

Updated Carbon Footprint of Australian Irrigated Cotton

Background

It was arranged between the CRDC and UQ / F Visser that an additional module will be added to project UQ1701 with the mandate to update the carbon footprint of Australian irrigated cotton, including ginning, for 2019. This will be done for the purposes of providing an updated outcome for the industry's Sustainability Report.

Introduction

The Australian cotton industry is reporting on its material sustainability topics for the five years to June 2019. One material topic is carbon emissions per bale of cotton. We have been asked to provide an updated outcome for 2019, and ideally one would have to employ the same methodology that was used by Hedeyati et al to provide an accurate 2019 comparison against the 2014 baseline.

- The 2014 Cotton Sustainability reported carbon emissions per bale of 383 kg based on Hedeyati et al¹.
- That baseline has now been restated, in consultation with the original paper's authors, to 324 kg CO_{2e} per bale due to a change in the methodology for the drying process at the ginning stage of production. Discussed further below.
- Applying the same methodology to the five years to 2018/19 results in an increase of carbon emissions to 364 kg CO_{2e} per bale.
- These figures are emissions only, they are not net carbon footprint figures as they don't include any potential on-farm sequestration of carbon.

Baseline Results

Our work to provide comparable 2014 and 2019 figures was complicated by the fact that Hedeyati et al used the software SimaPro where we don't have access to the formulation or calculations to align the methodologies. Unfortunately there is no common internationally recognised LCA standard for cotton, and studies could therefore present different outcomes depending on a range of assumptions made or data sources employed. Furthermore we had access to 2 published Hedeyati papers to evaluate the data; one only showed the inputs but no detailed emission outputs, and the other provided detailed outputs but no inputs used to

generate those results. We therefore tried to marry these two data outcomes and trusted that their relationship was reliable.

Considerable effort went into running various input scenarios and formulations to try and mimic the baseline results as far as possible, and then apply updated 2019 data to provide a representative modelled comparison outcome for the Report. We achieved a satisfactory level of alignment in terms of methodology / outcomes between the baseline levels and our model's results for the different emission sources, apart from the amount of energy / gas used to dry the lint in the ginning phase: 330.6 kg CO₂e per ton of lint versus 162.3 kg if we apply the corresponding input of 2.1 litres of LPG gas in the first paper, therefore a contradiction between the 2 papers. It appears that the 2.1 litres is a realistic number and that there may well be an error in the conversion of the ginning emissions calculation, as shown in the further analysis below. In trying to identify the reason for the gas emissions difference we consulted with one of the co-authors and LCA expert Tim Grant and they indicated that the Australian LCI database uses a default of 100 Mj per ton of lint as a guideline, which we also apply as a reference in the calculations below:

Ginning Carbon Footprint Comparison									
	LPG Gas (l) Per Bale	Per 1000kg Lint (l)	Energy Content (Gigajoule/kL)	Energy Content (Megajoule/L)	Mj / Ton Lint	Emission Factor kg CO ₂ e/GJ/kWh	Emission Factor kg CO ₂ e/MJ/kWh	Emissions ton Lint	
QLD Cotton	5.8	25.7	25.7	25.7	660.1	59.9	0.060	39.5	
Wathagar	0.93	4.1	25.7	25.7	105.2	59.9	0.060	6.3	
Aus LCI	0.885	3.9	25.7	25.7	100.1	59.9	0.060	6.0	
Hedeyati Conf Paper	2.1	9.2	25.7	25.7	237.5	59.9	0.060	14.2	
Hedeyati JCP Paper	28.18	124	25.7	25.7	3186.8	59.9	0.060	190.9	

From the analysis it shows in the first column that the 2.1 litres in the first paper is achievable, whereas the corresponding usage in the second paper of 28.18 litres per bale is not. The reference of 100 Mj per ton of lint converts to 0.9 litres which is on the lower side of the spectrum but still a realistic benchmark to use. We would therefore reach the conclusion that the error occurred in converting the litres to emissions and that we can use the 2.1 litres as the benchmark for the further analyses.

Forecasted Results

Once the conversion error is taken into consideration the results are acceptably aligned under the circumstances at 1423.7 kg for our model versus 1324.5 kg from the paper, as shown

below. We therefore felt that this provided an acceptable base from which to update the model with the 2019 data to generate the new comparative industry result.

	2014 Paper	2014 Going Sustainable
Yield	10.5 Bales/ha	10.5 Bales/ha
Chemicals	55.3	54
Electricity	39.6	23.8
Fertiliser	709	636.4
On-farm Fuel	259.4	253.5
Ginning (LPG + Electricity) Adjusted	162.3	162.3
Other items (Pre and on-farm)	117.5	117.5
Other (post farm)	80.6	80.6
Total (CO2e/t Lint)	1423.7	1328.1
Total (CO2e/bale)	323.6	301.8

Unfortunately the only 2019 data that one could update the results with were yield and N rate – they are two main drivers but obviously there could have been significant changes in other input parameters as well, therefore assuming that all the other inputs remained constant over the 5 years.

However, the next challenge was to determine which yield and N application rates to apply to the model. There were two main sources namely grower’s surveys and the forecasted production reports, as shown below:

Cotton yield data								
Bales/ha								
Year	14/15	15/16	16/17	17/18	18/19			
Source: Production Forecasts						Number used in analysis		
Irrigated Total	12	11.5				11.2	Excluding 18/19	
Irrigated Green			10.2	11.47	9.4	10.9	Average	
Dryland Total			1.34	2.57	1.44			
Dryland Green	2.9	2.7	2.56	4.9	2.78	3.17	Average	
Source: Grower Surveys								
Irrigated		12.4	9.88	11.22	10.23	10.9		
Partial Irrigated		6.4	2.98	2.43	8.08			
Dryland		3.6	0.95	1.16	1.47			
Cotton N Applied (kg N/ha)								
Source: Grower Surveys								
Irrigated		284	298	335.9	325	310	Average	
Partial Irrigated		126	97	68.7	166			
Dryland		78		33.9	92	67	Average	

The 18/19 production forecast 9.4 bales is indicative of the very dry conditions and the effect on yield although most of the production is based on irrigation. For comparison purposes we show the results both with the average yield over the 5 years (10.9 bales) as well as the average excluding 18/19 (11.2 bales) with the fertiliser breakdown, although the average number will be used in the report:

	2019 Going Sustainable No Drought (higher yield)	2019 Going Sustainable Drought (lower yield)
Yield	11.2 Bales/ha	10.9 Bales/ha
Chemicals	50.6	52
Electricity	22.3	22.9
Fertiliser	904.1	928.1
On-farm Fuel	237.6	244.2
Ginning (LPG + Electricity) Adjusted	162.3	162.3
Other items (Pre and on-farm)	110.2	113.2
Other (post farm)	80.6	80.6
Total (CO2e/t Lint)	1,567.7	1,603.3
Total (CO2e/bale)	356.3	364.4

Fertiliser 2019	Product Rate (kg/ha)	N-Rate (kg/ha)
Urea	382	175.5
AA	146	119.3
MAP	137	15.1
Total		309.9

The results represent an increase of the carbon emissions from 324 kg CO₂e / bale of lint in 2014 to 364 kg in 2019. This increase is mainly the result of the affordability of fertiliser. Growers will more or less maintain their N application rates despite the probability of lower yields.

Potential for Carbon Neutral Cotton

A few case studies have shown that carbon neutral cotton can be a realistic expectation in the Australian industry. The main drivers for a reduction in emissions are: productivity / yield increases and a reduction in fertilisers. Whereas emission credits are generated by an increase in soil carbon, the application of organic amendments and the extent of native vegetation. A climate friendly result is normally due to the combination of a number of these factors.

In order to appreciate the feasibility of carbon neutrality for the Australian industry, we compiled the following analysis showing the results of various combinations of factors. The challenge with this exercise is the extent of the native vegetation on the average Australian cotton farm. We therefore resorted to the 2019 grower's survey for this data. In that case the size of the average farm was 4400 ha, with 3200 ha cropped but cotton only made up 330 ha of this. This means that the cotton crop only gets a 10% share of the native vegetation credit, which may not always be representative and has a marked effect on these outcomes.

What the results do show below is that it is certainly achievable, even at reasonably high fertiliser rates. The increase of 200kg carbon per hectare represents a 0.05% increase in soil carbon per hectare per year – therefore from 0.5% to 0.55% in a year which is certainly achievable. What will be of great value is to do a number of 'test' audits of potential carbon neutral farms to develop achievable yardsticks.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Yield	13 Bales/ha	13 Bales/ha	13 Bales/ha	13 Bales/ha	13 Bales/ha	13 Bales/ha
Chemicals	89.3 kg CO ₂ e/T Lint	89.3 kg CO ₂ e/T Lint	89.3 kg CO ₂ e/T Lint	89.3 kg CO ₂ e/T Lint	89.3 kg CO ₂ e/T Lint	89.3 kg CO ₂ e/T Lint
CO2 Sequestration (Cultivation)	-248.2 kg CO ₂ e/T Lint 200kg C/ha	-248.2 kg CO ₂ e/T Lint 200kg C/ha	-310.3 kg CO ₂ e/T Lint 250kg C/ha	-347.5 kg CO ₂ e/T Lint 280kg C/ha	-347.5 kg CO ₂ e/T Lint 280kg C/ha	-347.5 kg CO ₂ e/T Lint 280kg C/ha
CO2 Sequestration (Native Vegetation)	-276.2 kg CO ₂ e/T Lint 10ha Riparian 63ha Grasses 60ha Forest	-325.8 kg CO ₂ e/T Lint 10ha Riparian 63ha Grasses 80ha Forest	-364.1 kg CO ₂ e/T Lint 10ha Riparian 100ha Grasses 80ha Forest	-364.1 kg CO ₂ e/T Lint 10ha Riparian 100ha Grasses 80ha Forest	-388.9 kg CO ₂ e/T Lint 10ha Riparian 100ha Grasses 90ha Forest	-575.1 kg CO ₂ e/T Lint 40ha Riparian 100ha Grasses 90ha Forest
Electricity	19.9 kg CO ₂ e/T Lint	19.9 kg CO ₂ e/T Lint	19.9 kg CO ₂ e/T Lint	19.9 kg CO ₂ e/T Lint	19.9 kg CO ₂ e/T Lint	19.9 kg CO ₂ e/T Lint
Fertiliser	722.8 kg CO ₂ e/T Lint AA 146kg/ha Urea 327kg/ha Map 137kg/ha	564.9 kg CO ₂ e/T Lint AA 100kg/ha Urea 300kg/ha Map 100kg/ha	564.9 kg CO ₂ e/T Lint AA 100kg/ha Urea 300kg/ha Map 100kg/ha	538.6 kg CO ₂ e/T Lint AA 100kg/ha Urea 280kg/ha Map 100kg/ha	455 kg CO ₂ e/T Lint AA 60kg/ha Urea 280kg/ha Map 60kg/ha	700.7 kg CO ₂ e/T Lint AA 60kg/ha Urea 435kg/ha Map 60kg/ha
On-farm Fuel	175.6 kg CO ₂ e/T Lint	175.6 kg CO ₂ e/T Lint	175.6 kg CO ₂ e/T Lint	175.6 kg CO ₂ e/T Lint	175.6 kg CO ₂ e/T Lint	175.6 kg CO ₂ e/T Lint
Total	483.2 kg CO ₂ e/T Lint	275.7 kg CO ₂ e/T Lint	175 kg CO ₂ e/T Lint	112 kg CO ₂ e/T Lint	3.3 kg CO ₂ e/T Lint	63 kg CO ₂ e/T Lint

