FINAL REPORT

For Public Release

Part 1 - Summary Details

CRDC ID: UQ1701

Project Title: **Appropriate Land-Use methodology for Australian cotton LCA assessments**

Project Start Date: 1/07/2016 **Project Completion Date:** 30/09/2019

Research Program: 2 Industry

Part 2 – Contact Details

Administrator: Ms Kim Turner

Organisation: Research Administration Officer, Grants UQ Research and Innovation
The University of Queensland

Postal Address: Building 72, Research Road, University of Queensland, St. Lucia, Brisbane, 4072

Ph: 07 334 67554 Fax: E-mail: sciencegrants2@research.uq.edu.au

Principal Researcher: Dr Francois Visser
Organisation: The University of Queensland

Postal Address:

Ph: Fax: E-mail: francois@goingsustainble.com.au

Supervisor: (Name & position of senior scientist overseeing the project).

Organisation:

Postal Address:

Ph: Fax: E-mail:

Researcher 2: (Name & position of additional researcher or supervisor).

Organisation:

Postal Address:

Ph: Fax: E-mail:

Signature of Research Provider Representative:

Date submitted: _30/01/2020______________________

Part 3 – Final Report

Introduction

The main aim of this study was to enable the Australian cotton industry to report on how the impact of cotton cropping on soil health can be monitored and improved in a practical and scalable manner; with the view of incorporating the results in the industry's sustainability reporting, and to proactively meet the textile industry demands in this regard. The report should also enable the cotton industry to participate or inform relevant discussion forums with regards to methodologies to monitor the environmental impacts of cotton cropping on soil. It was also decided to add an additional component to the study namely to do an update of 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.

Hence we need to consider where the market is at with regards to this new sustainability concern. In recent years a considerable number of industry sustainability initiatives have been launched to try and reassure the end customer that the relevant brands are environmentally and socially responsible. However, the two main schemes that may have an impact on the Australian cotton industry are the Sustainable Apparel Coalition (SAC) and the European Commission Product Environmental Footprint (PEF) programme. Both initiatives rely on LCA methodology to assess the environmental impacts associated with a unit of production, and have subsequently develop their own range of impact categories to do so.

In the case of the SAC the following diagram show the 5 impact categories or impact areas that are being assessed at this stage. It shows that Land Use is not included at this stage but may probably be added in the future. Interestingly cotton scores poorly in terms of its MSI (Material Sustainability Index) score with a total impact of 93, as against polyester with a score of 39. Of the total impact, raw material production makes up 60.5 of the 93, as shown below, with water scarcity as the main contributor.

Table 7: Cotton MSI score for raw material phase

	Impact area	MSI Score
	Global Warming	3.3
	Eutrophication	10.3
	Water Scarcity	44.2
	Abiotic Resource Depletion, Fossil Fuels	2.7
	Chemistry	0.0

The EC PEF programme is being developed as a comprehensive and scientifically robust scheme that will be regulated throughout the EC. The following is the list of impact factors and metrics that are being applied at this stage:

Table 2: Default EF impact categories (with respective EF impact category indicators) and EF impact assessment models for PEF studies

EF Impact Category	EF Impact Assessment Model	EF Impact Category indicators	Source
Climate Change	Bern model - Global Warming Potentials (GWP) over a 100 year time horizon.	kg CO_2 equivalent	Intergovernmental Panel on Climate Change, 2007
Ozone Depletion	EDIP model based on the ODPs of the World Meteorological Organization (WMO) over an infinite time horizon.	kg CFC-11 equivalent	WMO, 1999
Ecotoxicity for aquatic fresh water	USEtox model	CTUe (Comparative Toxic Unit for ecosystems)	Rosenbaum et al., 2008
Human Toxicity - cancer effects	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008
Human Toxicity – non-cancer effects	USEtox model	CTUh (Comparative Toxic Unit for humans)	Rosenbaum et al., 2008
Particulate Matter/Respiratory Inorganics	RiskPoll model	kg PM2.5 equivalent	Humbert, 2009
Ionising Radiation – human health effects	Human Health effect model	kg U^{235} equivalent (to air)	Dreicer et al., 1995
Photochemical Ozone Formation	LOTOS-EUROS model	kg NMVOC equivalent	Van Zelm et al., 2008 as applied in ReCiPe
Acidification	Accumulated Exceedance model	mol H+ eq	Seppälä et al.,2006; Posch et al., 2008
Eutrophication – terrestrial	Accumulated Exceedance model	mol N eq	Seppälä et al.,2006; Posch et al., 2008
Eutrophication – aquatic	EUTREND model	fresh water: kg P equivalent marine: kg N equivalent	Struijs et al., 2009 as implemented in ReCiPe
Resource Depletion – water	Swiss Ecoscarcity model	m^3 water use related to local scarcity of water	Frischknecht et al., 2008
Resource Depletion – mineral, fossil	CML2002 model	kg antimony (Sb) equivalent	van Oers et al., 2002
Land Transformation	Soil Organic Matter (SOM) model	Kg (deficit)	Milà i Canals et al., 2007

Here it shows that 'Land Use' in the form of Land Transformation has indeed been included as an impact category, and in the form of a decrease in soil organic matter as the single metric. Land transformation in LCA terminology usually refers to the 'conversion' of land (i.e. from forest to cropping) where the other form of land intervention (LUC) is 'occupation', which more relevant to Australian cotton production. However, for the purposes of this study we assume that the PEF standard includes the effect of occupation as well.

In summary it therefore appears that the industry programmes do not pose a real 'threat' at this point in time in terms of quantifying land use impacts. The single PEF soil carbon metric will be easy to comply with as this is available at farm level and a standard output in all soil test reports.

However, the EC Joint Research Centre recently published the report 'Land-use related environmental indicators for Life Cycle Assessment' which provides an authoritative overview of where the science and LCA methodology is at in this regard from the EC's perspective on behalf of an LCA practitioner. The study evaluated the strengths and limitations of 11 current models which can potentially be employed to assess the environmental impacts of land use, and the following are some of the key points from the study:

- *'In the last 15 years, substantial efforts have been made to improve the assessment of the impacts on land use derived from production supply chains. Yet, a consensus on the best available model for land use has not been achieved (Teixeira et al., 2015).'*
- *Soil quality is defined as the "capacity of a living soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health" (Doran, 2002).* For the purposes of this report we equate soil quality to soil health.
- *Therefore, there is a clear need to assess the extent to which soil quality is affected by current human interventions (Jandl et al., 2014).*
- *Given the complexity of the soil matrix, the assessment of soil quality is very challenging. In particular, it is increasingly evident that the selection of a specific indicator (or a set of indicators) is problematic, given the spatial and temporal variability of soil properties (Milài Canals et al., 2007b; Garrigues et al., 2012).* Therefore, ideally assessments should be site specific and in relation to the surrounding 'native soil'.
- *When deciding the most adequate indicator(s) among the proposed sets, it should be bore in mind that for many applications of LCA the ultimate target of the quantification of impacts is to compare the performance of different products rather than an accurate calculation of the full environmental impact on the soil.* The main aim of such a model is to support an LCA practitioner in undertaking such an assessment as part of an LCA study.
- Therefore in order to progress the development of an ideal model in this regard, further research is required to: *1. adopting a common land use cause - effect chain and land use classification; 2. accounting for different land management practices; 3. assessing the added value of using multi - indicators, as some evaluated models propose, for a comprehensive account of impacts of land use on soils; 4. ensuring consistency from midpoint to endpoint indicators; 5. providing guidance to calculate normalization factors; and 6. ensuring a systematic assessment of models results uncertainty.*

Currently, the ILCD handbook and above PEF framework recommends the use of the model by Milài Canals et al. (2007a), which proposes soil organic matter (SOM) as a stand - alone indicator. The report is critical of this: *' However, although SOM has a crucial role in provisioning (e.g. biotic production) and supporting services (e.g. climate regulation), important soil functions, such as resistance to erosion, or threats to soil such as compaction and salinization, are disregarded (Mattila et al. 2011)'*

The report recognises that a range of indicators should be applied, and one can expect that the single current indicator will be expanded on: '*Alternatively, to the use of a single indicator, there is a widespread interest around the need for a minimum set of soil indicators. The need for multiple indicators to thoroughly assess soil quality was expressed both by modelers that account for various* *drivers of impact (LANCA; Saad et al.,2013; SALCA-SQ) as well as pointed out by those using only one indicator (e.g. Garrigues et al., 2013).'*

Literature Review

An extensive and detailed literature review was undertaken to establish where the science and industry was at in this regard. The following summary is provided for the purposes of this final report:

- Efforts to develop a single, widely accepted land use LCA methodology are expected to continue in the literature, especially with all the 'gaps' identified in the above report.
- There are a number of alternative ways to quantify and convey these impacts, but greater credit appears to be given to methodologies which can aggregate impact results into a single score.
- It is reassuring that the literature recognises that the actual indicators and metrics to be assessed should be determined by the scope and goal of the particular industry.
- Impact assessments should be categorised and regionalised, ideally site specific, as the same practices may have very different impacts depending on the environmental conditions and soil types
- The aim should be to proactively engage with the textile supply chain to ensure that the industry level agreement is functional and practical at a producer or regional level.
- The Australian cotton industry will have to develop the most effective solution in this regard internally, while also meeting the requirements of the external industry environment.

The following is a combined list of potential land use indicators that was extracted from the literature:

- Occupancy - land use intensity
- Occupancy - input intensity
- Degradation / erosion
- Transformation of land (where LUC is applicable)
- Soil bio-activity
- Soil porosity / structure
- Soil pH
- Content of phosphorous and potassium in soil
- Soil organic carbon (SOC)
- Compaction
- Water storage nutrient toxicity levels
- Salinization / sodium %
- Nutrient depletion
- Groundwater depletion (if inside scope)
- Mineralisation potential

Outcomes

Development of land use indicator set for the Australian cotton industry

May we recommend that the follow criteria be considered when developing an indicator set for the Australian cotton industry:

General:

- Land use will probably be one of a number of environmental impact categories being assessed by an LCA practitioner as part of a sustainability assessment, each with their respective metrics, and therefore the number of land use metrics need to be practical and manageable from this perspective.
- Apart from meeting specific industry requirements, the cotton industry should also use this framework and initiative to communicate its own sustainability achievements as part of regular reporting.
- Through this initiative, the Australian cotton industry should aim to stay at the forefront in this space.
- This is a new sustainability space and industry is only applying a single indicator / metric for land use at present. The Australian cotton industry may therefore be afforded the leniency of adopting a conservative and phased approach whereby a limited and suitable number of indicators are implemented at first, with the intention of increasing this as practical data structures become available or put in place.
- Importantly the programme should be of direct benefit to growers to address their concerns about the state of the soil that they will be passing on the next generations.

Indicators:

- There is no single indicator or metric that will adequately represent the range of potential environmental impacts on cropping land.
- Assume that results need to be scaled to regional and national level.
- Data needs to be site specific to account for environmental variations.
- Results should be assessed in relation to the native soil at the site on not based on aggregated benchmarks or yardsticks.
- Process of collecting data must be as cost effective as possible by using current sources and structures without the need for site visits or validation.
- Decide on a feasible list of indicators that can assessed given the above considerations.

Therefore, specific recommendations:

1) Use 2 sources of data: firstly grower surveys to assess land use intensity and input intensity, and secondly soil test data for another 6 metric outcomes.
2) Indicators from soil tests: soil organic carbon, ph., phosphorous, potassium, nitrogen (total, nitrates and ammonia), CEC and % sodium.

3) Soil compaction is a major concern for growers and therefore an additional 'wet sieving' test will give an indication of soil structure and stability – it appears that Nutrient Advantage is not able to do this but EAL Laboratory can for $60, and separate samples will have to be sent there but it is probably justified.
4) All results received form Nutrient Advantage lab and therefore provides a common methodology and able to utilise historical grower data for the database and trending – growers that we have consulted is agreeable to this.
5) Form the "soil sustainability awareness group' SSAG with a pilot group of concerned growers to 'test' the programme to assess how it could be rolled out on a regional and national scale.
6) Growers are required to take soil test at those specific sites including a 'native' sample each year, according to a standardised procedure.
7) Results will be expressed as a % relative to the native soil, which can be benchmarked, aggregated as a single farm score, and scaled / aggregated to a regional and national level accordingly.
8) Results will be treated anonymously although will receive their specific results evaluations, along with their normal results via their agronomist / consultant.
9) CRDC / Cotton Australia or a funded project may have to cover the costs of the additional native soil test, the wet sieving test and potentially the assessments.

It is unfortunate that the above indicators will not assess soil biology / microbial life, but this is an expensive, time consuming procedure. Fortunately soil carbon is strong driver of soil biology, and perhaps a suitable proxy indicator could be introduced for this in the future.

We have had discussions with a number of growers, who have been very supportive of the idea, and keen to join such an initiative and are willing to provide their historical soil test data. We have also consulted with relevant scientists for their views and recommendations which have been taken into consideration. The assistance of Dr Oliver Knox (UNE) has been particularly valuable.

We previously developed a framework whereby two major selecting criteria could be considered when selecting developing an indicator suite, namely environmental impact value or relevance and practicality, which includes availability, scalability and cost. We have omitted this framework for this report due to the above recommendations which negates its relevance.

Conclusion

In conclusion the writer believes that the above recommendations provide a realistic and cost effective path whereby such a programme could be initiated. This can be implemented in the short term with such a pilot group of growers, and the initial assessments can be included as part of this project. In the event that the CRDC is not convinced of the merits of this approach, alternative data sources, methods and frameworks will be investigated to introduce such a process.

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 al[i].
- That baseline has now been restated, in consultation with the original paper's authors, to 324 kg CO2e 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 a considerable increase of carbon emissions to 364 kg CO2e 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 the identify the reason for the gas emissions difference we consulted with one of the co-authors and LCA expert Tim Hart 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 CO2e/GJ/kWh	Emission Factor kg CO2e/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 (CO_2e/t Lint)	1423.7	1328.1
Total (CO_2e/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 a considerable increase of the carbon emissions from 324 kg CO2e / bale of lint in 2014 to 364 kg in 2019, as opposed to a planned decrease. 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.

	Scenario1	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_2e/T Lint	89.3 kg CO_2e/T Lint	89.3 kg CO_2e/T Lint	89.3 kg CO_2e/T Lint	89.3 kg CO_2e/T Lint	89.3 kg CO_2e/T Lint
CO2 Sequestration (Cultivation)	-248.2 kg CO_2e/T Lint 200kg C/ha	-248.2 kg CO_2e/T Lint 200kg C/ha	-310.3 kg CO_2e/T Lint 250kg C/ha	-347.5 kg CO_2e/T Lint 280kg C/ha	-347.5 kg CO_2e/T Lint 280kg C/ha	-347.5 kg CO_2e/T Lint 280kg C/ha
CO2 Sequestration (Native Vegetation)	-276.2 kg CO_2e/T Lint 10ha Riparian 63ha Grasses 60ha Forest	-325.8 kg CO_2e/T Lint 10ha Riparian 63ha Grasses 80ha Forest	-364.1 kg CO_2e/T Lint 10ha Riparian 100ha Grasses 80ha Forest	-364.1 kg CO_2e/T Lint 10ha Riparian 100ha Grasses 80ha Forest	-388.9 kg CO_2e/T Lint 10ha Riparian 100ha Grasses 90ha Forest	-575.1 kg CO_2e/T Lint 40ha Riparian 100ha Grasses 90ha Forest
Electricity	19.9 kg CO_2e/T Lint	19.9 kg CO_2e/T Lint	19.9 kg CO_2e/T Lint	19.9 kg CO_2e/T Lint	19.9 kg CO_2e/T Lint	19.9 kg CO_2e/T Lint
Fertiliser	722.8 kg CO_2e/T Lint AA 146kg/ha Urea 327kg/ha Map 137kg/ha	564.9 kg CO_2e/T lint AA 100kg/ha Urea 300kg/ha Map 100kg/ha	564.9 kg CO_2e/T lint AA 100kg/ha Urea 300kg/ha Map 100kg/ha	538.6 kg CO_2e/T lint AA 100kg/ha Urea 280kg/ha Map 100kg/ha	455 kg CO_2e/T Lint AA 60kg/ha Urea 280kg/ha Map 60kg/ha	700.7 kg CO_2e/T lint AA 60/ha Urea 435kg/ha Map 60kg/ha
On-farm Fuel	175.6 kg CO_2e/T Lint	175.6 kg CO_2e/T Lint	175.6 kg CO_2e/T Lint	175.6 kg CO_2e/T Lint	175.6 kg CO_2e/T Lint	175.6 kg CO_2e/T Lint
Total	483.2 kg CO_2e/T Lint	275.7 kg CO_2e/T Lint	175 kg CO_2e/T Lint	112 kg CO_2e/T Lint	3.3 kg CO_2e/T Lint	63 kg CO_2e/T Lint

[1] Hedeyati M, Brock P, Simmons A, 2015. *How sensitive is the calculated climate change impact of cotton production in NW NSW to fertiliser N2O emission values.* 1st Australian Conference on Life Cycle Assessment for Agriculture and Food

Part 4 – Final Report Executive Summary

Development of a land use indicator set for the Australian cotton industry to demonstrate the sustainability impacts on soil health:

May we recommend that the follow criteria be considered when developing an indicator set for the Australian cotton industry:

General:

- Land use will probably be one of a number of environmental impact categories being assessed by an LCA practitioner as part of a sustainability assessment, each with their respective metrics, and therefore the number of land use metrics need to be practical and manageable from this perspective
- Apart from meeting specific industry requirements, the cotton industry should also use this framework and initiative to communicate its own sustainability achievements as part of regular reporting.
- Through this initiative, the Australian cotton industry should aim to stay at the forefront in this space
- This is a new sustainability space and industry is only applying a single indicator / metric for land use at present. The Australian cotton industry may therefore be afforded the leniency of adopting a conservative and phased approach whereby a limited and suitable number of indicators are implemented at first, with the intention of increasing this as practical data structures become available or put in place.
- Importantly the programme should be of direct benefit to growers to address their concerns about the state of the soil that they will be passing on the next generations

Therefore, specific recommendations:

1) Use 2 sources of data: firstly grower surveys to assess land use intensity and input intensity, and secondly soil test data for another 6 metric outcomes
2) Indicators from soil tests: soil organic carbon, ph., phosphorous, potassium, nitrogen (total, nitrates and ammonia), CEC and % sodium.
3) Soil compaction is a major concern for growers and therefore an additional ‘wet sieving’ test will give an indication of soil structure and stability – it appears that Nutrient Advantage is not able to do this but EAL Laboratory can for $60, and separate samples will have to be sent there but it is probably justified.
4) All results received form Nutrient Advantage lab and therefore provides a common methodology and able to utilise historical grower data for the database and trending – growers that we have consulted is agreeable to this.

5) Form the “soil sustainability awareness group’ SSAG with a pilot group of concerned growers to ‘test’ the programme to assess how it could be rolled out on a regional and national scale.
6) Growers are required to take soil test at those specific sites including a ‘native’ sample each year, according to a standardised procedure.
7) Results will be expressed as a % relative to the native soil, which can be benchmarked, aggregated as a single farm score, and scaled / aggregated to a regional and national level accordingly.
8) Results will be treated anonymously although will receive their specific results evaluations, along with their normal results via their agronomist / consultant.
9) CRDC / Cotton Australia or a funded project may have to cover the costs of the additional native soil test, the wet sieving test and potentially the assessments.

It is unfortunate that the above indicators will not assess soil biology / microbial life, but this is an expensive, time consuming procedure. Fortunately soil carbon is a strong driver of soil biology, and perhaps a suitable proxy indicator could be introduced for this in the future.

We have had discussions with a number of growers, who have been very supportive of the idea, and keen to join such an initiative and are willing to provide their historical soil test data. We have also consulted with relevant scientists for their views and recommendations which have been taken into consideration.