Department of Primary Industries
Department of Regional NSW

DPI Primefact

Benchmarking water productivity of Australian irrigated cotton – the latest results

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NSW DPI Water Productivity Benchmarking Team

Summary

Improving water productivity is a high priority for Australian agriculture, especially given increased pressure on available water supplies.

NSW Department Primary Industries (DPI) is working with the Australian cotton industry to improve the productive and sustainable use of irrigation water. NSW DPI, in partnership with the Cotton Research and Development Corporation, has been assessing the trend in water productivity of irrigated cotton since the 1990s.

Latest results from the 2021 season confirm the water productivity of Australian cotton increased from 0.62 bales/ML in 1997 to 1.23 bales/ML in 2021. However, the rate of productivity improvement has slowed to less than 0.6% per annum since 2007. The average water productivity of Australian cotton for 2001 to 2021 is 1.08 bale/ML. This is 2.25 times the global average, based on the latest available data in 2011.

The Australian industry's average water productivity in 2021 was 7% higher than the maximum achieved in 1998.

Australian cotton water sustainability indicators have improved significantly. The water used to produce one bale of cotton in 2021 was less than half the water used in 1997. The long-term average water consumption in Australia for 2001 to 2021 period was 0.93 ML/bale, which is less than half the global average of 2.07 ML/bale equivalents reported in 2011.

Improvements in Australian water productivity are the result of increased yield, reduced water inputs and increased irrigation efficiency, during a period when rainfall is declining.

Establishing water productivity benchmarks

DPI assessed the water productivity and irrigation use efficiency of Australian cotton farms for the 2019 and 2021[1] seasons. For 2021, we asked 57 cotton growers from across Australia's major cotton growing areas in Queensland and NSW who participated in previous surveys and a total of 31 responded. Collectively these farms produced 138,156 bales of cotton from an area of 11,748 ha, which represents 5.5% of the irrigated cotton bales produced in Australia, from 5.3% of the country's total cotton growing area.

Water productivity was assessed using the Gross Production Water Use Index (GPWUI) which is the established method used in the Australian cotton industry. We have continued to use the average GPWUI as the industry benchmark to ensure a valid and consistent presentation of the long-term trends (Tennakoon and Milroy 2003; Williams and Montgomery 2008; Montgomery and Bray 2010; Roth *et al.* 2013; Montgomery *et al.* 2014).

We used grower records of water use to estimate the water balance for each farm, capturing all water inputs and outputs. Details are provided in the standardised measures section below. This data was used to calculate water productivity and water sustainability indices, and irrigation efficiency metrics, as well as to identify where and how much irrigation water is lost, in the irrigated farming system.

Standardised measures

Gross Production Water Use Index (GPWUI) measures how productively water is used. It is the ratio of cotton yield (bales/ha) to all water potentially available for cotton crops (ML/ha) and is expressed as bales/ML (Equation 1). A bale is 227 kg of cotton lint.

Equation 1. $$GPWUI = \frac{cotton\ yield}{irrigation\ water + rainfall + soil\ moisture\ change}$$

Whole Farm Irrigation Efficiency (WFIE) is a measure of how efficiently irrigation water is used (Tennakoon and Milroy 2003). WFIE reflects the proportion of irrigation water used by the crop relative to the total irrigation water on farm (Equation 2).

Equation 2. $$WFIE = \frac{crop\ water\ use\ - effective\ incrop\ rain - soil\ moisture\ change}{total\ irrigation\ water\ used\ on\ farm} \times 100$$

A high WFIE value generally reflects low storage, transmission and field losses and that the crop has used a higher proportion of the water brought onto the farm. The WFIE is influenced by rainfall and will be higher in drier years when a greater proportion of crop water needs are met by irrigation.

[1] All years refer to the year the cotton was picked.

The Water Sustainability Index (WSI) is another measure of productivity to indicate how much water is used per unit of product. A smaller index demonstrates more sustainable water use. The index is sometimes referred to as the water use efficiency index. This index has become increasingly important to cotton buyers and consumers seeking to ensure the product they are purchasing has been produced efficiently (CRDC and CA 2020a,b).

Equation 3. $$WSI = \frac{irrigation\ water + rainfall\ -\ soil\ moisture\ change}{cotton\ yield}$$

We express the water sustainability index for irrigated cotton as ML/bale, which is the inverse of the GPWUI equation. Published water use data from most cotton producing countries does not include changes in soil moisture. To enable comparisons with international data, we have not included the soil moisture component in total water inputs in our Australian calculations.

Improvements in water productivity of Australian cotton

The average GPWUI of irrigated cotton has increased by 4% on average annually over 24 years, and by a total of 98% since 1997:

- GPWUI has increased from an average 0.62 bales/ML in 1997 to 1.20 bales/ML in 2018. It further increased to 1.23 bales/ML in 2021 (Figure 1).
- The annual rate of improvement from 1997 to 2007 was 9% but has slowed since 2007 to less than 0.6%.
- The average water productivity in 2021 was 7% higher than the maximum productivity achieved in 1998.
- The average GPWUI of 1.23 bales/ML achieved in 2021 demonstrates progress towards the industry target of 1.32 bales/ML by 2023.
- The water productivity achieved by the Australian cotton industry consistently exceeds the global average published in 2011[2] as demonstrated below:
  - The average water productivity of Australian cotton between 2001 and 2021 is 1.08 bales/ML or 2.25 times the global average of 0.48 bales/ML equivalent (Mekonnen and Hoekstra 2011).
  - The average water productivity of Australian cotton for 2001 to 2010 was 0.97 bales/ML which was twice the global average published in 2011. For the 2011 to 2021 period the Australian cotton industry achieved water productivity of 1.17 bales/ML.

[2] The most recent publicly available global data on cotton lint water consumption was reported in 2011.

- The average GPWUI dropped from 1.20 bales/ML in 2018 to 0.93 bales/ML in 2019. This was due to severe drought requiring greater irrigation water inputs at the same time as cotton yields dropped from 12.38 bales/ha in 2018 to 11.19 bales/ha in 2019 (Figure 2).
  - These drought conditions have affected the rate of long-term improvement in GPWUI.
  - This shows the vulnerability of irrigated cotton to climate change.

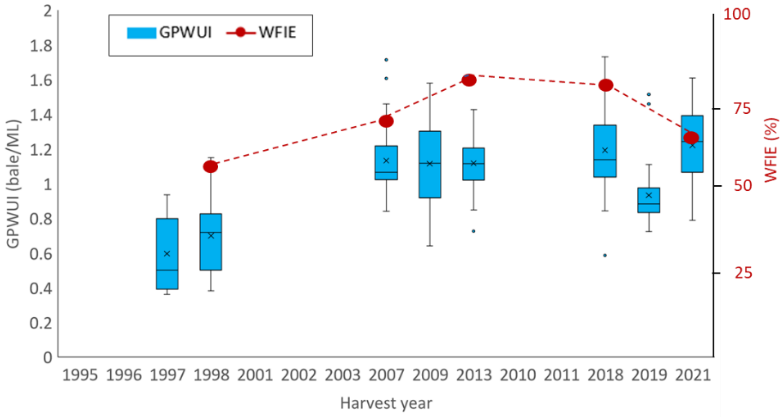

***Figure 1**. **GPWUI and WFIE (1997 to 2021 cotton seasons)**: The blue boxes represent the distribution of GPWUI values in the harvest year the benchmarking occurred. The x in the centre of each blue box is the average GPWUI, the top of the blue box represents the water productivity obtained by the top 25% of growers. The red circles represent WFIE. Data prior to 2019 are redrawn from previous benchmarking (Tennakoon and Milroy 2003; Williams and Montgomery 2008; Montgomery and Bray 2010; Roth et al. 2013; Montgomery et al. 2014).*

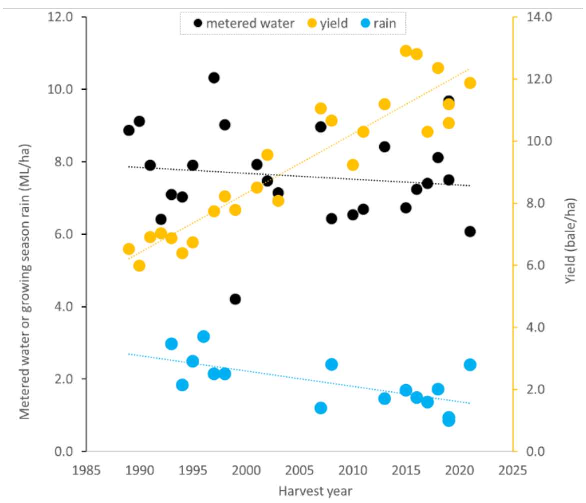

***Figure 2. Cotton yield, rainfall and irrigation water trends:** The trend of rising cotton yields since the 1990s (represented by the yellow dots) has occurred while total growing season rainfall (blue dots) and irrigation water use on farm (black dots) has been trending downwards. Data prior to 2019 are redrawn from previous benchmarking (Tennakoon and Milroy 2003; Williams and Montgomery 2008; Montgomery and Bray 2010; Roth et al. 2013; Montgomery et al. 2014).*

Irrigation efficiency (WFIE) has improved significantly but can decline in periods of high rainfall:

- WFIE increased from 60% in 1998 to 80% in 2018 (Figure 1).
- However, in the very wet year 2021, which followed severe drought, it fell back to 60%.
- WFIE will always be lower during very wet seasons (Equation 2) due to evaporation and drainage losses that are inherent in wet periods (Figure 4).

These improvements in Australian cotton water productivity are the result of increased yield, reduced water inputs and increased irrigation efficiency during a period when rainfall is declining (Figures 2).

The Australian cotton industry demonstrates improvement in the sustainable water use indicator by consuming less water to produce each bale of cotton from 1997 to 2021:

- Long-term water consumption in the Australian cotton industry averaged 0.93 ML/bale between 2002 and 2021, which is less than half the global average of 2.07 ML/bale (Mekonnen and Hoekstra 2011)[2].
- The cotton water sustainability indicator has improved significantly. In 1997,1.54 ML was needed to produce a bale of cotton, in 2021 this had fallen by 53% to 0.72 ML (Figure 3).
- Water used to produce a bale of cotton lint has reduced significantly since 1985, but the rate of reduction is declining.

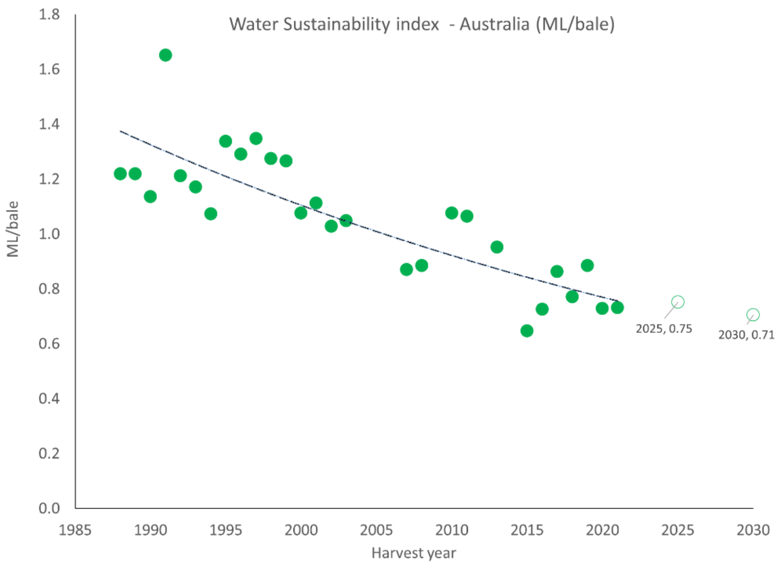

Figure 3. Change in cotton water sustainability indicator in Australia 1985 to 2021*: Projected values for 2025 and 2030 are based on continuation of the current trend. Data prior to 2019 are redrawn from previous benchmarking (Tennakoon and Milroy 2003; Williams and Montgomery 2008; Montgomery and Bray 2010; Roth et al. 2013; Montgomery et al. 2014).*

Improved irrigation efficiency from 1998 to 2018 is attributed to reduced losses from storages and channels, and improvement in irrigation infrastructure and management. However, during the wet season of 2021, efficiency (based on WFIE) declined from 80% to 60% (Figure 1).

Field application losses increase from 10% in 2011 to 20% during the wetter than normal season of 2021 (Figure 4). Greater losses are probably the result of water being stored longer in dams and channels while growers capitalise on rainfall and soils are wetter for longer periods.

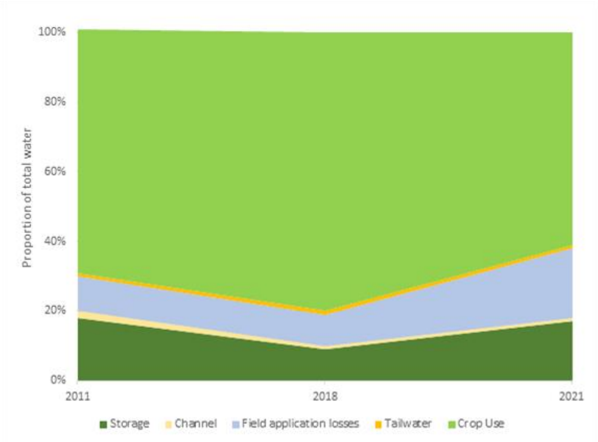

Figure 4. The partitioning of irrigation water into crop use and various on farm losses from 2011, 2018 and in 2021: *The proportion of seepage and storage losses doubled from 2018 to 2021 due to a very wet season.*

Key messages

- Australian water productivity has doubled over the last 24 years from 0.62 bales/ML in 1997 to 1.23 bales/ML in 2021
- The annual rate of improvement from 1997 to 2007 was 9% but has slowed since 2007 to less than 0.6%
- The industry's average water productivity in 2021 was 7% higher than the maximum achieved in 1998
- The water sustainability indicator has also doubled, with half as much water being used to produce a bale of cotton
- Improved water productivity and water sustainability are driven by increased yield and reduced water consumption, during a period when rainfall is declining
- The average water productivity of Australian cotton for the 2001 to 2021 period is 2.25 times the global average identified in 2011[2]

Future directions

Increasing water productivity continues to be a high priority for the Australian cotton industry. DPI will benchmark cotton water productivity until at least 2025. Future benchmarking will rely on surveys that are less time consuming for growers and wherever possible utilise data from other sources. The aim is to increase the effectiveness and efficiency of data collection and allow annual benchmarking of water productivity and water sustainability. In addition, benchmarking will also include rain fed cotton systems.

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