is not to provide a definitive economic assessment of the Australian cotton industry compared to the international industry but rather to provide some indication of its relative efficiency compared to other producing countries.

The International Cotton Advisory Committee (ICAC) conducts regular world wide surveys of yields, the cost of production and returns for both irrigated and rainfed cotton production. In their most recent survey, published in 1995, data was collected from 28 regions or countries. This included lint yield, production and other costs and net return. Data from 22 regions and countries is reproduced in Annex 3.6. A summary of this table is presented below (Table 3.5). Unfortunately, no data or estimates were available in this survey on the quantity of water needed to produce the crop. In the introduction to the ICAC document the authors highlighted the difficulties associated with the collection of data and warned of the need to interpret it carefully. However, in the absence of better material a sample is presented.

Table 3.5  
Summary of ICAC survey

Country/ Region	Lint Yield kgs/ha	Income US\$/ha	Tot. Costs US\$/ha	Net return US\$/ha
NSW	1415	2394	1265	1129
Qld	1524	2658	1486	1172
Israel	1800	3846	4203	-357
SW USA	1269	1751	2020	-269
Transvaal	1243	2623	1587	1036
Syria	992	2089	1830	259
China	864	1536	713	823
Punjab- Pakistan	833	1675	1282	393
Argentina	700	1482	730	752
Nth India	498	1257	563	694
<b>Average</b>	<b>933</b>	<b>1950</b>	<b>1594</b>	<b>356</b>
<b>Std deviation</b>	<b>399</b>	<b>869</b>	<b>1001</b>	<b>724</b>

Source: Survey of the cost of Production of Raw Cotton, International Cotton Advisory Committee, October 1995

The major points to note from the table include the significant variability of yields between countries, average cotton prices and the resulting level of income and costs. The only country (or area) to attain higher average yields than Australia in the survey was Israel where cotton is drip irrigated. The table and survey shows two things of importance to the Australian industry: firstly, apart from Israel, Australia's irrigated cotton yields are the highest of the countries surveyed and approximately 60% above the average for all the countries which participated in the survey; and, secondly the net return from irrigated cotton production in Australia is the highest of the countries surveyed (including Israel) and over three times the average return for all countries in the ICAC survey. To achieve these returns

average per hectare costs in Australia were only 85% of the average for the survey countries.

### Output Value Efficiency of Water Use, Cotton, Rice, and Other Irrigated Crops

#### National Data

Charts 3.3 and 3.4 which follow show the value of Australian production of cotton and rice and the value of exports for the two crops from 1971-72 to 1995-96. Data on production and exports is from ABS and cotton production from irrigation is estimated using ABS data and data from Section 2. In 1971-72 the value of production of both crops was negligible but by 1995-96 the value of cotton production was an estimated \$1,112 million (of which an estimated \$925 million was from irrigation) and the estimated value of the rice crop was \$200 million or about 20% of the value of the cotton crop. The data for exports shows a similar trend in that in 1995-96 the value of cotton exports was estimated at \$760 million (of which an estimated \$710 million was from irrigation) and the value of rice exports was \$320 million or 42% of the value of estimated cotton exports.

It is interesting to note that the value of production for cotton is increasing at a much greater rate than for rice. More importantly, the current value of production for cotton can be seen to be around five times that of rice, whereas Section 2 notes that the total irrigation water used for rice in 1992-93 was 15% higher than the total water used for irrigated cotton and in 1993-94 some 32% higher.

Chart 3.3  
Value of Australian Production- Cotton and Rice  
(Source ABS)

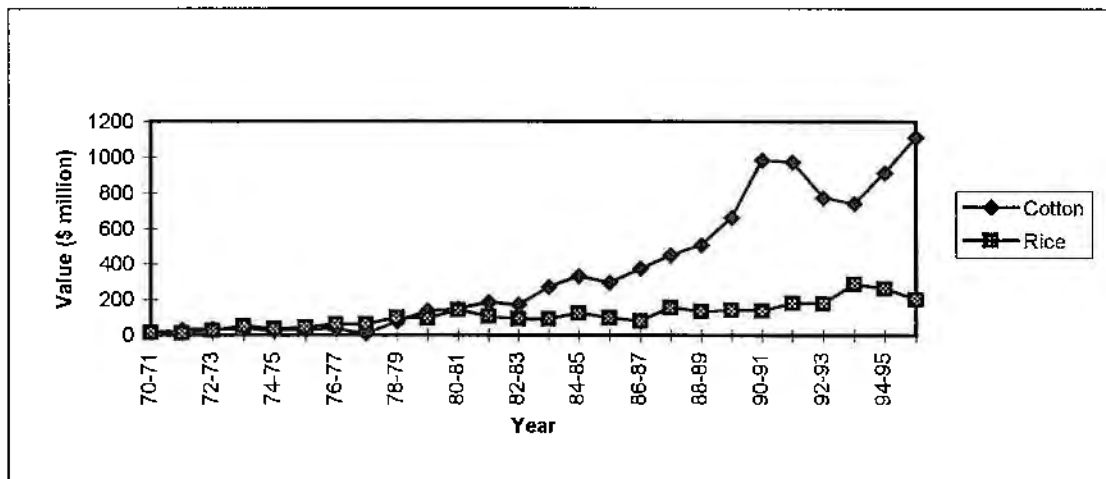
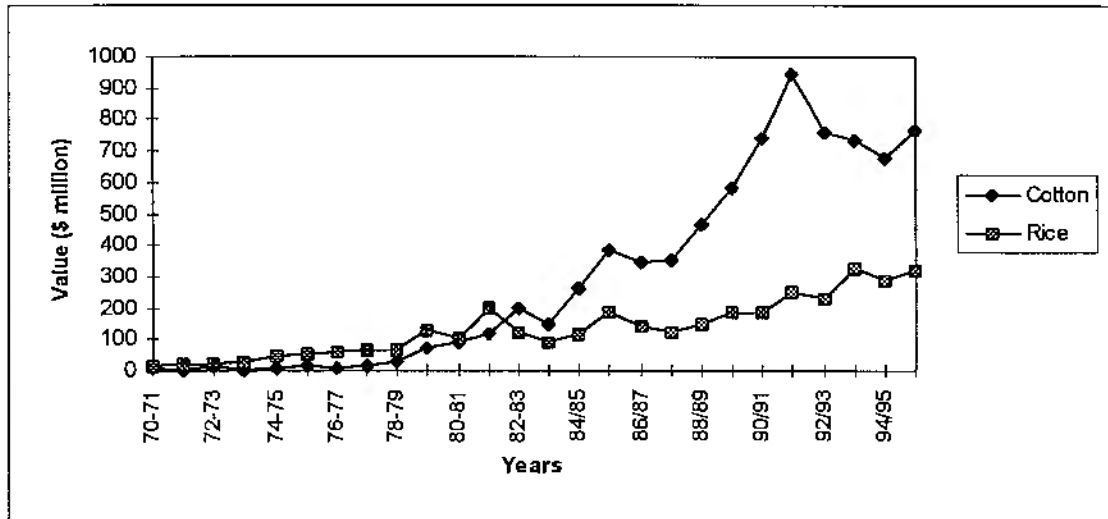


Chart 3.4  
Value of Australian Exports- Cotton and Rice  
(Source ABS)



Looking at this data in more detail, in terms of value of output, cotton uses water about four times more efficiently than rice. In 1992-93 the gross value of cotton production was \$770 million from an estimated input of 1 million ML of irrigation water. Of this an estimated \$740 million was from irrigation. The gross output per ML of water is therefore estimated at \$740 per ML. In the same year the estimated output from rice was \$177 million from an input of 1.18 million ML of irrigation water which converts to a gross output per ML of \$150. Using this measure of efficiency, cotton converts water to output at about five times the efficiency of rice. The data for 1993-94 is similar in that for cotton 1.05 million ML was used to produce \$739 million in output of which an estimated \$690 million was from irrigation. This is \$660 of output per ML. Rice, in comparison, used 1.4 million ML to produce \$285 million in output. This is \$200 of output per ML of irrigation input. The average of the two years 1992-93 and 1993-94 for cotton is \$700 per ML of irrigation input compared to \$180 per ML for rice.

#### Gross Margin Data

Analyses using gross margin material<sup>3</sup> confirm the output efficiency of cotton. Annex 3.7 details gross margins and estimated water usage for a variety of crops grown in the northern cotton producing valleys of Australia and irrigated crops grown in southern Australia. Gross margin data is based on budgeted values of water and, as noted in Section 2, the calculated usage of water for cotton and rice as determined in this study is less than that in published gross margin material. Because of this the water usage data in the gross margins was scaled down on a pro rata basis to correspond to water usage data determined in Section 2.

Gross margin data for the Gwydir Valley were used as representative of all cotton producing areas. The table shows that for the Gwydir, irrigated cotton

<sup>3</sup> Gross margin data includes an assessment of yield, product price, and variable costs only. No assessment is made of fixed costs or capital requirements in gross margins.

produces output of about \$590 per ML, well above any of the other summer crops. The other four crops evaluated (sorghum, sunflowers, soybean, and maize) had an output range of between \$237 and \$320 per ML. In terms of gross margin per ML cotton also has the highest gross margin for the northern crops at \$237 per ML with the other four crops ranging between \$100 and \$190 per ML.

In southern Australia Annex 3.7 shows that of the crops assessed canola has the highest output per ML of \$413 per ML closely followed by biscuit wheat at \$410 per ML. Long grain rice is \$170 per ML and soybean comes in with the lowest efficiency at \$144 per ML. Canola and biscuit wheat have similar gross margins per ML at about \$175 per ML. The rice gross margin is \$93 per ML of irrigation water. The cotton gross margin per ML of water is therefore about 2 ½ times that of rice.

### **Cost of Applying Water**

The cost of water to irrigators is often quoted as the cost imposed by the water supply authority for the water pumped on to the farm. This assessment is erroneous as it does not include substantial on-farm investment costs necessary to apply irrigation water at the times required by the crop in the northern cotton producing regions, but which are not needed in the southern valleys.

A major problem with irrigated cotton farming is river reliability. Unreliable rivers increase the cost of applying water because of the infrastructure which is required to help even out fluctuations in water availability and their associated fixed costs. Farmers in the more reliable south do not require the infrastructure of the northern farmers and do not have the associated fixed costs. The fixed costs associated with the distribution of water in the cotton producing river valleys are also spread over less water because of the river reliability problem. This results in a significantly higher cost per ML delivered on to the field than if the river had a history of high reliability.

To demonstrate the cost of applying water to irrigation fields an analysis was undertaken of the Coleambally Irrigation Area and the Gwydir River. A typical licence was used in each case, 972 ML for the Gwydir and 1400 ML for Coleambally. Given average water requirements determined in Section 2 of 5.9 ML and 11.3 ML for cotton and rice respectively, this results in the capacity for the Gwydir licence to produce 165 ha of cotton from the 972 ML, and the Coleambally licence to produce 124 ha of rice from the 1400 ML. The details of this analysis are shown in Annex 3.8. An important part of this assessment was the determination of river reliability. This data showed that over the ten years 1987-88 to 1996-97 the allocation of the Gwydir varied between 0% and 100% of licensed allocation and averaged 30% while the allocation of the Murrumbidgee and its off river schemes varied between 120% and 100% to average 115%. The table below summarises the results of the assessment.

Table 3.6  
Comparative costs of irrigation  
Gwydir River and Coleambally Irrigation Area

Data	Gwydir River- River pumper	Coleambally- scheme irrig.
Capital costs (\$)	240,000	31,000
Annual operating costs		
- Fixed costs (\$)	47,120	12,740
- Variable costs (\$)	9,510	12,020
Total costs (\$)	56,630	24,760
Full allocation (ML)	972	1,400
Cost/ML @ full alloc. (\$)	58.25	17.70
Full allocation + 33% off allocation (ML)	1290	1,862
Cost/ML full all. +33% (\$)	46.15	15.45
Ave alloc. over last 10 years + 150 ML off alloc (ML)	450	1760
Cost/ML @ ave + 150 ML (\$)	114.50	15.85

This analysis clearly demonstrates the difference in the cost of applying water in an irrigation scheme in southern Australia to that of applying water to cotton in northern NSW and southern Queensland. It shows that the estimated capital costs per average single licence associated with the supply and drainage of irrigation water are about eight times higher on cotton farms than on rice farms and that fixed operating charges are about four times greater on cotton farms. Given a full allocation, the cost per ML applied on the cotton farm example is about 3.5 times higher than that of southern scheme rice producers. In a more realistic situation where river reliability is taken in to consideration and there is some off allocation supply then the cost per ML of water applied to the northern irrigator is about \$114 per ML- seven times that of the southern rice irrigator.

Despite the much higher cost per ML of applying water to irrigated crops in the Gwydir when compared to Coleambally, the return per ML is still higher for cotton production in the Gwydir in an average water year than in Coleambally even though the calculated price of delivering water in the Gwydir is seven times that of Coleambally.

## Annex 2.1 Sources of Data

The sources of ABS data were publications (chiefly Catalogue Nos. 71131.1, 7321.1, 7321.3, 7501.0, 7503.0) and the AGSTATS database. Statistics published by *The Australian Cotton Grower* magazine (ACG) were used to estimate the percentage of the crop that was irrigated when this information was not included in the ABS statistics. The ACG data were also used to partition the ABS data for the Moree and Yallaroi Shires between the Gwydir and Macintyre valleys, which are separate irrigation areas.

In NSW data on irrigation water usage was not easily accessible. In Queensland there were clear anomalies in the published data. It was only through the unfailing helpfulness of the officers of the Departments in both States that sufficient data were obtained.

In NSW water usage data were not available from a single agency but had to be obtained separately from the DLWC and from the recently privatised bodies - Murrumbidgee Irrigation, Coleambally Irrigation and Murray Irrigation. Within the DLWC, data on regulated rivers was provided by the Water Administration Unit of the Water Management Directorate in Parramatta, who also kindly obtained unregulated rivers and groundwater usage from other sections within the DLWC. It took staff of the Water Administration Unit a month to locate all required data. Staff at the Narrabri office of the Department also provided written and verbal information on groundwater usage. The DLWC volumetric data from surface sources was broken down by crops, but not for ground water, for which the opinion of the local DLWC officers was used. For surface water in NSW the "other" category included off-allocation water pumped into on-farm storage for subsequent irrigation of cotton. In the northern valleys the stored water for cotton was separated from the "other" crops usage by assuming 5 MI per ha of those crops.

For the southern parts of NSW (Murrumbidgee and Murray) most data were obtained from the privatised bodies. In the case of Murrumbidgee Irrigation, offices at both Griffith and Leeton had to be approached. Different categories were used by different agencies for the breakdown among crops, which made collation of data from different sources difficult, if not impossible in some cases. Coleambally Irrigation could not supply data on water usage on rice, apparently at the request of The Rice Growers Association, and the statistic was estimated on the basis of 70% of Coleambally usage being on rice (Humphries et al 1994).

In Queensland the water usage data obtained from the Annual Reports of the Department of Natural Resources (previously DPI Water Resources) were not broken down by crops. Volumes of water used on crops were estimated as proportional to crop area weighted by the recommended crop water requirements, supplemented by verbal and written information from officers of the Department at Toowoomba, Emerald, Biloela and Theodore.

There were two major anomalies in the published data on the Darling Downs, which necessitated special treatment and additional assumptions for the region. The first anomaly was that for two years there was no irrigated cotton in the DNR data, when farmers and industry bodies know that there was irrigated cotton, supported by the ABS and ACG data. The DNR office in Toowoomba supplied the area of cotton for the missing years. The second anomaly was that the areas of irrigated cotton reported by the DNR were about half the area given by the ABS and ACG; the

means from 1988 to 1994 were 9543 ha from DNR, 18477 ha from ABS and 17377 ha from ACG. The ABS area is taken as the most reliable, but when used with the volume of water from DNR clearly implausible estimates of GP WUE, MP WUE and IE resulted ( 911, 506 and 169% respectively, far outside the range for the other regions). The anomaly is most likely related to water harvested from overland flows. Land irrigated from such water is included in ABS and ACG data, but excluded from DNR data. In order to correct the anomaly, it is assumed that the rate of irrigation in MI/ha from the DNR data also applies to land water from water harvested from overland flows. When this was done the estimates of GP WUE, MP WUE and IE were 404, 222 and 74% respectively, consistent with the other regions. However these efficiencies for the Darling Downs must be treated with even more caution than other regions in view of the additional assumptions made.

Annex 2.2  
Indices for Evaluation of Water Use

Water Use Efficiency.

The term water use efficiency (WUE) has been used in a number of different ways, but in this report it is used as follows:

*i) Physiological WUE (PWUE).* PWUE is the ratio between the rates of gas exchange (CO<sub>2</sub> entering as raw material for photosynthesis and water vapour leaving in the process of transpiration) between the atmosphere and the leaves over a short time span (minutes). PWUE is not part of this study but its definition is important because it is a component of all other definitions of WUE. It is the amount of CO<sub>2</sub> fixed per unit of water transpired. Because carbon dioxide and water vapour exchange are linked by sharing a common diffusive pathway through the stomata, and are both driven by solar radiation, it might therefore be expected that PWUE would be a unique constant for a crop. However this is not so because although there is only one source of energy for photosynthesis (solar), there are two for transpiration. Heat in the air mass moving across a crop provides the additional energy source for transpiration, sometimes referred to as advection. The proportion of advective to solar energy is not constant. It is high in desert climates and low in humid climates, and can vary from season to season in the cotton growing valleys of Australia. Consequently PWUE, and other WUE indices dependent on it, are lower in desert climates than in humid climates, and vary from season to season in Australia.

*ii) Crop WUE (CWUE).* CWUE is calculated by dividing yield (kg/ha) by evapotranspiration (ET MI/ha).

$$\text{CWUE (kg/ML)} = \text{kg\_lint} / \text{MI\_ET}$$

Crop water use efficiency (CWUE) is the amount of lint produced in a season per MI of ET. CWUE therefore takes account of soil evaporation (the E of ET) as well as transpiration. It measures how efficiently crops use evapotranspiration in producing lint. It is the integral (or sum) of PWUE for the whole season multiplied by the harvest index (the fraction of dry matter produced by the crop that ends up in the lint). Because PWUE is not a unique constant but varies among climates and seasons, CWUE likewise varies in a similar way. CWUE is also affected by agronomic practices (such as pest control) that affect HI, though HI is remarkably constant (Constable and Hearn 1981, Sadras et al 1996). Variation in soil evaporation (E) as a proportion of ET (increased by frequent irrigation for example) also contributes to variation in crop WUE.

*iii) Farm WUE (FWUE).* FWUE is total production divided by all water delivered to the farm gate plus rainfall.

$$\text{FWUE (kg/ML)} = \text{kg\_lint} / \text{MI\_water\_received}$$

FWUE is the amount of lint produced by a farm per MI of water received during the season, without deduction of losses in the storage and distribution system or deduction for ineffective rainfall.

*iv) Gross production WUE (GPWUE).* GPWUE is total production of a farm or in a region divided by all water delivered to the farm gate.

$$\text{GPWUE (kg/ML)} = \text{kg\_lint\_produced} / \text{MI\_water\_delivered}$$

... comment on farm water accounting apply also here; x.....

It is the amount of lint produced by a farm or in a region for each ML of water delivered. The amount of water therefore includes losses in the storage and distribution system as well as ET, but does not include rainfall.

GPWUE measures how much a farm or region, or the industry as a whole, puts into the economy in relation to the amount of water drawn from national water resources.

**v) Marginal production WUE (MPWUE).** MPWUE is total production less production attributed to rainfall divided by all water delivered to the farm gate.

$$\text{MPWUE (kg/ML)} = (\text{kg\_lint\_produced} - \text{ha} * \text{rainfed\_yield}) / \text{MI\_water\_delivered}$$

MPWUE is the marginal increase in production of lint attributed to irrigation per ML of water delivered to the farm gate (ie received or pumped). It is derived by estimating how much the irrigated area would have produced had it not been irrigated ie. the area in ha multiplied by the rainfed yield. Rainfall is thus taken into account.

Several farms that supplied data also supplied an estimate of crop WUE. Most of the estimates take some but not all of the losses into account in estimating the amount of water used. Consequently these estimates are neither CWUE nor FWUE as defined above but are somewhere between the two.

To summarise, three efficiencies were calculated at the regional level: (i) Gross Production WUE (GPWUE) = total production divided by all water delivered to the farm gate, (ii) Marginal Production WUE (MPWUE) = total production less production attribute to rainfall divided by all water delivered to the farm gate, (iii) irrigation efficiency. Three efficiencies were also calculated at the farm level: (i) Gross Production WUE (GPWUE) = total production divided by all water delivered to the farm gate, (ii) Farm WUE (FWUE) = total production divided by all water delivered to the farm gate plus rainfall, (iii) irrigation efficiency. Note that to calculate FWUE rainfall is taken into account in a different way than in calculating MPWUE. WUE was calculated at the field level Crop .

#### **Irrigation Efficiency.**

Irrigation Efficiency (IE) is the percentage of the water delivered to the farm gate (ie received or pumped) used in crop ET. It takes into account losses in the storage and distribution system. Losses include evaporation and seepage from storages and channels, deep drainage and any runoff not recycled. In this study IE is estimated in two ways:

**(i) Farm Irrigation Efficiency.** In the body of the report CWUE, FWUE and IE were shown to be related thus:

$$\begin{aligned} \text{CWUE} &= \text{lint} / \text{ET} \\ \text{FWUE} &= \text{lint} / \text{water\_input} \\ \text{IE} &= \text{ET} / \text{water\_input} \end{aligned}$$

If CWUE and FWUE are known, IE can be estimated by dividing FWUE by CWUE thus:

$$\text{IE} = \text{FWUE} / \text{CWUE}$$

$$\begin{aligned}
 &= (\text{lint} / \text{water\_input}) / (\text{lint} / \text{ET}) \\
 &= (\text{lint} / \text{water\_input}) * (\text{ET} / \text{lint}) \\
 &= \text{ET} / \text{water\_input}
 \end{aligned}$$

Calculated this way IE includes the efficiency with which rainfall is used. Water harvested on the farm and subsequently used for irrigation increases IE.

**(ii) Regional Irrigation Efficiency.** At the region level MPWUE replaces CWUE

$$\text{MPWUE} = \text{lint} / \text{water\_input}$$

IE is estimated by dividing MPWUE by CWUE thus:

$$\begin{aligned}
 \text{IE} &= \text{MPWUE} / \text{CWUE} \\
 &= (\text{lint} / \text{water\_input}) / (\text{lint} / \text{ET}) \\
 &= (\text{lint} / \text{water\_input}) * (\text{ET} / \text{lint}) \\
 &= \text{ET} / \text{water\_input}
 \end{aligned}$$

Annex 2.3  
Cotton Water Use by Regions

	Irrigated area %age	Irrigated area ha	Irrigated production tonnes	Irrigated yield kg/ha	Irrigation water MI/region	Irrigation water MI/ha	GPWUE kg/MI	MPWUE kg/MI	Irrigation efficiency
<b>Macquarie Valley</b>									
1988-89	100%	20641	27069	1311	202049	9.79	134		
1989-90	100%	25764	33011	1281	231101	8.97	143		
1990-91	100%	26290	40347	1535	245696	9.35	164		
1991-92	100%	29453	41037	1393	280548	9.53	146		
1992-93	98%	30194	41745	1383	118439	3.92	352	309	103%
1993-94	99%	29306	45055	1537	278941	9.52	162	110	37%
1994-95	100%	37458	62366	1665					
Mean	100%	28444	41519	1444	226129	8.51	184	209	70%
<b>Namoi Valley</b>									
1988-89	99%	34921	53542	1533	306241	8.77	175	121	40%
1989-90	98%	41743	51460	1233	303740	7.28	169	85	28%
1990-91	97%	48867	72458	1483	325544	6.66	223	110	37%
1991-92	94%	50916	84512	1660	314482	6.18	269	165	55%
1992-93	86%	43430	66596	1533	316905	7.30	210	152	51%
1993-94	79%	42713	62035	1452	365057	8.55	170	116	39%
1994-95	96%	42651	66186	1552					
Mean	93%	43606	65255	1492	321995	7.45	203	125	42%
<b>Gwydir Valley</b>									
1988-89	96%	52885	94095	1779	262360	4.96	359	243	81%
1989-90	93%	62027	78267	1262	272065	4.39	288	177	59%
1990-91	88%	63610	107275	1686	413037	6.49	260	135	45%
1991-92	84%	76173	127154	1669	308708	4.05	412	211	70%
1992-93	79%	48203	56622	1175	107180	2.22	528	423	141%
1993-94	76%	51974	38517	741	74385	1.43	518	503	168%
1994-95	50%	11677	12166	1042					
Mean	81%	52364	73442	1336	239623	3.92	394	282	94%
<b>Macintyre Valley (Border Rivers)</b>									
1988-89	91%	9953	18232	1832	164547	16.53	111	75	25%
1989-90	85%	9133	15028	1646	190862	20.90	79	44	15%
1990-91	82%	16599	28467	1715	208239	12.55	137	67	22%
1991-92	82%	28489	46939	1648	191850	6.73	245	133	44%
1992-93	82%	27876	50991	1829	169854	6.09	300	254	85%
1993-94	69%	13756	23709	1724	103911	7.55	228	171	57%
1994-95	71%	17092	31478	1842					
Mean	80%	17557	30692	1748	171544	11.73	183	124	41%
<b>Bourke</b>									
1988-89	100%	6863	10122	1475	96527	14.06	105		
1989-90	100%	8260	12095	1464	86461	10.47	140		
1990-91	100%	7161	12833	1792	76085	10.62	169		
1991-92	100%	8636	13532	1567	75245	8.71	180		
1992-93	100%	6937	10788	1555	44068	6.35	245		
1993-94	100%	10419	14449	1387					
1994-95	100%	12270	19675	1604					
Mean	100%	8649	13356	1549	75677	10.04	168		
<b>Emerald</b>									
1988-89	98%	7492	10454	1395	46521	6.21	225	91	30%
1989-90	98%	9542	11715	1228	90136	9.45	130	83	28%
1990-91	97%	11450	15257	1332	76217	6.66	200	92	31%
1991-92	98%	14314	23510	1642	100028	6.99	235	138	46%

	Irrigated area %age	Irrigated area ha	Irrigated production tonnes	Irrigated yield kg/ha	Irrigation water MI/region	Irrigation water MI/ha	GPWUE kg/MI	MPWUE kg/MI	Irrigation efficiency
1992-93	98%	13679	26274	1921	130659	9.55	201	173	58%
1993-94	98%	15502	24925	1608	115788	7.47	215	155	52%
1994-95	98%	16506	24314	1473	132194	8.01	184	133	44%
Mean	98%	12641	19493	1514	98792	7.76	199	124	41%
Biloela/Theodore									
1988-89	25%	3865	4376	1132	21547	5.57	203	90	30%
1989-90	41%	5382	6244	1160	26972	5.01	231	198	66%
1990-91	58%	4865	6731	1384	27279	5.61	247	170	57%
1991-92	74%	5072	7355	1450	26410	5.21	278	200	67%
1992-93	82%	4497	7257	1614	27769	6.17	261	218	73%
1993-94	87%	3951	6417	1624	27702	7.01	232	198	66%
1994-95	89%	4626	6998	1513	36089	7.80	194	189	63%
Mean	65%	4608	6483	1411	27681	6.06	235	180	60%
Darling Downs									
1988-89	86%	6375	12303	1930	31967	5.01	385	224	75%
1989-90	50%	13410	19348	1443	39753	2.96	487	249	83%
1990-91	46%	15359	24416	1590	48973	3.19	499	237	79%
1991-92	53%	18032	28917	1604	76897	4.26	376	200	67%
1992-93	58%	18371	26408	1437	68772	3.74	384	269	90%
1993-94	37%	15243	20025	1314	72556	4.76	276	173	58%
1994-95	57%	22921	35685	1557	84196	3.67	424	206	69%
1995-96	40%	26000	39195	1508					
Mean	49%	18477	27713	1493	60445	3.94	404	222	74%
St George									
1988-89	100%	19408	18157	936	73582	3.79	247		
1989-90	100%	12514	18852	1506	80681	6.45	234		
1990-91	100%	14470	22989	1589	76618	5.29	300		
1991-92	100%	12722	21985	1728	76867	6.04	286		
1992-93	100%	10595	16924	1597	42056	3.97	402		
1993-94	100%	6275	9720	1549	26829	4.28	362		
1994-95	100%	13000	21645	1665	44408	3.42	487		
Mean	100%	12712	18610	1510	60149	4.75	331		

Annex 2.4  
Cotton Water Use on Farms

		Yield lint kg/ha	Water at farmgate MI/ha	GPWUE kg/MI	FWUE kg/MI	CWUE kg/MI	Irrigation efficiency	
Farm 1	1994-95	1965	8.20	240	181		60%	
	1995-96	1491	7.30	204	171		57%	
	Mean	1728	7.75	222	176		59%	
Farm 2	1991-92	1668	5.11	326	183		61%	
	1992-93	1595	5.51	290	243		81%	
	1993-94	1427	3.47	411	175		58%	
	1994-95	1145	3.25	353	161		54%	
	1995-96	1408	1.72	819	206		69%	
	Mean	1449	3.81	440	194		65%	
Farm 3	1991-92	1699	2.57	661	289	363	80%	
	1992-93	1446	3.87	373	237	258	92%	
	1993-94	1564	4.68	334	210	309	68%	
	1994-95	1512	7.87	192	130	527	25%	
	1995-96	1412	5.50	257	137	261	53%	
	Mean	1527	4.90	363	201		63%	
Farm 4	1994-95	1988	4.65	428	232		77%	
	1995-96	1690	3.67	461	195		65%	
	Mean	1839	4.16	444	214		71%	
Farm 5	1989-90	1311	7.42	177	141		47%	
	1990-91	1717	6.15	279	197		66%	
	1991-92	1789	5.10	350	202		67%	
	1992-93	610	0.52	1178	302		101%	
	1993-94	424	2.18	194	96		32%	
	1994-95	432	1.27	341	93		31%	
	1995-96	1227	4.30	285	145		48%	
	Mean	1073	3.85	401	168		56%	
Farm 6	1991-92	1606	5.51	291	173		58%	
	1992-93	1845	5.96	309	195		65%	
	1993-94	1273	5.89	216	141		47%	
	1994-95	1501	6.91	217	125		42%	
	1995-96	1773	5.52	321	183		61%	
	Mean	1599	5.96	271	163		54%	
Farm 7	1987-88	637	1.87	341	137		46%	
	1988-89	1250	4.59	272	215	293	73%	
	1989-90	709	6.33	112	79	264	30%	
	1990-91	1677	7.46	225	181	266	68%	
	1991-92	1971	5.06	389	254	297	85%	
	1992-93	133	0.75	177	39		13%	
	1993-94	180	0.66	273	76		25%	
	Mean	937	3.82	256	140		49%	
Farm 8	1992-93	1267	2.65	478	184		61%	
	1993-94	419	0.70	596	154		51%	
	1994-95	1604	10.90	147	106		35%	
	1995-96	1323	3.27	405	258		86%	
	Mean	1153	4.38	407	175		58%	
Farm 9	1991-92	2001	6.95	288	196		65%	
	1992-93	2167	5.55	390	287		96%	
	1993-94							
	1994-95	1778	8.53	209	143		48%	
	1995-96	1667	4.65	358	229		76%	
	Mean	1903	6.42	311	214		71%	

		Yield lint kg/ha	Water at farmgate MI/ha	GPWUE kg/MI	FWUE kg/MI	CWUE kg/MI	Irrigation efficiency
Farm 10	1991-92	2005	6.40	313	207		69%
	1992-93	1955	5.54	353	259		86%
	1993-94	1579	9.82	161	110		37%
	1994-95	1994	4.02	496	250		83%
	1995-96	1264	4.33	292	182		61%
	Mean	1760	6.02	323	202		67%
Farm 11	1994-95	1748	5.91	296	221	261	85%
	1995-96	1925	10.08	191	182	255	71%
	Mean	1836	8.00	243	201		78%
Mean Overall		1528	5.37	335	186		63%

Annex 2.5  
Field Level Data- Yield, crop water us (ET)  
Measured by probe and CWUE

<i>Farm</i>	<i>Year</i>	<i>Fields</i>	Yield kg/ha	ET MI/ha	CWUE kg/MI
<i>Farm 3</i>	1991-92	Field A	2132	4.17	511
		Field B	1829	3.77	485
		Field C	1608	4.43	363
		Field D	1476	6.67	221
		Field E	1520	6.53	233
		Mean			
	1992-93	Field F	1864	7.20	259
		Field G	1552	7.34	211
		Field H	1606	6.48	248
		Field I	1906	5.90	323
		Field J	1700	6.80	250
		Mean			
	1993-94	Field K	1770	7.53	235
		Field L	1779	3.95	450
		Field M	1522	3.36	453
		Field N	1579	8.18	193
		Field O	1421	6.72	211
		Mean			
	1994-95	Field P	1566	3.51	446
		Field Q	1575	3.09	510
		Field R	1463	1.78	822
		Field S	1573	3.79	415
		Field T	1525	3.44	443
		Mean			
	1995-96	Field F	1586	10.48	151
		Field G	1323	8.78	151
		Field U	1374	4.69	293
Field V		1511	4.71	321	
Field W		1486	3.80	391	
Mean					261
	Mean all years				344
<i>Farm 7</i>	1988-89	Field A	1436	4.25	338
		Field B	1454	4.78	304
		Field C	1512	5.19	291
		Field D	1737	5.88	295
		Field E	1418	5.94	239
		Mean			
	1989-90	Field F	1436	5.45	263
		Field G	1636	5.61	292
		Field H	1721	6.30	273
		Field I	1742	5.98	291
		Field J	1449	7.28	199
		Mean			
	1990-91	Field K	1796	6.53	275
		Field J	1537	6.58	234
		Field D	1994	6.30	316
		Field N	1442	5.17	279
		Field O	1782	7.94	224
		Mean			
	1991-92	Field G	2124	7.26	293
		Field Q	2012	6.46	311
		Field J	1717	6.63	259

<i>Farm</i>	<i>Year</i>	<i>Fields</i>		<i>Yield</i> kg/ha	<i>ET</i> MI/ha	<i>CWUE</i> kg/MI
		Field	D	1881	6.60	285
		Field	T	2171	6.46	336
		Mean				297
		Mean all years				280
<i>Farm 11</i>	1994-95	Field	A	2223	9.80	227
		Field	B	1891	7.10	266
		Field	C	2229	8.40	265
		Field	D	2115	6.40	330
		Field	E	1732	8.00	217
		Mean				261
	1995-96	Field	A	2182	10.40	210
		Field	B	1958	8.50	230
		Field	C	2373	9.20	258
		Field	D	2190	7.50	292
		Field	E	2300	8.10	284
	Mean				255	
	Mean all years				258	
	Mean all farms				294	

Annex 3.1  
World and Australian lint production and yield 1960/61 to 1995/96

Year	World			Australia		
	Harv. Area ( <sup>'000</sup> ha)	Tot pdn ( <sup>'000</sup> tonn)	Yield (kg/ha)	Harv. area ( <sup>'000</sup> ha)	Tot pdn ( <sup>'000</sup> tonn)	Yield (kg/ha)
1960-61	32120	9812	305	N.A.	N.A.	
1961-62	32413	9682	299	N.A.	N.A.	
1962-63	31780	10224	322	N.A.	N.A.	
1963-64	32882	11052	336	N.A.	N.A.	
1964-65	33551	11700	349	17	10	575
1965-66	33326	12380	371	22	20	940
1966-67	31210	11381	365	23	18	814
1967-68	30964	11218	362	29	33	1127
1968-69	31921	12383	388	32	34	1053
1969-70	32487	11909	367	32	28	866
1970-71	31801	11991	377	35	20	566
1971-72	33043	12871	390	40	43	1080
1972-73	33538	13450	401	43	31	725
1973-74	32849	13638	415	42	31	731
1974-75	33530	13860	413	35	33	940
1975-76	29889	11745	393	30	25	836
1976-77	30568	12272	401	34	28	831
1977-78	33568	13905	414	41	44	1073
1978-79	32901	12988	395	49	53	1073
1979-80	32211	14255	443	71	83	1165
1980-81	32272	13823	428	84	99	1183
1981-82	32972	14952	453	104	134	1298
1982-83	33381	14505	435	97	101	1045
1983-84	30920	14314	463	137	141	1028
1984-85	33723	19302	572	183	249	1358
1985-86	31582	17480	553	177	267	1510
1986-87	29360	15367	523	148	222	1497
1987-88	30878	17641	571	245	284	1162
1988-89	33756	18374	544	194	286	1474
1989-90	31567	17362	550	240	305	1273
1990-91	33170	18935	571	270	433	1604
1991-92	34820	20832	598	282	502	1780
1992-93	32631	17952	550	262	373	1424
1993-94	30706	16700	544	264	329	1245
1994-95	31144	18623	598	222	335	1512
1995-96 p	35377	19921	563	304	421	1384

Source: Australian Bureau of Statistics, Australian Commodity Statistics 1996

Annex 3.2  
World and Australian rice production and yield 1960/61 to 1995/96

Year	World			Australia		
	Harv. Area (mill ha)	Tot pdn (mill tonn)	Yield (tonn/ha)	Harv. area (mill ha)	Tot pdn (mill tonn)	Yield (tonn/ha)
1960-61	120	151	1.26	0.0187	0.1143	6.11
1961-62	116	147	1.27	0.0203	0.1342	6.61
1962-63	120	155	1.29	0.0222	0.1358	6.12
1963-64	122	169	1.39	0.0240	0.1420	5.92
1964-65	125	181	1.45	0.0249	0.1530	6.14
1965-66	124	173	1.40	0.0261	0.1817	6.96
1966-67	126	179	1.42	0.0298	0.2143	7.19
1967-68	127	189	1.49	0.0307	0.2145	6.99
1968-69	129	195	1.51	0.0337	0.2482	7.36
1969-70	131	201	1.53	0.0402	0.2470	6.14
1970-71	133	213	1.60	0.0407	0.2998	7.37
1971-72	135	216	1.60	0.0405	0.2484	6.13
1972-73	133	209	1.57	0.0452	0.3086	6.83
1973-74	136	228	1.68	0.0675	0.4088	6.06
1974-75	138	226	1.64	0.0756	0.3867	5.12
1975-76	143	243	1.70	0.0748	0.4170	5.57
1976-77	141	236	1.67	0.0920	0.5298	5.76
1977-78	143	251	1.76	0.0914	0.4903	5.36
1978-79	144	262	1.82	0.1102	0.6922	6.28
1979-80	141	257	1.82	0.1164	0.6131	5.27
1980-81	144	270	1.88	0.1039	0.7598	7.31
1981-82	144	278	1.93	0.1230	0.8570	6.97
1982-83	141	285	2.02	0.0848	0.5198	6.13
1983-84	145	307	2.12	0.1191	0.6342	5.32
1984-85	144	317	2.20	0.1218	0.8641	7.09
1985-86	145	318	2.19	0.1061	0.6875	6.48
1986-87	145	316	2.18	0.0959	0.5492	5.73
1987-88	142	315	2.22	0.1054	0.7611	7.22
1988-89	146	332	2.27	0.0970	0.8051	8.30
1989-90	147	344	2.34	0.1048	0.9236	8.81
1990-91	147	352	2.39	0.0850	0.7660	9.01
1991-92	147	355	2.41	0.1230	1.0940	8.89
1992-93	147	355	2.41	0.1230	0.9440	7.67
1993-94	145	356	2.46	0.1320	1.0820	8.20
1994-95	148	365	2.47	0.1280	1.1370	8.88
1995-96 p	148	370	2.50	0.1490	0.9512	6.38

Source: Australian Bureau of Statistics, Australian Commodity Statistics 1996

Annex 3.3  
World Indicator prices- selected commodities 1971/72- 1996/97

Year	Cotton USc/lb	Wheat US\$/t	Rice US\$/t	Sugar USc/lb	Wool Ac/kg	Beef Ac/kg
1971-72	37	58	141	6.2		61
1972-73	40	91	187	8.7		69
1973-74	76	195	593	18.5		79
1974-75	53	167	439	30.3	234	34
1975-76	62	147	303	13.6	263	35
1976-77	84	113	275	8.3	340	45
1977-78	65	119	365	7.5	344	49
1978-79	76	142	340	8.2	381	108
1979-80	85	169	409	21	449	145
1980-81	94	181	492	24.7	467	134
1981-82	74	165	380	10.4	491	116
1982-83	76	163	280	7.6	506	130
1983-84	88	154	278	6.7	541	159
1984-85	71	150	240	3.7	586	171
1985-86	51	133	225	6	594	168
1986-87	58	110	221	6.2	697	186
1987-88	74	125	294	9	1118	194
1988-89	64	172	317	11.6	1091	210
1989-90	82	168	323	13.9	969	213.4
1990-91	84	127	313	9.4	699	203.9
1991-92	64	160	308	9.1	593	203
1992-93	58	156	274	9.6	519	220.4
1993-94	69	153	391	11	547	222.6
1994-95	92	175	340	13.9	788	201.8
1995-96	86	231	389	12.2	619	155

Source: ABARE

Annex 3.3 continued  
 World Price Index Indicator- selected commodities. 1971/72 to 1996/97  
 (1971-72 as base year = 100)

Year	Cotton Ac/lb	Wheat A\$/t	Rice A\$/t	Sugar Ac/lb	ox & cow	
					Wool Ac/kg	Beef Ac/kg
1971-72	100	100	100	100		100
1972-73	93	135	114	121		107
1973-74	136	223	279	198		108
1974-75	88	176	190	299	100	40
1975-76	98	149	126	129	100	36
1976-77	128	110	110	76	113	41
1977-78	93	108	136	64	104	41
1978-79	99	118	117	64	107	83
1979-80	103	130	130	152	114	101
1980-81	100	123	137	157	109	86
1981-82	75	106	101	63	104	67
1982-83	81	111	78	48	96	67
1983-84	91	102	76	41	96	77
1984-85	82	111	73	26	99	80
1985-86	61	101	70	43	93	72
1986-87	67	81	67	42	100	73
1987-88	72	78	75	52	149	71
1988-89	52	89	67	56	136	72
1989-90	65	85	67	66	112	67
1990-91	62	60	61	42	76	61
1991-92	48	76	60	40	64	60
1992-93	47	80	58	46	55	64
1993-94	55	78	82	53	57	64
1994-95	67	81	65	60	80	56
1995-96	59	100	70	50	60	41

Source ABARE

Annex 3.4  
Selected average farm business financial statistics 1991/92 to 1994/95

Crop & year	INCOME			Value added (\$'000)	Wages (\$'000)	Int paid (\$'000)	Cash Op surplus (\$'000)	Capital expend (\$'000)	Land value (\$'000)	Total assets (\$'000)	Total debt (\$'000)	Net worth (\$'000)	Equity %	Return on assets %	Return on equity %	Assets	Assets
	Crop (\$'000)	Stock sales (\$'000)	Total (\$'000)													to prod. \$1 'over	to prod. \$1 v. add.
<b>Cotton</b>																	
- 1991/92	1222.7	81.0	1428.8	639.7	137.7	116.2	301.2	107.7	2552.0	3809.9	952.3	2857.6	75.0	11.0	10.5	2.7	6.0
- 1992/93	1038.6	110.5	1240.0	497.1	114.5	82.0	234.4	109.6	2822.2	3938.5	1018.5	2920.0	74.1	8.0	8.0	3.2	7.9
- 1993/94	1157.2	59.5	1364.7	553.1	117.1	84.0	268.6	135.5	2894.7	4391.5	1088.6	3302.9	75.2	8.0	8.1	3.2	7.9
- 1994/95	866.7	21.8	1011.7	400.7	93.3	80.9	160.6	102.9	2634.3	3919.0	1140.1	2778.9	70.9	6.2	5.8	3.9	9.8
<b>Average</b>	<b>1071.3</b>	<b>68.2</b>	<b>1261.3</b>	<b>522.7</b>	<b>115.7</b>	<b>90.8</b>	<b>241.2</b>	<b>113.9</b>	<b>2725.8</b>	<b>4014.7</b>	<b>1049.9</b>	<b>2964.9</b>	<b>73.8</b>	<b>8.3</b>	<b>8.1</b>	<b>3.2</b>	<b>7.7</b>
<b>Poultry</b>																	
- 1991/92	11.2	116.1	461.2	187.9	47.7	33.6	73.1	33.3	1008.2	1440.0	267.8	1172.2	81.4	7.4	6.2	3.1	7.7
- 1992/93	6.9	163.3	519.1	180.0	62.7	25.2	65.6	45.8	874.8	1250.5	291.6	958.9	76.7	7.3	6.8	2.4	6.9
- 1993/94	3.6	162.3	504.7	196.6	53.9	22.5	93.9	43.8	784.6	1122.7	321.7	801.0	71.3	10.4	11.7	2.2	5.7
- 1994/95																	
<b>Average</b>	<b>7.2</b>	<b>147.2</b>	<b>495.0</b>	<b>188.2</b>	<b>54.8</b>	<b>27.1</b>	<b>77.5</b>	<b>41.0</b>	<b>889.2</b>	<b>1271.1</b>	<b>293.7</b>	<b>977.4</b>	<b>76.9</b>	<b>8.2</b>	<b>7.9</b>	<b>2.6</b>	<b>6.8</b>
<b>Grain</b>																	
- 1991/92	157.8	11.3	192.0	84.5	9.7	17.7	41.7	20.4	620.8	856.5	140.8	715.7	83.6	6.9	5.8	4.5	10.1
- 1992/93	187.6	19.8	236.8	104.6	11.2	15.4	64.2	24.1	642.7	929.8	157.7	772.1	83.0	8.6	8.3	3.9	8.9
- 1993/94	205.1	25.2	262.0	114.2	10.9	14.0	68.7	25.8	711.4	1047.2	173.0	874.2	83.5	7.9	7.9	4.0	9.2
- 1994/95	221.7	29.8	291.8	122.3	15.5	16.3	76.5	38.0	843.1	1215.8	210.8	1005.0	82.7	7.6	7.6	4.2	9.9
<b>Average</b>	<b>193.1</b>	<b>21.5</b>	<b>245.7</b>	<b>106.4</b>	<b>11.8</b>	<b>15.9</b>	<b>62.8</b>	<b>27.1</b>	<b>704.5</b>	<b>1012.3</b>	<b>170.6</b>	<b>841.8</b>	<b>83.2</b>	<b>7.8</b>	<b>7.5</b>	<b>4.1</b>	<b>9.5</b>
<b>Grain/sheep/beef</b>																	
- 1991/92	98.0	28.2	173.0	77.9	10.5	17.8	31.7	15.2	740.2	988.0	139.3	848.7	85.9	5.0	3.7	5.7	12.7
- 1992/93	99.0	35.8	183.2	80.5	10.9	14.8	38.8	16.2	739.5	1018.7	147.2	871.5	85.6	5.3	4.5	5.6	12.7
- 1993/94	88.1	39.6	177.2	90.8	11.6	11.7	34.0	15.9	767.7	1057.4	138.3	919.1	86.9	4.3	3.7	6.0	11.6
- 1994/95	96.3	43.0	201.3	74.0	11.4	17.0	36.5	22.3	772.9	1085.1	186.7	898.4	82.8	4.9	4.1	5.4	14.7
<b>Average</b>	<b>95.4</b>	<b>36.7</b>	<b>183.7</b>	<b>80.8</b>	<b>11.1</b>	<b>15.3</b>	<b>35.3</b>	<b>17.4</b>	<b>755.1</b>	<b>1037.3</b>	<b>152.9</b>	<b>884.4</b>	<b>85.3</b>	<b>4.9</b>	<b>4.0</b>	<b>5.6</b>	<b>12.8</b>
<b>Sheep/beef</b>																	
- 1991/92	3.8	68.6	134.5	53.2	17.4	19.4	9.2	13.3	939.0	1286.0	143.2	1142.8	88.9	2.2	0.8	9.6	24.2
- 1992/93	4.3	78.1	145.0	65.6	17.0	13.9	15.2	7.2	972.7	1312.1	147.9	1164.2	88.7	2.2	1.3	9.0	20.0
- 1993/94	3.6	84.3	147.0	92.4	17.0	11.6	20.4	12.1	991.8	1377.0	148.1	1228.9	89.2	2.3	1.7	9.4	14.9
- 1994/95	11.8	83.2	173.6	62.2	13.7	13.5	32.4	9.6	1012.0	1389.7	148.2	1241.5	89.3	3.3	2.6	8.0	22.3
<b>Average</b>	<b>5.9</b>	<b>78.6</b>	<b>150.0</b>	<b>68.4</b>	<b>16.3</b>	<b>14.6</b>	<b>19.3</b>	<b>10.6</b>	<b>978.9</b>	<b>1341.2</b>	<b>146.9</b>	<b>1194.4</b>	<b>89.1</b>	<b>2.5</b>	<b>1.6</b>	<b>8.9</b>	<b>19.6</b>
<b>Sheep</b>																	
- 1991/92	6.4	19.5	101.3	44.9	10.9	15.7	2.3	5.3	714.1	894.7	129.2	765.5	85.6	2.0	0.3	8.8	19.9
- 1992/93	9.9	34.2	114.2	53.2	11.6	14.5	12.7	5.9	764.9	985.6	140.2	845.4	85.8	2.8	1.5	8.6	18.5
- 1993/94	10.4	30.0	123.1	70.4	14.1	10.0	18.5	7.0	784.0	1055.0	121.2	933.8	88.5	2.7	2.0	8.6	15.0
- 1994/95	9.0	33.6	141.6	56.4	12.1	11.5	31.9	12.7	731.3	936.8	121.4	815.4	87.0	4.6	3.9	6.6	16.6
<b>Average</b>	<b>8.9</b>	<b>29.3</b>	<b>120.1</b>	<b>56.2</b>	<b>12.2</b>	<b>12.9</b>	<b>16.4</b>	<b>7.7</b>	<b>748.6</b>	<b>968.0</b>	<b>128.0</b>	<b>840.0</b>	<b>86.8</b>	<b>3.0</b>	<b>1.9</b>	<b>8.1</b>	<b>17.2</b>
<b>Beef cattle</b>																	
- 1991/92	4.7	136.1	154.4	49.5	16.1	16.4	15.8	10.3	873.2	1406.8	143.9	1262.9	89.8	2.3	1.3	9.1	28.4
- 1992/93	7.0	153.3	173.1	74.8	15.3	13.5	30.2	15.5	930.1	1495.8	151.8	1344.0	89.9	2.9	2.2	8.6	20.0
- 1993/94	4.2	143.5	167.8	82.3	13.0	12.4	28.2	13.0	833.7	1348.6	146.1	1202.5	89.2	3.0	2.3	8.0	16.4
- 1994/95	6.7	148.4	179.3	54.1	14.2	12.5	28.5	16.2	933.9	1511.9	174.1	1337.8	88.5	2.7	2.1	8.4	27.9
<b>Average</b>	<b>5.7</b>	<b>145.3</b>	<b>168.7</b>	<b>65.2</b>	<b>14.7</b>	<b>13.7</b>	<b>25.7</b>	<b>13.8</b>	<b>892.7</b>	<b>1440.8</b>	<b>154.0</b>	<b>1286.8</b>	<b>89.3</b>	<b>2.7</b>	<b>2.0</b>	<b>8.5</b>	<b>22.1</b>
<b>Dairy</b>																	
- 1991/92	2.0	20.5	152.9	71.0	9.4	12.7	38.8	10.2	574.0	844.2	100.2	744.0	88.1	6.1	5.2	5.5	11.9
- 1992/93	2.7	20.9	189.3	94.8	10.9	11.3	57.4	19.2	640.3	930.0	115.5	814.5	87.6	7.4	7.0	4.9	9.8
- 1993/94	4.6	24.3	192.8	97.0	12.3	12.2	51.4	21.3	597.1	908.8	133.6	775.2	85.3	7.0	6.6	4.7	9.4
- 1994/95	2.9	23.0	201.0	101.7	11.9	13.7	40.4	16.8	640.9	1012.2	147.6	864.6	85.4	5.3	4.7	5.0	10.0
<b>Average</b>	<b>3.1</b>	<b>22.2</b>	<b>184.0</b>	<b>91.1</b>	<b>11.1</b>	<b>12.5</b>	<b>47.0</b>	<b>16.9</b>	<b>613.1</b>	<b>923.8</b>	<b>124.2</b>	<b>799.6</b>	<b>86.6</b>	<b>6.4</b>	<b>5.9</b>	<b>5.0</b>	<b>10.1</b>
<b>Pigs</b>																	
- 1991/92	21.4	321.3	376.3	106.1	33.0	20.9	39.5	12.3	501.6	865.7	174.8	690.9	79.8	7.0	5.7	2.3	8.2
- 1992/93	16.8	324.0	370.2	102.8	35.8	12.6	33.3	21.3	547.4	903.4	142.6	760.8	84.2	5.1	4.4	2.4	8.8
- 1993/94	30.1	358.1	426.4	129.3	32.8	15.5	58.7	20.1	669.0	1061.7	197.1	864.6	81.4	7.0	6.8	2.5	8.2
- 1994/95	28.3	426.5	509.2	131.8	44.4	20.4	43.1	34.7	652.7	1183.9	245.6	938.3	79.3	5.4	4.6	2.3	9.0
<b>Average</b>	<b>24.2</b>	<b>357.5</b>	<b>420.5</b>	<b>117.5</b>	<b>36.5</b>	<b>17.4</b>	<b>43.7</b>	<b>22.1</b>	<b>592.7</b>	<b>1003.7</b>	<b>190.0</b>	<b>813.7</b>	<b>81.1</b>	<b>6.1</b>	<b>5.4</b>	<b>2.4</b>	<b>8.5</b>
<b>Sugar</b>																	

Crop & year	INCOME			Value added	Wages	Int paid	Cash surplus	Op expend	Capital Land	Total assets	Total debt	Net worth	Equity	Return on assets	Return on equity	Assets	Assets
	Crop (\$'000)	Stock sales (\$'000)	Total (\$'000)													to prod. \$1 t'over	to prod. \$1 v. add.
- 1991/92	134.5	2.0	150.3	70.8	10.1	12.9	43.0	12.6	596.2	809.2	127.1	682.1	84.3	6.9	6.3	5.4	11.4
- 1992/93	164.0	1.6	183.8	90.2	11.4	10.6	58.8	13.1	730.9	964.4	116.8	847.6	87.9	7.2	6.9	5.2	10.7
- 1993/94	207.1	4.2	230.0	104.4	19.5	9.2	65.7	30.1	852.7	1124.0	133.3	990.7	88.1	6.7	6.6	4.9	10.8
- 1994/95	258.1	2.6	284.8	156.3	24.9	8.4	110.5	29.1	817.2	1082.2	156.3	925.9	85.6	11.0	11.9	3.8	6.9
<b>Average</b>	<b>190.9</b>	<b>2.6</b>	<b>212.2</b>	<b>105.4</b>	<b>16.5</b>	<b>10.3</b>	<b>69.5</b>	<b>21.2</b>	<b>749.3</b>	<b>995.0</b>	<b>133.4</b>	<b>861.6</b>	<b>86.6</b>	<b>8.0</b>	<b>8.1</b>	<b>4.7</b>	<b>9.4</b>
<b>All agriculture</b>																	
- 1991/92	70.4	44.7	169.4	73.4	16.9	16.6	28.2	13.0	704.7	988.9	135.2	853.7	86.3	4.5	3.3	5.8	13.5
- 1992/93	81.0	51.2	189.2	85.8	18.1	14.1	38.5	15.7	741.7	1049.0	145.1	903.9	86.2	5.0	4.3	5.5	12.2
- 1993/94	87.1	56.8	200.5	98.3	19.3	12.1	41.3	18.1	746.6	1083.3	148.1	935.2	86.3	4.9	4.4	5.4	11.0
- 1994/95	91.4	58.8	219.2	91.0	20.8	14.1	45.1	19.5	783.7	1139.0	170.3	968.7	85.0	5.2	4.7	5.2	12.5
<b>Average</b>	<b>82.5</b>	<b>52.9</b>	<b>194.6</b>	<b>87.1</b>	<b>18.8</b>	<b>14.2</b>	<b>38.3</b>	<b>16.6</b>	<b>744.2</b>	<b>1055.1</b>	<b>149.7</b>	<b>915.4</b>	<b>85.9</b>	<b>4.9</b>	<b>4.2</b>	<b>5.5</b>	<b>12.2</b>

Source: ABS

Annex 3.5  
Estimate of Marginal Return from Irrigation for Cotton Production  
by Valley 1990/91 to 1995/96

	Macquarie Valley	Namoi Valley	Gwydir Valley	Border Rivers	Bourke Region	Other Region	E'erald Region	Biloela	Darling Downs	St George	Australia
<b>1990/91</b>											
Ha of irrigated cotton	26290	48865	63610	16599	7161		11450	4865	15359	14470	208669
Tonnes lint/ha of irr. Cotton	1.535	1.483	1.686	1.715	1.792		1.332	1.384	1.59	1.589	
Tonnes lint/ha rainfed cotton	1.1	0.817	0.794	0.862			0.726	0.749	0.953		
Benefit from irrig. (t/ha of lint)	0.435	0.666	0.892	0.853	1.792		0.606	0.635	0.637	1.589	
Benefit from irrig. (t/ha seed)	0.63	0.97	1.30	1.24	2.61		0.88	0.92	0.93	2.31	
Tonnes of lint from irrigation	11436	32544	56740	14159	12833		6939	3089	9784	22993	170516
Tonnes of seed from irrigation	16625	47311	82486	20583	18655		10087	4491	14223	33428	247887
Val of lint/tonne (\$) (see note 1)	2490	2490	2490	2490	2490	2490	2490	2490	2490	2490	
Value of seed per tonne (\$)	135	135	135	135	135	135	135	135	135	135	
Value of irr. Cotton (\$ mill)	31	87	152	38	34		19	8	26	62	458
Val of r'fed cott- irrig. land (\$ mill)	78	107	136	38			22	10	39		430
<b>1991/92</b>											
Ha of irrigated cotton	29453	50916	76173	28489	8636	5000	14314	5072	18032	12722	248807
Tonnes lint/ha of irr. Cotton	1.393	1.66	1.669	1.648	1.567	1.544	1.642	1.45	1.604	1.728	
Tonnes lint/ha rainfed cotton		0.681	0.663	0.885			0.568	0.831	0.772		
Benefit from irrig. (t/ha of lint)	1.393	0.979	0.806	0.763	1.567	1.544	1.074	0.619	0.832	1.728	
Benefit from irrig. (t/ha seed)	2.03	1.42	1.17	1.11	2.28	2.24	1.56	0.90	1.21	2.51	
Tonnes of lint from irrigation	41028	49847	61395	21737	13533	7720	15373	3140	15003	21984	250759
Tonnes of seed from irrigation	59644	72464	89253	31600	19673	11223	22349	4564	21810	31959	364540
Val of lint/tonne (\$) (see note 1)	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	
Value of seed per tonne (\$)	130	130	130	130	130	130	130	130	130	130	
Value of irr. Cotton (\$ mill)	89	108	133	47	29	17	33	7	33	48	544
Val of r'fed cott- irrig. land (\$ mill)		75	143	55			18	9	30		329
<b>1992/93</b>											
Ha of irrigated cotton	30194	43430	48203	27876	6937	5000	13679	4497	18371	10595	208782
Tonnes lint/ha of irr. Cotton	1.383	1.533	1.175	1.829	1.555	1.317	1.921	1.614	1.437	1.597	
Tonnes lint/ha rainfed cotton	0.227	0.454	0.272	0.295			0.227		0.34		
Benefit from irrig. (t/ha of lint)	1.156	1.079	0.903	1.534	1.555	1.317	1.694	1.614	1.097	1.597	
Benefit from irrig. (t/ha seed)	1.68	1.57	1.31	2.23	2.26	1.91	2.46	2.35	1.59	2.32	
Tonnes of lint from irrigation	34904	46861	43527	42762	10787	6585	23172	7258	20153	16920	252930
Tonnes of seed from irrigation	50742	68124	63278	62165	15682	9573	33886	10552	29297	24598	367696
Val of lint/tonne (\$) (see note 1)	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	
Value of seed per tonne (\$)	186	186	186	186	186	186	186	186	186	186	
Value of irr. cotton (\$ mill)	79	105	98	96	24	15	52	16	45	38	569
Val of r'fed cott- irrig. land (\$ mill)	15	44	30	19			7		14		129
<b>1993/94</b>											
Ha of irrigated cotton	29306	42713	51974	13756	10419	7000	15502	3951	15243	6275	196139
Tonnes lint/ha of irr. Cotton	1.537	1.452	0.741	1.724	1.387	1.135	1.608	1.624	1.314	1.549	
Tonnes lint/ha rainfed cotton	0.227	0.5	0.272	0.227			0.454	0.227	0.318		
Benefit from irrig. (t/ha of lint)	1.31	0.952	0.469	1.497	1.387	1.135	1.154	1.397	0.996	1.549	
Benefit from irrig. (t/ha seed)	1.90	1.38	0.68	2.18	2.02	1.65	1.68	2.03	1.45	2.25	
Tonnes of lint from irrigation	38391	40663	24376	20593	14451	7945	17889	5520	15182	9720	194729
Tonnes of seed from irrigation	55811	59113	35436	29937	21008	11550	26006	8024	22071	14130	283086
Val of lint/tonne (\$) (see note 1)	2340	2340	2340	2340	2340	2340	2340	2340	2340	2340	23400
Value of seed per tonne (\$)	232	232	232	232	232	232	232	232	232	232	
Value of irr. cotton (\$ mill)	103	109	65	55	39	21	48	15	41	26	
Val of r'fed cott- irrig. land (\$ mill)	18	57	38	8			19	2	13		155
<b>1994/95</b>											
Ha of irrigated cotton	37458	42651	11677	17092	12270	5000	16506	4626	22921	13000	183201
Tonnes lint/ha of irr. Cotton	1.665	1.552	1.042	1.842	1.604	1.249	1.473	1.513	1.557	1.665	
Tonnes lint/ha rainfed cotton		0.567	0.567	0.567			0.409	0.454	0.681		
Benefit from irrig. (t/ha of lint)	1.665	0.985	0.475	1.275	1.604	1.249	1.064	1.059	0.876	1.665	
Benefit from irrig. (t/ha seed)	2.42	1.43	0.69	1.85	2.33	1.82	1.55	1.54	1.27	2.42	
Tonnes of lint from irrigation	62368	42011	5547	21792	19681	6245	17562	4899	20079	21645	221829
Tonnes of seed from irrigation	90667	61074	8063	31680	28611	9079	25531	7122	29189	31466	322483
Val of lint/tonne (\$) (see note 1)	2850	2850	2850	2850	2850	2850	2850	2850	2850	2850	

	Macquarie Valley	Namoi Valley	Gwydir Valley	Border Rivers	Bourke Region	Other Region	E'erald Region	Biloela	Darling Downs	St George	Australia
Value of seed per tonne (\$)	196	196	196	196	196	196	196	196	196	196	
Value of irr. cotton (\$ mill)	196	132	17	68	62	20	55	15	63	68	695
Val of r'fed cott- irrig. land (\$ mill)		76	21	30			21	7	49		204
<b>1995/96</b>											
Ha of irrigated cotton	14000	48000	42000	25000	11000	5000	9500	5000	26000	13400	198900
Tonnes lint/ha of irr. Cotton	1.657	1.612	1.612	1.657	1.692	1.453	1.725	1.657	1.508	1.702	
Tonnes lint/ha rainfed cotton		0.749	0.681	0.794			0.409	0.409	0.817		
Benefit from irrig. (t/ha of lint)	1.657	0.863	0.931	0.863	1.692	1.453	1.316	1.248	0.691	1.702	
Benefit from irrig. (t/ha seed)	2.41	1.25	1.35	1.25	2.46	2.11	1.91	1.81	1.00	2.47	
Tonnes of lint from irrigation	23198	41424	39102	21575	18612	7265	12502	6240	17966	22807	210691
Tonnes of seed from irrigation	33724	60220	56844	31365	27057	10561	18175	9071	26118	33155	306291
Val of lint/tonne (\$) (see note 1)	2670	2670	2670	2670	2670	2670	2670	2670	2670	2670	
Value of seed per tonne (\$)	171	171	171	171	171	171	171	171	171	171	
Value of irr. cotton (\$ mill)	68	121	114	63	54	21	36	18	52	67	615
Val of r'fed cott- irrig. land (\$ mill)		105	83	58			11	6	62		326
<b>Average 1990/91 to 1995/96</b>											
Ha of irrigated cotton	27784	46096	48940	21469	9404	4500	13492	4669	19321	11744	207416
Tonnes lint/ha of irr. Cotton	1.522	1.552	1.394	1.731	1.593	1.324	1.614	1.537	1.507	1.647	
Tonnes lint/ha rainfed cotton	0.255	0.636	0.609	0.624			0.460	0.461	0.660		
Benefit from irrig. (t/ha of lint)	1.268	0.916	0.786	1.107	1.593	1.324	1.154	1.076	0.847	1.647	
Benefit from irrig. (t/ha seed)	1.84	1.33	1.14	1.61	2.32	1.93	1.68	1.56	1.23	2.39	
Tonnes of lint from irrigation	35221	42225	38448	23770	14983	5960	15573	5024	16361	19345	216909
Tonnes of seed from irrigation	51202	61384	55893	34555	21781	8664	22639	7304	23785	28122	315330
Val of lint/tonne (\$) (see note 1)	2406	2360	2281	2320	2444	2352	2343	2382	2391	2409	
Value of seed per tonne (\$)	182	175	161	178	177	183	182	182	179	168	
Value of irr. cotton (\$ mill)	94	110	97	61	40	16	41	13	43	51	567
Val of r'fed cott- irrig. land (\$ mill)	19	77	75	35			16	6	34		251

Note 1 Source ABS- Australian base price for raw cotton; equivalent to "in store" price

Annex 3.6  
World Production and Cost Analysis- Irrigated Cotton

Country	Lint yield kg	Pdn cost per ha US\$	Pdn cost per kg US\$	Ginning cost/ha US\$	Admin. cost/ha US\$	Total cost/ha US\$	Total cost/kg US\$	Val. seed & lint/ha US\$	Val. seed		Gross margin/kg US\$
									& lint/kg of lint US\$	Gross Margin/ha US\$	
Australia											
- NSW	1415	775.32	0.55	382.00	107.89	1265.21	0.89	2394.23	1.69	1129.02	0.80
- Queensland	1524	984.94	0.65	411.44	89.53	1485.91	0.98	2658.47	1.74	1172.56	0.77
Argentina	700	441.31	0.63	246.40	42.56	730.27	1.04	1481.90	2.12	751.63	1.07
China	864	649.92	0.75	21.66	41.75	713.33	0.83	1536.94	1.78	823.61	0.95
Colombia	900	1624.53	1.81	222.24		1846.77	2.05	2499.54	2.78	652.77	0.73
India											
- North	498	562.54	1.13			562.54	1.13	1256.56	2.52	694.02	1.39
- C. South	505	758.40	1.50			758.40	1.50	1235.61	2.45	477.21	0.94
- Extra fine	494	912.70	1.85			912.70	1.85	1531.67	3.10	618.97	1.25
Iran	640	747.64	1.17	52.39		800.03	1.25	1372.31	2.14	572.28	0.89
Israel											
- Upland	1800	2025.82	1.13	285.12	1892.67	4203.61	2.34	3846.00	2.14	-357.61	-0.20
- Pima	1580	2118.50	1.34	378.24	1958.34	4455.08	2.82	4076.94	2.58	-378.14	-0.24
Kirghiztan	639	498.82	0.78	92.95	88.09	679.86	1.06	755.18	1.18	75.32	0.12
Mexico	1242	1335.43	1.08	239.39	240.91	1815.73	1.46	2177.64	1.75	361.91	0.29
Pakistan											
- Punjab	833	899.54	1.08	249.23	133.44	1282.21	1.54	1675.27	2.01	393.06	0.47
- Sindh	600	639.03	1.07	179.52	162.06	980.61	1.63	1211.90	2.02	231.29	0.39
Philippines	724	810.05	1.12	190.01	100.75	1100.81	1.52	2164.36	2.99	1063.55	1.47
South Africa											
- M. Trans	1243	951.69	0.77		635.08	1586.77	1.28	2623.98	2.11	1037.21	0.83
- N. Cape	355	1502.36	4.23	16.57	38.39	1557.32	4.39	749.65	2.11	-807.67	-2.28
- N. Natal	888	707.08	0.80		62.98	770.06	0.87	1875.14	2.11	1105.08	1.24
Syria	992	1532.23	1.54	174.67	123.54	1830.44	1.85	2088.64	2.11	258.20	0.26
Turkey											
- Aegean	1140	1352.63	1.19	45.83	4.38	1402.84	1.23		0.00	-1402.84	-1.23
USA											
- Southwest	1269	1250.17	0.99	245.77	524.00	2019.94	1.59	1751.05	1.38	-268.89	-0.21
- Nat Ave.	616	639.76	1.04	126.74	323.25	1089.75	1.77		0.00	-1089.75	-1.77
Average	933.09	1031.3	1.11	197.79	364.98	1594.09	1.60	1950.6	2.09	356.53	0.38
Std deviation	398.94	474.72	0.74	122.35	592.40	1000.55	0.78	869.33	0.77	723.94	0.98

Source: ICAC

Annex 3.7  
Production and productivity of various irrigated crops- 1996 budget data A\$

Crop	Yield t/ha	Price/t	Other income	Total income	Water Use (ML)	Variable costs	Gross margin	Income /ML	GM/ML
Irrigated crops- Gwydir Valley									
Cotton	1.5	2070	312	3484	5.9	2085	1399	590.5	237.1
Sorghum	8.0	160		1280	4	528	752	320.0	188.1
Sunflowers	3.0	340		1020	4	585	435	255.0	108.7
Soybean	3.0	380		1140	4.8	495	645	237.5	134.3
Maize	10.0	180		1800	5.6	730	1070	321.4	191.0
Irrigated crops- Murrumbidgee Valley									
Long grain rice	8.0	240		1920	11.3	870	1050	169.9	93.0
Maize grit	9.5	180		1710	6.8	1064	646	251.5	95.0
Sorghum	6.5	160		1040	6.4	618	422	162.5	66.0
Soybeans	2.8	390		1092	7.6	783	309	143.7	40.7
Sunflowers	3.0	340	30.6	1050.6	6.4	714	336	164.2	52.6
Lucerne	14.0	120		1680	8	1266	414	210.0	51.7
ASW wheat	4.5	175		787.5	2.9	505	282	271.6	97.3
Bisc. Wheat	4.8	190		902.5	2.2	515	388	410.2	176.1
Feed barley	5.0	170		850	2.3	513	337	369.6	146.6
Oats grain only	3.3	120		390	2.3	383	7	169.6	3.1
Canola	2.8	340		952	2.3	554	398	413.9	173.1
Fababeans	3.5	250		875	2.9	540	335	301.7	115.4

Source: NSW Agriculture

Annex 3.8  
Indicative cost of irrigation- Gwydir Valley- 162 ha

**Capital costs**

<b>Earthworks</b>	
Storages 5 ML per ha @ \$100 per ML	81,000
Supply channels 0.5 km @ \$12,000 per km	6,000
Head ditches 1.0 km @ \$2,000 per km	2,000
Field drains 1.0 km @ \$5,000 per km	5,000
Structures	20,000
Tailwater return drains 2.0 km @ \$8,000 per km	<u>16,000</u>
Sub total	130,000
<b>Pumps</b>	
Main pump	70,000
Tailwater pump	<u>40,000</u>
Sub total	110,000
<b>Total</b>	<u>240,000</u>

**Annual Operating Costs**

<b>Fixed costs</b>	
Interest on capital items @ say 10%	24,000
<b>Depreciation</b>	
Storage say 30 year life	2,700
Channels, drains & struct. say 50 year life	1,000
Pumps say 10 year life	<u>11,000</u>
Sub total	14,700
<b>System repairs and maintenance</b>	
Channel maintenance	5,000
<b>Irrigation &amp; licence charges</b>	
Licence renewal fee (\$878/5 years)	170
Entitlement charge 972 ML @ \$2.00	1,940
Water management charge 972 ML @\$1.35	<u>1,310</u>
Sub total	3,420
<b>Sub total</b>	<u>47,120</u>

**Variable costs**

<b>Pumping costs</b>	
Fuel- river pump 972 ML @ lift of 12 meters @ \$5.50 per ML	5,340
Fuel- tail water pump- 300 ML @ lift of 6 meters @ \$2.75 per ML	820
Maintenance main pump @ \$1.30 per ML	1,260
Maintenance tail water pump @ \$1.30 per ML	<u>390</u>
Sub total	7,810
<b>Irrigation &amp; licence charges</b>	
Usage charge 972 ML @ \$1.50 per ML	1,460
Water quality monitoring levee 972 ML @ \$0.25	<u>240</u>
Sub total	1,700
<b>Sub total</b>	<u>9,510</u>

<b>Total</b>	<u>\$56,630</u>
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Cost/ML pumped from river at full allocation	\$58.25
Cost/ML pumped from river at full alloc. + 33% off alloc	\$46.15
Av. alloc over last 10 years was 30% or say 300 ML plus say 150 ML average off allocation/licence to give total of 450 ML per 972 ML licence	<u>\$114.50</u>

Annex 3.8

Indicative cost of irrigation- Coleambally irrigation area- 1,400 ML licence

**Capital costs**

<b>Earthworks</b>	
Supply channels 0.5 km @ \$8,000 per km	4,000
Head ditches 1.0 km @ \$2,000 per km	2,000
Field drains 1.0 km @ \$5,000 per km	<u>5,000</u>
Sub total	11,000
<b>Pumps</b>	
Small recirculating pump	20,000
<b>Total</b>	<u>31,000</u>

**Annual Operating Costs**

<b>Fixed costs</b>	
Interest on capital items @ say 10%	3,100
<b>Depreciation</b>	
Channels and drains say 50 year life	220
Pump say 10 year life	<u>2,000</u>
Sub total	2,220
<b>System repairs and maintenance</b>	
Channel maintenance	2,500
<b>Irrigation &amp; licence charges</b>	
Scheme administration fee	300
Delivery service charge 1400 ML @ \$0.90	1,260
Entitlement charge 1400 ML @ \$1.05	1,470
Water Management charge 1400 ML @ \$1.35	<u>1,890</u>
Sub total	4,920
<b>Sub total</b>	<u>12,740</u>
<b>Variable costs</b>	
<b>Irrigation &amp; licence charges</b>	
Usage charge 1,400 ML @ \$8.00 ML	11,200
Pumping costs 300ML @ \$2.75/ML	<u>820</u>
Sub total	12,020
<b>Total</b>	<u>24,760</u>

Cost per ML delivered at full allocation \$17.70

The average allocation for the last ten years for the Murrumbidgee has always been equal to or exceeded 100%. The cost per ML is therefore much the same as above ie, \$17.70.

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