Good Earth Cotton (property known as “Keytah”) Carbon Emissions Audit

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Introduction

This document outlines two carbon footprint assessment studies undertaken at Keytah property near Moree in NSW for the 2017-2018 season. Study 1 assesses the whole-farm carbon footprint for that same season. Study 2 looks at the greenhouse gas emissions for irrigated cotton production from 'farm to ship' including ginning, transport to port and warehousing.

These studies include estimation of carbon emissions and sequestrations from:

- On farm emissions from fuel use, direct soil N_20 emissions, atmospheric deposition, leaching and runoff from fertiliser, and soil carbon emissions;
- Scope 3 fuel emissions from transport of fertiliser, chemicals, seed, bales and gin-trash to the farm;
- Fuel, fertiliser and chemical (insecticide, herbicide, growth regulator, adjuvant and fertiliser) production emissions;
- Seed production emissions;
- Off farm emissions from ginning, transport and warehousing at port;
- Carbon sequestration / offset from an off-farm woodlot;
- Native vegetation credits per type of vegetation
- Agisted cattle emissions including pastures; and
- On farm electricity emissions.

In addition, the studies were repeated with cattle production components replaced by native vegetation. This was undertaken to investigate the benefits of returning the agisted cattle production land back to native vegetation (forest) as the recent practice has been not to agist cattle any longer.

Summary of Results

Whole Farm Assessment

The carbon footprint outcome for the Keytah operation as a whole, including cattle, is:

Whole-farm
-26,682 T CO_2e

This is a "negative-emission" result meaning that the farm is climate positive or a carbon sink or as opposed to a source of carbon emissions. The corresponding result replacing cattle with native vegetation is:

Whole-farm (with cattle replaced with forest)
-41,490 T CO_2e

Irrigated Cotton Assessment

The Keytah irrigated cotton carbon footprint at port for the 2017-2018 season is:

Irrigated Cotton (without shared offsets) **-185.0 kg CO_2e/bale**

This is also a climate positive outcome thereby resulting in a "carbon-neutral" cotton crop at point of export. This result is dominated by the soil carbon sequestration that resulted from a number of practice changes that were introduced. The post farm emissions to ship's side amount to 45.4 kg CO_2e per bale, which ginning comprises 39.7 kg CO_2e, transport to port 5.0 kg CO_2e and warehousing in Brisbane 0.7 kg CO_2e per bale.

The total farm has an accumulated carbon credit resulting from the extent of the native vegetation and an 'offset' woodlot investment. When we apportion these credits over the whole farm area, including cropping, then the carbon footprint outcome for the irrigated cotton crop, excluding cattle, is:

Irrigated Cotton (with shared offsets) **-220.3 kg CO_2e/bale** (Recommended)

In the alternative study when we replace cattle production with native forest, we achieve an emissions value of:

Irrigated Cotton (with shared offsets and cattle replaced with forest) **-253.3 kg CO_2e/bale**

Evolution of Studies

The results presented in this report supersedes any previous results that have been presented to the Sundown Pastoral Company. This study was undertaken over 3 months from April to June 2019 with results being amended as the study progressed and further information was processed. Keytah is a comprehensive and diversified cropping enterprise of over 25,000 hectares and the team compiled more than 100 data files in the auditing process. The on-site farm visit was extremely valuable in establishing what information was still outstanding and appreciating the complexity of the operation. We sincerely appreciate the assistance provided by David Statham, Steve Moore and Nick Gillingham for facilitating the farm visit, providing the data and responding to our numerous queries and questions.

The calculations are very detailed and the total emissions are calculated on a per land-use basis which are then scaled up to a crop and farm basis to correspond to the total farm area.

Inputs and Assumptions

The following sections provides an overview of each study and outlining the input data assumptions. It describes the input-data extraction, and inputs to the calculations grouped around the following categories.

- Carbon sequestration
- Climate/Soil Global variables
- Fuel usage
- Irrigated cotton production
- Dryland cotton production
- Winter crops production
- Cattle agistment and pasture production
- Fallowed fields
- Woodlot emissions
- Native Vegetation
- Electricity

Overview of Study 1

Study 1 estimates the whole farm carbon emissions based around different land-uses. It includes all on-farm activity, and inputs to the farm. It does not include post-farm processes such as ginning, transport and storage of produce. Emissions are reported at total emissions in T CO_2e/ha. Land-uses for each paddock are described in Appendix 1.

Overview of Study 2

Study 2 focuses on the farm to port emissions associated with irrigated cotton production. It includes all of the on-farm irrigated cotton processes outlined in Study 1, as well as post-farm processing of cotton including ginning, distribution to port and warehousing. Emissions are reported as kg CO_2e/bale of cotton produced.

Included in this result are some shared credits/debits related to “whole-farm” emissions, which are not specific to any type of production. This includes credits from native vegetation and woodlot, and emissions from whole farm electricity.

This analysis uses a different on-farm fuel rate, as we did have a more accurate estimate of fuel usage for irrigated cotton production. This was not available for other crops.

Replacing Cattle/Pasture with Native Forest

Both studies were repeated with cattle production components replaced by native vegetation. This was undertaken to investigate the benefits of returning the agisted cattle production land back to native vegetation (forest) as the recent practice has been not to agist cattle any longer.

We've chosen native forest rather than pasture/grasses as this will present the most extreme results, to demonstrate what is achievable. Therefore, in Study 1, all cattle-areas (6000ha) have been converted to native vegetation categorised *Forest and Floodplain*. The additional emissions from the native vegetation are then re-incorporated into Study 2, to recalculate the effect on irrigated cotton production.

Data Extraction

The input data required for this analysis was provided via several Excel spreadsheets that were exported from the PAM Farm Management software totalling over 20,000 lines of data. These files were representative of cotton production, winter cropping, cattle production and fallows, providing information on:

- Paddock name and area;
- Chemical application events;
- Fertiliser application events;
- Machinery operations;
- Seeding and planting operations;

Computer code was written to extract important data from these spreadsheets and generate summary files for each data type including:

- Detailed chronological lists of type of events (chemicals, fertiliser etc)
- Summary files detailing the total amount of each chemical and fertiliser applied.

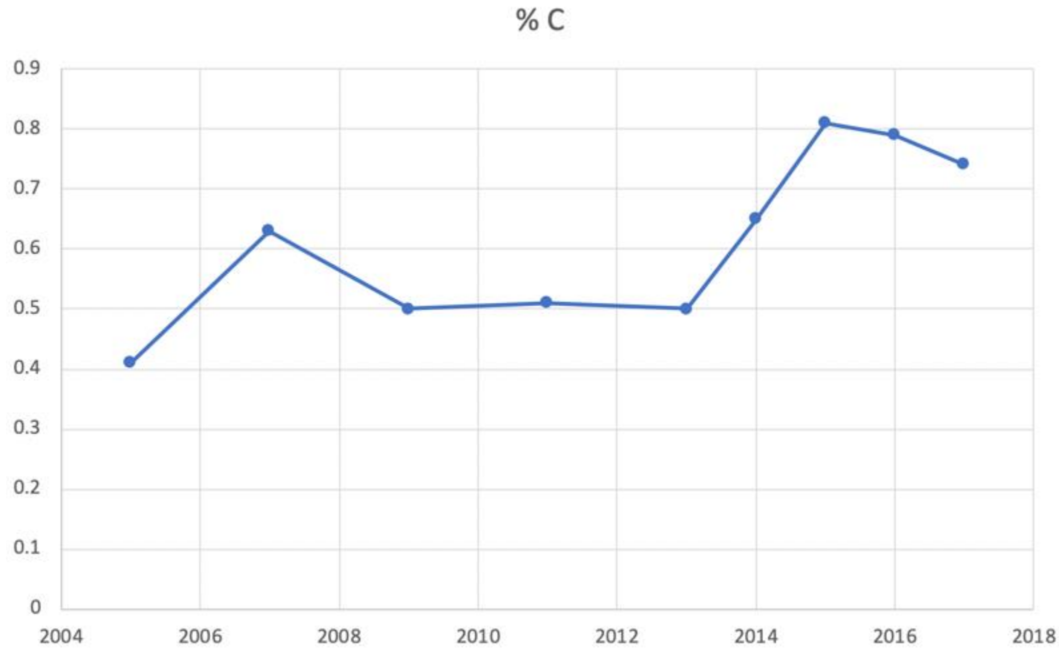
This data extraction exercise took up more than 80% of the total study time. This was complicated due to some inconsistencies in the quality, completeness and format of the data provided. We sincerely appreciate the scale and complexity of the operation and sincerely appreciate the level of detail provided; however, some of the challenges were:

- Over 1700ha (7% of whole farm) of dryland and cattle paddocks (assumed fallow) did not have any data-events recorded although they would have been subjected to herbicide treatments.
- Paddock duplications across data-files.
- Part of Urea application data in irrigated cotton production was not recorded into the PAM software.
- Some "fallow" paddocks contained crops instead of fallow events.
- Some inconsistencies in report format (different export options), naming conventions, date formats, reporting of paddock area, and some incomplete data.

A range of validation tools were specifically developed to audit these files and to try and detect inconsistencies in the input data and errors in extraction.

Carbon Sequestration

The standout feature of the 2018 irrigated cotton crop carbon assessment is that the farm has remarkably raised the soil carbon levels from 0.5% in 2013 to 0.74% in 2017 (see graph)



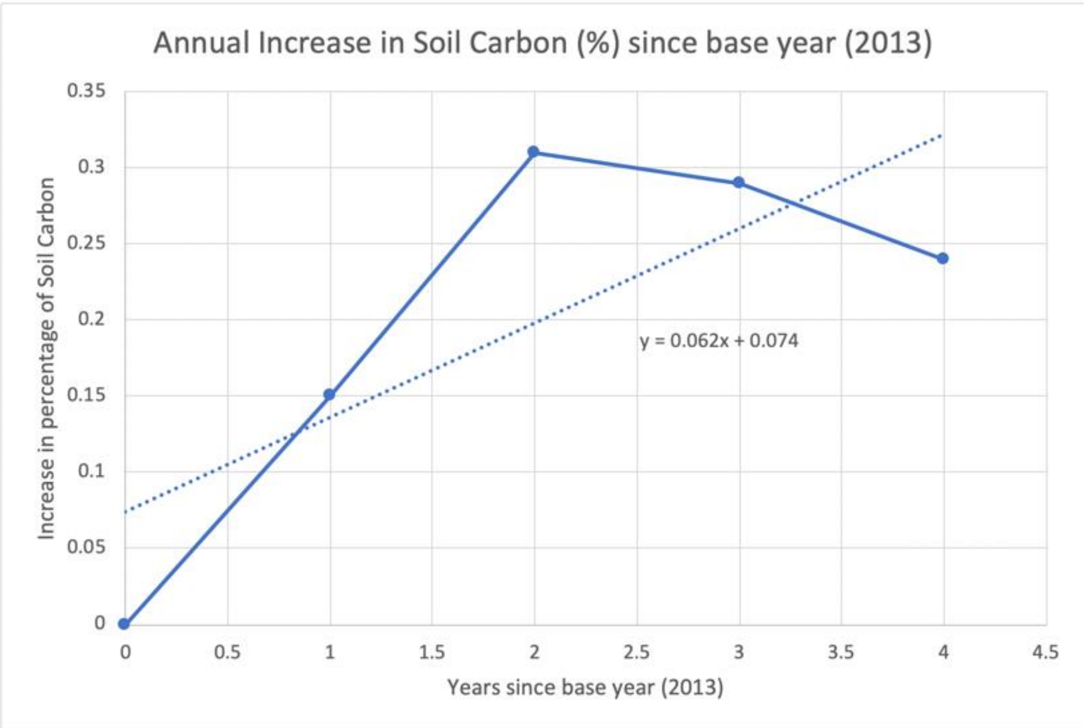
To a certain extent soil carbon results can vary from year to year due to fluctuations in soil organic matter and climatic conditions. The soil sampling regime being followed at Keytah is based on current best practices and although the metric is not the most reliable indication, it is the best methodology that is currently available for carbon accounting purposes. Therefore, to assess the change in soil carbon due to management, we need to assess this over a number of years since the management changes were introduced. The process we have adopted is to identify a “base-line” or “base-year” representing “normal” soil carbon levels, and then monitor subsequent years and estimate an average increase or decrease using a linear regression technique.

In this study, the base-line was identified as the rather consistent soil carbon levels from 2009 to 2013. We therefore adopted 2013 as the “base-year”, which coincided with the introduction of a number of management practices to improve soil health and productivity, in particular in the case of irrigated cotton; these included:

- Controlled traffic,
- Permanent beds

- Reducing row lengths by 50%
- Regular laser-levelling of paddocks
- Introduction of bank less irrigation
- Minimum till,
- and 100% fallow between cotton crops (plant every second year)

We then apply a linear regression to the data in the years 2013 to 2017 by plotting change in soil carbon against years since the base-year. This gives us an increase in soil carbon of 0.062% C/year.



We apply the following commonly recognised formula (Donovan, Peter. 2013. *Measuring Soil Carbon Change.* soilcarboncoalition.org.) to convert % soil carbon to kg C/year:

$$C_T = C_F \times D \times V$$

where C_T is total carbon for the layer in metric tons, C_F is the fraction of carbon (percentage carbon divided by 100), D is soil bulk density, and V is volume of the soil layer in cubic meters.

In the case study area over 1 hectare; bulk density 1.35; depth top 15cm, soil carbon 0.062, we have:

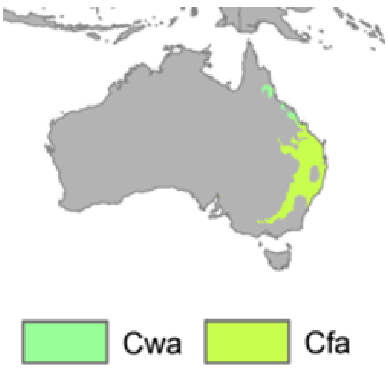
Total soil carbon/ha/yr = 0.00062 x 1.35 x 0.15 x 10 000 (tons)
= 1.255 tons CO_2e /ha/yr

=1,255 kg CO_2e /ha/yr

Site specific climatic and soil characteristic factors for N_2O emissions

In order to improve the accuracy and site specific relevance of the fertiliser application outcomes, we apply the following factors to the soil nitrous oxide emissions in accordance with the ABOM model developed in *Visser et al. (2014).* We assign Keytah as sub-tropical in terms of the classification based on the reference below:

Moree experiences a humid subtropical climate (CFA - from Köppen climate classification) with slight semi arid influence (from wikipedia - https://en.wikipedia.org/wiki/Moree,_New_South_Wales)



(Extracted from https://en.wikipedia.org/wiki/Humid_subtropical_climate#/media/File:Koppen_World_Map_Cwa_Cfa.png)

Soil factor	Irrigated Cotton
Soil texture	Course: -0.472
Drainage	Average: -0.21
Soil Carbon	Low: (<1%) = 0
Soil Ph	Alkaline (>7.3)= -0.352
Climate	Subtropical = 0.4

Fuel

Fuel use is categorised into 3 separate components:

- On-farm diesel use

- On-farm aviation fuel use (minor component)
- Contractor diesel and aviation fuel use.

We were provided with a realistic estimate of "total" on-farm diesel use, however, this could not be assigned to individual paddocks or cropping types. We have therefore obliged to use an average value of fuel use across all land-uses. This average value was calculated as the annual average value over 5 years of recorded data which amounted to 81.3 l/ha. Because of this assumption, we will be slightly underestimating fuel production emissions for the irrigated cotton crop, and overestimating fuel production emissions for the other non-irrigated land-uses and fallows. Therefore to be conservative we do not apply the average to the irrigated cotton but an estimated 105 l/ha instead.

All chemical spraying events were undertaken by external contractors and their fuel usage was not accounted for in the original total on-farm fuel usage figures. This had to be calculated separately, using an average fuel rate for both ground-rig spraying, and aerial spraying. This was estimated by going through the machinery event data and assigning "GROUND" or "AIRCAIR" to any chemical spray event. In this process, we have made assumptions including:

- Multiple chemical events on a single day are applied by mixing chemicals in a single event.
- When ground-rig and aerial events occur on the same day, we cannot differentiate between the two and assign those chemical events as being delivered by ground-rig, introducing a small error into the analysis.
- Therefore, the aerial spraying fuel use will be slightly underestimated, and ground-rig based spraying will be slightly overestimated.
- We calculate fuel usage by accumulating the total area (ha) sprayed, and then dividing by the paddock area.
- For the contractor fuel use, fuel-use rates are assumed as:
  - Contract ground-rig spray fuel rate = 0.75 l/ha
  - Contract aerial spray fuel rate = 2.0 l/ha

There was also a small amount of fertiliser applied by aerial delivery, which is estimated in a similar process to that for contractor chemical application fuel usage.

Transport

Assumptions:

- Transport (chemicals, fertiliser etc) fuel rate was estimated at 0.55 L/km.
- Distances from the farm and key distribution centres was provided as:
  - Distance port to farm = 503km
  - Distance port to regional depot = 128km
  - Distance regional depot to local depot= 349km
  - Distance local depot to farm = 30km
  - Distance seed depot to farm = 150km

- Distance Farm to Gin =20km

Irrigated Cotton

Assumptions:

- These crops are irrigated over an area of 5106ha.
- Carbon sequestration of 1100 kg/ha/yr is averaged over a number of years. Soil tests exist to substantiate this figure.
- Non-contractor fuel use is slightly under-estimated as we are using a farm average. Irrigation incurs additional fuel usage.
- Season is greater than 1 year (472 days). Its been calculated using an area weighted average of fallow-crop lengths for each paddock.
  - Carbon-sequestration for Study1 need to be scaled up to this length.
  - Results for Study2 are then scaled back to one year.
- Contractor fuel use is estimated based one paddock event per day (mixing chemicals), but segregated into ground-based and aerial-based events.
  - Chemical ground spray area: 24061 ha
  - Chemical aerial spray area: 38659 ha
- Seeding rate is assumed as 15kg/ha
- Fertiliser rates are:
  - Urea product rate 551.7 kg/ha (provided by Nick Gillingham) – only half the events were entered into the PAM software.
  - MAP Product rate 135.8 kg/ha

Dryland Crops (Cotton, wheat chickpea and Oats)

Assumptions:

- These crops are NOT irrigated.
- Planted area is 5890ha.
- Assume carbon sequestration is 0 for dryland practices. Not enough soil tests to substantiate.
- Non-contractor fuel use is slightly over-estimated as we are using a farm average, of which there is a significant irrigation contribution.
- Contractor fuel use is estimated based one paddock-event per day (mixing chemicals), but segregated into ground-based and aerial-based events
- Season is greater than 1 year (625 days). This has been calculated using an area weighted average of fallow-crop lengths for each paddock.
  - Results for Study2 are then scaled back to one year.
- Seeding rate is assumed as 50kg/ha, although this will not be representative of all crops. However, the emissions associated with seed production are relatively minor.
- There is no fertiliser applied to these paddocks.

Winter Crops (Wheat and chickpea)

Assumptions:

- These crops are NOT irrigated, but are on irrigated land
- Planted area is 4625ha.
- Carbon sequestration of 1100 kg/ha/yr is averaged over a number of years. Soil tests exist to substantiate this figure.
- Season is less than 1 year (175 days). Results are then scaled up to annual basis
- Non-contractor fuel use will be slightly over-estimated as we are using a farm average, of which there is a significant irrigation contribution.
- Contractor fuel use is estimated based one paddock-event per day (mixing chemicals), but segregated into ground-based and aerial-based events
- Seeding rate is assumed as 90kg/ha, although this will not be representative of all crops. However, the emissions associated with seed production are relatively minor.
- There is no fertiliser applied to these paddocks.

Cattle and Pasture

Pasture assumptions:

- These crops are NOT irrigated.
- Planted area is 1563 ha.
- Assume carbon sequestration is 0 for dryland practices. Not enough soil tests to substantiate.
- Non-contractor fuel use will be slightly over-estimated as we are using a farm average.
- Contractor fuel use is estimated based one paddock-event per day (mixing chemicals), but segregated into ground-based and aerial-based events
- Season is greater than 1 year (625 days). This has been calculated using an area weighted average of fallow-crop lengths for each paddock.
    - Results for Study2 are then scaled back to one year.
- Seeding rate is assumed as 20kg/ha, although this will not be representative of all crops. However, the emissions associated with seed production are relatively minor.
- There is an amount of gin trash applied to this paddock as compost (888 Tonnes applied in 2 events)

In addition, we have estimated emissions from cattle using the “FarmGas” software which returned emissions of 1,691,000 kg CO_2e for the herd per year. This is based on average herd numbers of:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1008	676	624	508	864	1235	2685	2040	1047	645	703	1200

As mentioned above it has lately been decided not to agist cattle on Keytah any longer and rather return those paddocks to native vegetation.

Fallowed paddocks

Assumptions:

- Fallowed area is 1960 ha.
- Assume carbon sequestration is 0 or a neutral state for dryland practices. Not enough soil tests to substantiate.
- Non-contractor fuel use will be slightly over-estimated as we are using a farm average.
- Contractor fuel use is estimated based one paddock-event per day (mixing chemicals), but segregated into ground-based and aerial-based events
- Season is greater than 1 year (400 days). This has been calculated using an area weighted average of fallow-crop lengths for each paddock.
    - Results for Study2 are then scaled back to one year.
- Seeding rate is 0;
- We will assume that there is not fertiliser applied to these paddocks.

Paddocks with no recorded events.

There is 1,706ha of paddocks with no records entered into the PAM system for the study-season. We are assuming that this is all fallowed land, and that herbicide was applied but not recorded. We therefore will use the average chemical use from the Dryland Fallow documented in the previous section. Other assumptions:

- Fallowed area (with no recorded events) is 1706 ha.
- Assume carbon sequestration is 0 for dryland practices. Not enough soil tests to substantiate.
- Non-contractor fuel use will be slightly over-estimated as we are using a farm average.
- Contractor fuel use is estimated based one paddock-event per day (mixing chemicals), but segregated into ground-based and aerial-based events
- Season is greater than 1 year (400 days). This has been calculated using an area weighted average of fallow-crop lengths for each paddock.
    - Results for Study2 are then scaled back to one year.
- Seeding rate is 0;
- We will assume that there is no fertiliser or mulch applied to these paddocks.

Woodlot emissions

Woodlot emissions were calculated separately by an external consultancy returning a value of 5,154,000 kg CO_2e sequestrated (negative emissions) in total per year for a woodlot area of 462ha.

Native Vegetation and Farm Infrastructure

Native vegetation (non-cropping) provides a sink for carbon sequestration. It is classified into three categories with the estimated amount of carbon sequestered per hectare per year based on a study undertaken by the University of New England. Importantly these rates do not account for the carbon captured in the standing biomass; therefore more conservative estimates.

- Forest and floodplain (600 kg CO_2e carbon/ha/year)
- Grass and pasture (350 kg CO_2e)
- Riparian vegetation (2,700 kg CO_2e)

Estimates for these areas on Keytah were provided to us, along with farm infrastructure areas. It appeared that some portions of the other areas of the farm were also 'vegetative' in being non-cropped carbon sinks. In particular, there was 667ha of classified un-arable pasture land (that wasn't planted with crops), along with trees and grasses within the farm infrastructure areas (3,243ha). However, it was not possible to get accurate measurements/breakdowns of these, so we've had to make some assumptions, of which we have tried to be conservative. We've allocated:

- 10% of the farm infrastructure land to *Forrest and Floodplain*.
- 10% of the farm infrastructure land to *Grasses and Pasture.*
- 10% of the un-arable pasture land to *Forrest and Floodplain.*
- 40% of the un-arable pasture land to *Grasses and Pasture.*

The final allocations used for Studies 1 and 2 were:

- Forest and floodplain: 140 + 0.1 x 3243 + 0.1 x 667 = 531 ha
- Grass and pasture: 800 + 0.1 x 3243 +0.4 x 667 = 1391 ha
- Riparian vegetation: 131 ha

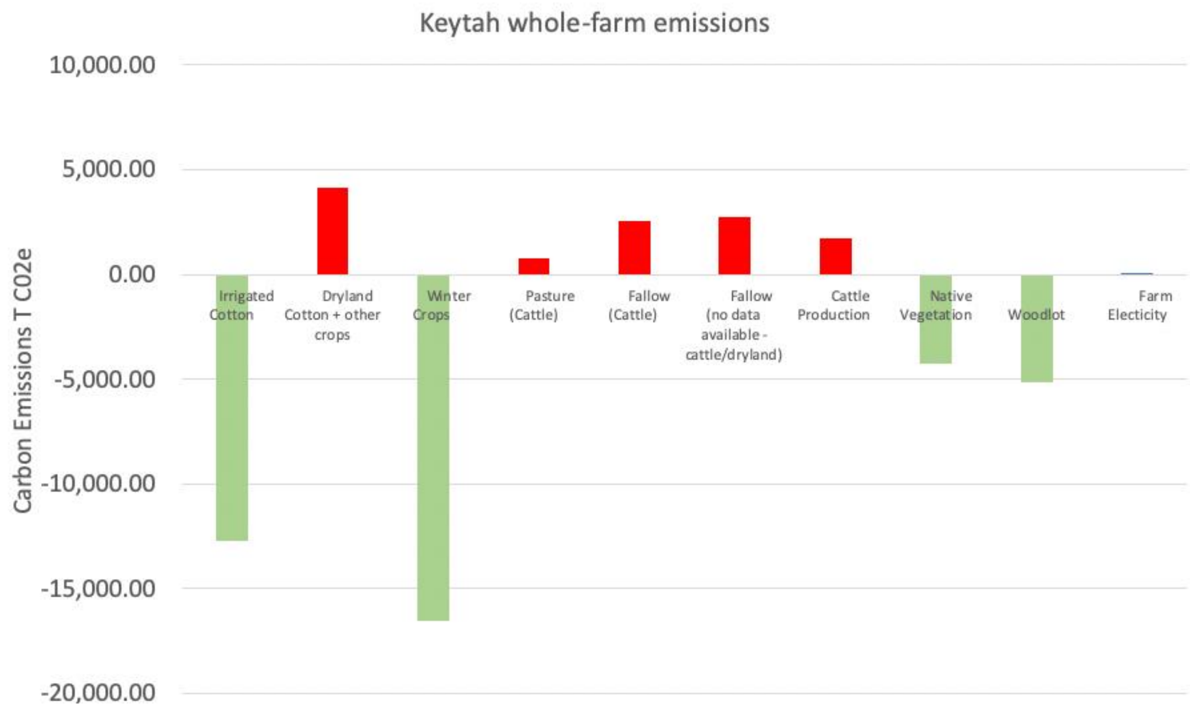
For the alternative scenario where the cattle are removed and pasture is replaced with native forest, all of the pasture land (4657ha including both arable and non-arable) converts to *Forest and Floodplain*. Thus in total we have:

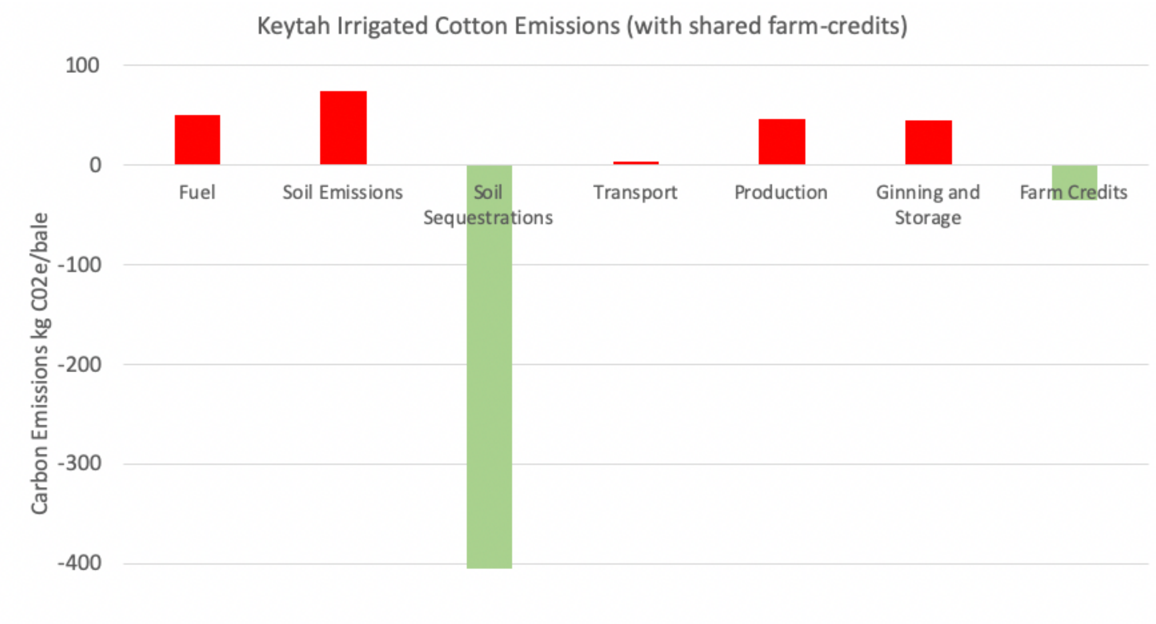
- Forest and floodplain: 140 + 0.1 x 3243 + 4657 = 5121 ha
- Grass and pasture: 0.1 x 3243 = 324ha
- Riparian vegetation: 131 ha

To clarify, for the purposes of this study, we do not account for the carbon captured in the standing biomass of the crops, nor for the carbon captured in the cotton seed generated through the ginning process. Previous cotton LCA studies have accounted for the carbon in the cotton seed.

Results

The following graphs depicts the overall carbon footprint for Study 1 and Study 2, showing all sources of emissions as well as sinks where carbon is actually sequestered.





Study 1 - Whole Farm Emissions

Scenario 1: Including cattle emissions

Source	Emissions T CO_2e/yr
Irrigated Cotton	-12,741.6
Dryland Cotton + other crops	4,151.7
Winter Crops	-16,533.6
Pasture (Cattle)	789.4
Fallow (Cattle)	2,562.8
Fallow (no data available-cattle/dryland)	2,725.0
Cattle Production	1,691.0
Native Vegetation	-4,250.7
Woodlot	-5,154.0
Farm Electricity	78.4
TOTAL	-26,681.6

Scenario 2: Cattle and pasture replaced with Forest

Source	Emissions T CO_2e/yr
Irrigated Cotton	-12,741.6
Dryland Cotton + other crops	4,146.5
Winter Crops	-16,533.6
Pasture (Cattle)	0
Fallow (Cattle)	0
Fallow (no data available-cattle/dryland)	1,695.2
Cattle Production	0
Native Vegetation	-12,981.1
Woodlot	-5,154.0
Farm Electricity	78.4
TOTAL	-41,490.2

Results of Study 2 - Irrigated Cotton Emissions

Scenario 1: Cotton crop only

	kg CO2e/ha	kg CO2e/bale
On-farm Emissions		
Fuel use - Diesel	284.5	20.8
Fuel use - Avgas	9.3	0.7
Fuel use - Contractor	400.6	29.3
Soil N2O Emissions (Direct)	846.7	62
Atmospheric deposition Fertiliser (Indirect)	130.1	9.5
Leaching/runoff Fertiliser (Indirect)	36.6	2.7
Soil Carbon Emissions	-5541.0	-405.6
Transport Fuel Emissions		
Transport Diesel	1.9	0.1
Transport Fertiliser	10.6	0.8
Transport Chemicals	1.6	0.1
Transport Seed	0.3	0
Transport to Gin	8.1	0.6
Gin Transport to Farm	0	0
Total Diesel Scope 3	27.1	2
Production Emissions		
Insecticide	32.6	2.4
Herbicide	288.7	21.1
Growth Regulator	35.5	2.6
Adjuvant	10.1	0.7
Fertiliser	261.1	19.1
Seed production	9.5	0.7
Ginning and Storage		
Ginning		39.7
Transport to Warehouse		5
Warehousing		0.7
Total		-185.0

Scenario 2: Including cattle missions and including farm credit

	kg CO2e/ha	kg CO2e/bale
On-farm Emissions		
Fuel use - Diesel	284.5	20.8
Fuel use - Avgas	9.3	0.7
Fuel use - Contractor	400.6	29.3
Soil N2O Emissions (Direct)	846.7	62
Atmospheric deposition Fertiliser (Indirect)	130.1	9.5
Leaching/runoff Fertiliser (Indirect)	36.6	2.7
Soil Carbon Emissions	-5541.0	-405.6
Transport Fuel Emissions		
Transport Diesel	1.9	0.1
Transport Fertiliser	10.6	0.8
Transport Chemicals	1.6	0.1
Transport Seeed	0.3	0
Transport to Gin	8.1	0.6
Gin Transport to Farm	0	0
Total Diesel Scope 3	27.1	2
Production Emissions		
Insecticide	32.6	2.4
Herbicide	288.7	21.1
Growth Regulator	35.5	2.6
Adjuvant	10.1	0.7
Fertiliser	261.1	19.1
Seed production	9.5	0.7
Ginning and Storage		
Ginning		39.7
Transport to Warehouse		5
Warehousing		0.7
Partial Whole Farm Credit/Debit assignment		
Native Vegetation + Woodlot + Electricity		-35.3
Total		-220.3

Scenario 3: Excluding cattle missions and including farm credit

	kg CO2e/ha	kg CO2e/bale
On-farm Emissions		
Fuel use - Diesel	284.5	20.8
Fuel use - Avgas	9.3	0.7
Fuel use - Contractor	400.6	29.3
Soil N2O Emissions (Direct)	846.7	62
Atmospheric deposition	130.1	9.5
Leaching/runoff	36.6	2.7
Soil Carbon Emissions	-5541.0	-405.6
Transport Fuel Emissions		
Transport Diesel	1.9	0.1
Transport Fertiliser	10.6	0.8
Transport Chemicals	1.6	0.1
Transport Seeed	0.3	0
Transport to Gin	8.1	0.6
Gin Transport to Farm	0	0
Total Diesel Scope 3	27.1	2
Production Emissions		
Insecticide	32.6	2.4
Herbicide	288.7	21.1
Growth Regulator	35.5	2.6
Adjuvant	10.1	0.7
Fertiliser	261.1	19.1
Seed production	9.5	0.7
Ginning and Storage		
Ginning		39.7
Transport to Warehouse		5
Warehousing		0.7
Partial Whole Farm Credit/Debit assignment		
Native Vegetation + Woodlot + Electricity		-68.3
Total		-253.3

Comments on Study

The results of this study are dominated by the significant increase in soil-carbon in the irrigated paddocks during the 2013 to 2017 seasons. By using the average annual increase in soil carbon to estimate soil carbon-sequestration, we end up with a high carbon-negative result for both irrigated cotton and whole-farm emissions. It is assumed that this is a direct result of more sustainable tillage and crop rotation practices over this period since it appears that little additional mulch or manure was applied to these paddocks.

Given the inherent variability and difficulties in achieving representative paddock values in soil carbon testing, there is a measure of risk involved in using these study results in decision-making. Future soil tests could demonstrate some variability again, however, we have to work with the current information at hand, and these test results are the best estimate we have for undertaking this analysis. To mitigate against any possible future drops or high variability in soil carbon test results, one should continue to base estimations on the 2013 "base-year", and therefore updating the regression analysis with each year of new data. This will dampen any abrupt change or anomalies in soil carbon results, while being consistent with this methodology.

Disclaimer

The calculations and analyses in this report are based on published scientific methodologies as far as possible and on input data provide by Sundown Pastoral Company. We have carried out our best endeavours to ensure that the results are accurate and a true reflection of the situation, given that data inputs were not always complete. In cases where we were not provided with data for paddocks, we have made assumptions based on average values for similar paddocks where data was available. Several validations were undertaken on the extraction of input data and the results of the modelling to ensure that results are as reliable as possible.

To the maximum extent permitted by law, The University of Queensland and its contractors disclaims all liability for any loss, damage, expense and / cost incurred by any person arising from the use of information contained in this report.

Appendix 1 Paddock Allocations

A1.1 Irrigated Cotton

Paddock	Crop	Area
B10	Cotton	114
B11	Cotton	114
B12	Cotton	116
C01	Cotton	99
C02	Cotton	137
C03	Cotton	132
C04	Cotton	147
C05	Cotton	135
C07	Cotton	84
C08	Cotton	86
C09	Cotton	77
C10	Cotton	98
C11	Cotton	102
C12	Cotton	13
C12	Cotton	74
C21	Cotton	110
C22	Cotton	162
C23	Cotton	125
C24	Cotton	80
C25	Cotton	101
C26	Cotton	104
C27	Cotton	105
K01	Cotton	256
K02	Cotton	124
K03	Cotton	71
K04	Cotton	52
K05	Cotton	62
K06	Cotton	74

Paddock	Crop	Area
K10	Cotton	75
K28	Cotton	93
K29	Cotton	33
K30	Cotton	12
L1	Cotton	124
L3	Cotton	124
W056	Cotton	262
W07	Cotton	126
W08	Cotton	127
W09	Cotton	137
W10	Cotton	112
W11	Cotton	173
W12	Cotton	179
W13	Cotton	185
W14	Cotton	106
W15	Cotton	57
W16	Cotton	27
W19A	Cotton	14
W19B	Cotton	16
W19C	Cotton	16
W20A	Cotton	11
W20B	Cotton	16
W20C	Cotton	16
W21A	Cotton	29
W21B	Cotton	23
W21C	Cotton	19
W22	Cotton	23
W23	Cotton	21

A1.2 Dryland Crops

Paddock	Crop	Area
2223 Grass	Wheat/Lancer	143
B Block	Chickpea/Seamer	31
Blair Athol	Cotton	342
Blair Athol	Cotton	399
Challicum	Wheat/Lancer	725
Chantress	Cotton	381
Claridges East	Chickpea/Seamer	160
Cobban	Chickpea/Kyabra	533
Cudg 1	Chickpea/Seamer	837
Cudg 2	Chickpea/Seamer	400
Dillon's	Chickpea/Seamer	14
Horse+Ram	Chickpea/Kyabra	405
Keytah Tip 1	Wheat/Lancer	58
Keytah Tip 2	Wheat/Lancer	67
Keytah Tip 3	Wheat/Lancer	48

Paddock	Crop	Area
Mailbox	Wheat/Lancer	22
Nth Bull East	Chickpea/Seamer	92
Nth Bull West	Chickpea/Seamer	58
Percy's	Chickpea/Kyabra	220
River Block Dryland	Chickpea/Seamer	55
Tarran Ck 1	Wheat/Lancer	73
Tarran Ck 2	Wheat/Lancer	44
Tarran Ck 5	Wheat/Lancer	39
Tarran Ck 6	Wheat/Lancer	40
Tarren Ck 3/4	Wheat/Lancer	136
Wathagar Yards	Cotton	45
Webbs Central	Oats/Alladin	59
Woodcourt Nth	Wheat/Lancer	178
Woodcourt Sth	Wheat/Lancer	285

A1.3 Winter Crops (non-irrigated, but on irrigated land)

Paddock	Crop	Area
B01	Wheat	118
B02	Wheat	124
B03	Wheat	214
B04	Wheat	209
B05	Wheat	92
B06	Wheat	58
B07	Wheat	116
B08	Wheat	107
B09	Chickpea	87
B13	Wheat	113
B14	Wheat	93
B15	Wheat	94
B16	Wheat	83
B17	Wheat	110
B18	Wheat	104
C06	Chickpea	103
C13	Chickpea	126
C14	Chickpea	91
C15	Chickpea	110
C16	Chickpea	99
C17	Wheat	90
C18	Chickpea	21
C19	Chickpea	118
C20	Wheat	93

Paddock	Crop	Area
K07	Wheat	139
K08	Wheat	81
K11	Wheat	25
K12	Wheat	145
K13	Wheat	85
K15	Wheat	6
K16	Wheat	13
K17	Wheat	13
K18	Wheat	85
K19	Wheat	138
K20	Chickpea	92
K22	Chickpea	50
K23	Wheat	63
K24	Wheat	63
K25	Wheat	112
K26	Chickpea	49
K27	Chickpea	74
L2	Chickpea	108
L4	Chickpea	123
W01	Wheat	85
W02	Wheat	140
W03	Wheat	176
W04	Wheat	184

A1.4 Cattle Pasture

Paddock	Crop	Area
Big Tank 1	Barley/Dictator	97
Big Tank 2	Barley/Dictator	124
Big Tank 3	Barley/Dictator	92
Big Tank 4	Barley/Dictator	78
Cobban 01	Oats/Alladin	52
Cobban 02	Oats/Alladin	52
Cobban 03	Oats/Alladin	50
Cobban 04	Oats/Alladin	50
Cobban 05	Oats/Alladin	40
Cobban 06	Oats/Alladin	45
Cobban 07	Oats/Alladin	44
Cobban 08	Oats/Alladin	86

Paddock	Crop	Area
Cobban 09	Oats/Alladin	49
Cobban 10	Oats/Alladin	48
Cobban 11	Oats/Alladin	42
Cobban 12	Oats/Alladin	41
Graemes East	Barley/Dictator	78
Graemes West	Barley/Dictator	66
Homestead Storage	Barley/Dictator	78
Sportsground East	Oats/Alladin	54
Sportsground West	Oats/Alladin	35
Webbs East	Oats/Alladin	81
Webbs North	Oats/Alladin	81
Webbs West	Barley/Dictator	102

A1.5 Fallow (Cattle)

Paddock	Crop	Area
BELAH	Fallow	153
BINDI LIGNIN	Fallow	101
BINDIARBA SHED 1	Fallow	67
BINDIARBA STORAGE EAST.	Fallow	97
BLAIREMORE EAST	Fallow	100
BOORONDARRA 01	Fallow	78
BOORONDARRA 02	Fallow	78
BOORONDARRA 03	Fallow	85
BOORONDARRA 04	Fallow	68
BOORONDARRA 05	Fallow	78
BOORONDARRA 06	Fallow	78

Paddock	Crop	Area
BOORONDARRA 11	Fallow	74
BOORONDARRA 12	Fallow	69
BOORONDARRA REFUGE	Fallow	267
BROWN'S CREEK	Fallow	102
CHALLICUM 1	Fallow	45
CHALLICUM 2	Fallow	45
CHALLICUM 3	Fallow	45
FENCELINES LANEWAYS	Fallow	50
GRAEME'S GRASS	Fallow	129
HOMESTEAD FLOODWAY	Fallow	79
SPORTSGROUND GRASS	Fallow	72

A1.6 Undefined Paddocks (no data)

Paddock	Area	Land type
B3 BUG	8	Dryland
B7 BUG	20	Dryland
BINDIARBA SHED 2	67	Cattle
BINDIARBA STORAGE WEST.	185	Cattle
BOORONDARRA 07	85	Cattle
BOORONDARRA 08	68	Cattle
BOORONDARRA 09	80	Cattle
CRYNUM 1	55	Cattle
CRYNUM 2	76	Cattle
CRYNUM 3	86	Cattle
CRYNUM 4	115	Cattle
CRYNUM BUG	39	Dryland
KEYTAH BUG	40	Dryland

Paddock	Area	Land type
ORCHARD	10	Cattle
SCOTT'S 1	40	Cattle
SCOTT'S 2	40	Cattle
SCOTT'S 3	40	Cattle
SCOTT'S 4	45	Cattle
SCOTTS BUG	38	Dryland
W17 ABCDEFG	174	Irrig (NEW)
W18 ABCDEFG	158	Irrig (NEW)
W26	59	Dryland
WEBBS SOUTH	71	Cattle
WOODCOURT 5	68	Cattle
WOODCOURT 6	39	Cattle

Reference

Visser, F., et al., Application of the Crop Carbon Progress Calculator (CCAP) in a 'farm to ship' cotton production case study in Australia, Journal of Cleaner Production (2014).