SUMMER SCHOLARSHIP
Final Report

Part 1 - Summary Details

Cotton Catchment Communities CRC Project Number:

Project Title: Life cycle assessment of cotton-corn rotations

Project Commencement Date: November 2011

Project Completion Date: 31 March 2012

Research Program: The Farm

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Signature of Research Provider Representative: ______________________________

Part 3 – Scholarship Report

The points below are to be used as a guideline when completing your final report.

1. Background:

In today's society, global warming and climate change are two of the most important issues facing all aspects of production within Australia, and throughout the world (Fischer *et al.* 2002). Given this broad public concern more attention is now placed on the lifecycle environmental impacts of food and fibre production (Khabbaz 2010), including the extent to which agriculture contributes to these greenhouse gas (GHG) emissions and global warming. Recently new opportunities have also emerged within Australia with the introduction of carbon trading markets, such as the Carbon Farming Initiative (Dept. of Climate Change 2011). It is therefore important to have an accurate picture of the emissions profile of these agricultural industries. Australia agriculture produced an estimated 84.7 Mt carbon dioxide (CO_2) emissions or 15.5 % of national inventory emissions in 2009 (Dept. of Climate Change 2011), of this 31.5% is attributed to non-livestock activities such as cropping. There is a need for more detailed analysis to determine the impacts from different enterprises, with differing practices and emissions. For this project, case studies of cotton and corn were selected as they are two economically important irrigated crops in Australian agriculture. Australia's cotton sector is one of Australia's largest rural export earners, generating approximately $825 million in export revenue in the year 2006–07 (ABARE 2007), and even though the corn industry is relatively small in Australia, demand is increasing due to the added competition for the production of and animal feed and biofuels (Glover *et al*. 2008).

Life-cycle assessment (LCA) is a dissection tool which allows the analysis of each stage in the production process of a system. It allows the identification of the processes that produce GHG throughout the production. For example pre-field and in-field emissions associated with individual practices and inputs. Through the proposed LCA, the energy balance and GHG emitted as a result of growing cotton and corn crops will be identified and quantified for each activity throughout the production of these crops from cradle-to-gate. From this data it will be possible to identify major GHG emission sources and explore opportunities to reduce emissions from these farming systems and possibly recommend practice change in the cotton and corn industries within Australia.

2. Aims and Objectives:

This project aims to determine the energy balance and greenhouse lifecycle of different cotton and corn production systems in the Namoi Valley, Australia.

3. Methodology:

This project explored issues related to cotton-corn rotation system vis-a-vis conventional cropping practices such as continuous cotton, cotton-corn and corn or cotton in rotation. This analysis was a "cradle-to-gate" (farm gate) analysis which considered all of the upstream costs for growing a crop (e.g., fertiliser, crop establishment, and crop maintenance) in both dryland (rain-fed) and irrigated scenarios. Data for these analyses was accessed from four co-operating growers in the lower Namoi (two dry-land, two irrigated), and a long-term experiment at the Australian Cotton Research Institute (ACRI).

Data was collected from actual crop history records was obtained by interviewing each farmer face-to-face with a pre-developed questionnaire and the necessary crop information such as crop rotations, machinery use for the crop, products and rates used for the crop in selected fields was collected.

This collated data was analysed using the computer software Simapro, which can model products and systems from a lifecycle assessment (LCA) perspective. LCA is a computational tool used to calculate greenhouse gas (GHG) balances and energy efficiency of crop species (Davies *et al.* 2009; Yan *et al.* 2011) and is useful because it allows analysis of each stage in the production process of a system. Simapro was chosen because of its ability to model not only CO_2, but other significant GHG such as nitrous oxide (N_2O) and methane. N_2O has a Global Warming Potential (GWP) of 298 (i.e. one N_2O molecule is equivalent to 298 CO_2 molecules in terms of its ability to warm the atmosphere) and methane has a GWP of 25. N_2O is a major GHG produced via irrigated cropping agriculture (Grace 2010). Details on the LCA method can be found in Brock *et al.* (2012).

The information produced was assessed to allow for a number of comparisons in the emission levels of different production systems, crops and practices used in each case study, and was used to identify any emission hotspots in these production systems, resulting in potential opportunities for reducing the carbon footprint of cotton and corn farming systems.

4. Results:

Preliminary results have only been obtained from the research farm at the Australian Cotton Research Institute (ACRI). The greenhouse gas emissions from the production of 1 kg of cotton lint and seed on-farm were calculated (see Table 1 and Figure 1):

Table 1. Greenhouse gas emissions from the production of 1 kg of cotton lint and seed on-farm

Input type and stage of production	Inputs per ha	Inputs/kg cotton lint and seed	Emissions (kg CO_2-e/kg cotton seed and lint)	% contribution
Pre-farm				
Production of urea	391 kg	0.0741 kg	0.108	26.35
Production of glyphosate	0.09 kg	1.7 E-5 kg	0.000165	0.04
Production of pendimethalin (Stomp / dinitroaline)	1 kg	0.000189 kg	0.00125	0.31
Production of bipyridymium (paraquat and diquat) (Sprayseed)	1 kg	0.00189 kg	0.00185	0.45
Production of cotton	18 kg	0.0034 kg	0.000896	0.22
Production of Diuron (proxy for Dropp Ultra defoliant)	0.045kg	8.52 E-6 kg	8.43 E-5	0.02
Insecticides	0.20 kg	3.79 E-5 kg	0.0006	0.15
Transport of inputs, other than diesel		0.40133 t.km	0.004729	1.15
Production and transport of diesel[1]			0.018484	4.51
Embodied energy for tractor and harvester		low		
Pre-farm subtotal			0.1361	33.2
On-farm				

N_2O emissions directly from fertiliser		0.000267 kg N_2O	0.0801	19.55
N_2O emissions indirectly from fertiliser (volatilised and redeposited)		5.35 E-5 kg N_2O	0.016	3.90
N_2O emissions indirectly from fertiliser (leaching)		0.00012 kg CO_2	0.0361	8.81
CO_2 emissions from use of urea		0.05476 kg CO_2	0.0546	13.32
Combustion of diesel in tractor and harvester				
• Picking	45 L diesel		0.02331	5.69
• Slash and mulch	17.71 Ldiesel		0.0093	2.27
• Go devilling	10 L diesel		0.00518	1.26
• Fertiliser spreading	6 L diesel		0.003104	0.76
• Spot spraying	1 L diesel		0.000456	0.11
• Lillistones	8 L diesel		0.00414	1.01
• Boom spray	6 L diesel		0.003104	0.76
• Roller	4 L diesel		0.002067	0.50
• Sowing	5 L diesel		0.00259	0.63
• Irrigation pump	5 x 496 MJ		0.033283	8.12
• Aircraft for spraying	2.4 t.km		0.000403	0.10
On-farm subtotal			0.2737	66.80
Total emissions			**0.4098**	**100**

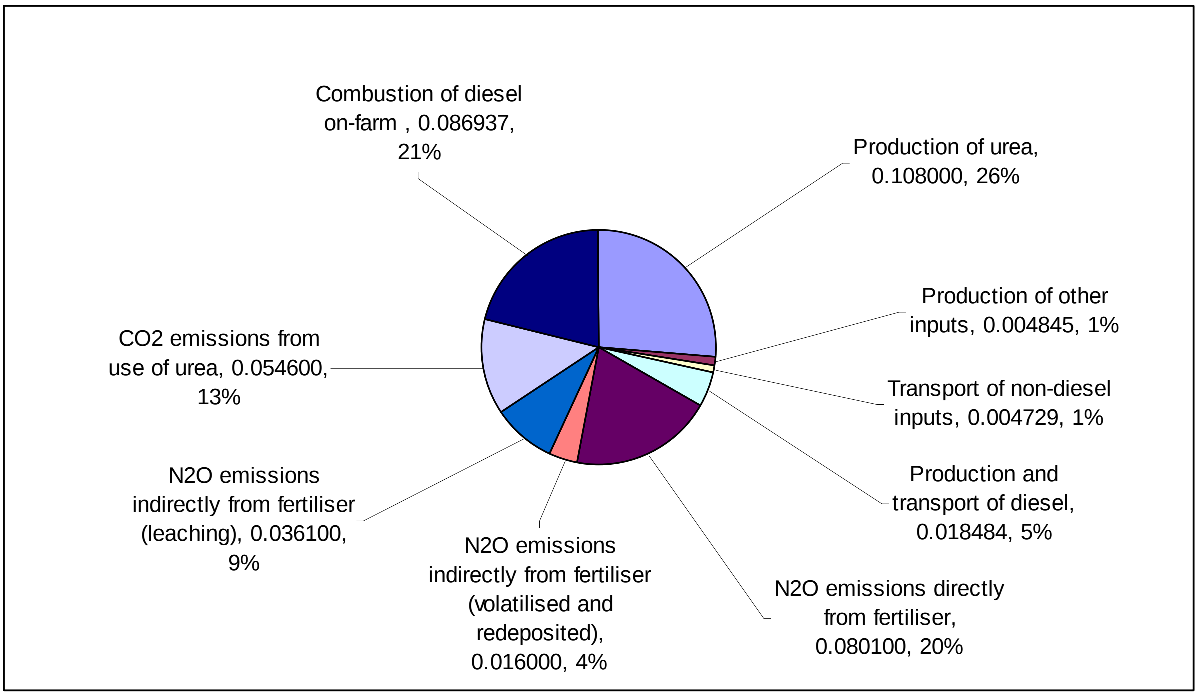

Figure 1. Greenhouse gas emissions from the production of 1 kg of cotton lint and seed on-farm at ACRI, Narrabri, NSW.

Our preliminary result is a total of 0.41 kg CO_2-e per kg cotton as lint and seed (or just as cotton with an economic allocation of 37% to a lint weight of 2043 kg/ha), which was lower than the 3.3 kg CO_2e estimated by Grace (2009) while producing 1 kg of cotton in Australia. The difference with other reports could stem from our allocation by mass to the lint i.e., the lint is only bearing 37% of total emissions, the groundwater pumping may be higher than the surface water used here, and the emissions factor used may also be different. The greenhouse gas emissions from the production of 1 kg of corn on-farm were also calculated (see Figure 2) and our preliminary result is a total of 0.342 kg CO_2-e per kg corn.

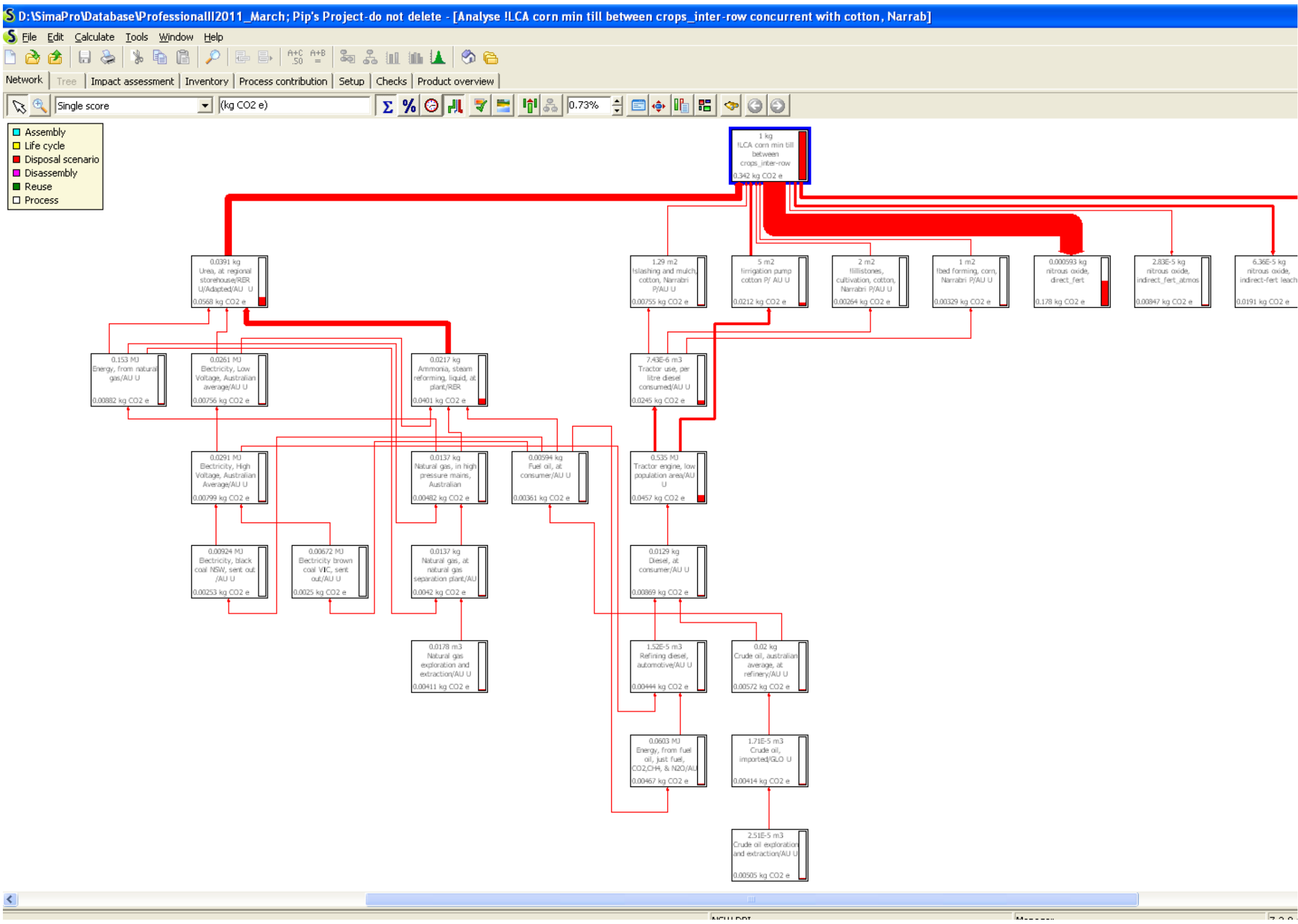

Figure 2. Greenhouse gas emissions from the production of 1 kg of corn on-farm at ACRI, Narrabri, NSW.

These data found the emissions profiles to be dominated by the production and use of synthetic nitrogenous fertilisers, at 72% for cotton and 65% for corn. This agrees with the UK study by Williams *et al.* (2006) showing that nitrous oxide (N_2O) was the single largest contributor to GWP for all agricultural commodities except tomatoes, exceeding 80% in some cases. This is also consistent with a study by Liska *et al.* (2009) showing that across the United States, an average of 64% of GHG emissions from on-farm corn production were a result of N_2O emissions and the application of nitrogen fertilisers. The alkaline grey vertosols on which cotton and corn is predominately grown, tend to use nitrogen fertiliser inefficiently, due largely to nitrogen loss (commonly 50 - 100 kg N/ha) through the process of denitrification (Grace *et al.* 2010). The high water holding capacity soil is ideal for growing cotton and corn, but it is also ideal for denitrification and its associated losses of N_2O.

However, Barnes *et al.* (2009) found that the two main contributors of GHG emissions in a typical U.S cotton field were irrigation, approximately 31% (175.1 kg CO_2-e /ha), and N_2O emissions from the soil approx. 22% (119.8 kg CO_2-e /ha). The energy stored in the cotton seeds was approximately 2.25 kg CO_2-e /kg of fibre, which was larger than the 1.8 kg CO_2-e /kg of fibre emissions due to production, growing and ginning. If this was taken into account in this assessment, the oil which was produced from the cotton seed could potentially give the cotton lifecycle a positive energy balance. This positive energy could be further increased if the diesel used in the study was replaced with biodiesel produced from the cotton seed (Barnes *et al.* 2009).

5. Conclusions:

Greenhouse gas emissions from the production of 1 kg of cotton lint and seed on-farm is 0.41 kg CO_2-e and from the production of 1 kg of corn is 0.342 kg CO_2-e. The emissions are dominated by the production and use of nitrogenous fertilisers. Replacing these fertilisers with biologically fixed N using a legume-based system may reduce these emissions.

6. Highlights:

This project continued to build capacity and develop further team collaboration between the University of Sydney and NSW DPI.

7. Presentations and public relations:

A poster abstract entitled “Identifying opportunities to reduce greenhouse gas emissions from agricultural production: a Life Cycle Assessment approach” has been submitted by Dr Pip Brock to the coming Soil Science Conference in Tasmania later this year (2-7 December 2012) (http://www.soilscience2012.com/).

8. References:

ABARE (2007) *Australian Crop Report, September 2007 no.143*, ABARE, Canberra, Australia

Barnes E and Reed J. (2009) Life Cycle Inventory for Cotton. Summary of Life Cycle Inventory data for Cotton. Cotton Incorporated.

Brock P, Madden P, Schwenke G, Herridge D (2012). Greenhouse gas emissions profile for 1 tonne of wheat produced in Central Zone (East) New South Wales: A Life Cycle Assessment approach. *Crop and Pasture Science* (in press).

Davis SC, Anderson-Teixeira KJ, Delucia EH (2009). Life-cycle analysis and the ecology of biofuels. *Trends in Plant Science* **14**, 140-146.

Department of Climate Change and Energy Efficiency (2011) Australian national greenhouse gas accounts December Quarter 2010.

Fischer G, Shah M, Van Velthuizen H. (2002) Climate Change and Agricultural Vulnerability *World Summit on Sustainable Development, Johannesburg 2002*

Glover J, Johnson H, Lizzio J, Wesley V, Hattersley P and Knight C (2008) Australia’s crops and pastures in a changing climate – can biotechnology help? Department of Agriculture, Fisheries and Forestry.

Grace P, Gane M, and Garcia F (2009) Life Cycle Assessment of a 100% Australian Cotton T-shirt. Queensland University of Technology, Brisbane.

Grace P (2010) A cotton farm’s carbon and greenhouse footprint, *Institute for Sustainable Resources, Queensland University of Technology.*

Khabbaz B (2010) Life cycle energy use and greenhouse gas emissions of Australian cotton: impact of farming systems *University of Southern Queensland*

Liska AJ, Yang HS, Bremer VR, Klopfenstein TJ, Walters DT, Erickson G and Cassman KG (2009). "Improvements in Life Cycle Energy Efficiency and Greenhouse Gas Emissions of Corn-Ethanol" NCESR Publications and Research. Paper 1.

Yan XY, Tan DKY, Inderwildi OR, Smith JAC, King DA (2011). Life cycle energy and greenhouse gas analysis for agave-derived bioethanol. *Energy & Environmental Science* (Published online in 2011).

Williams AG, Audsley E and Sandars DL (2006) "Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities." Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra.

9. Executive Summary:
(provide a one paragraph summary of the Summer Scholarship, suitable for posting on the Cotton CRC web site)

The aim of this project was to determine the energy balance and greenhouse lifecycle of different cotton and corn production systems in the Namoi Valley, Australia. Actual crop history records was obtained by interviewing farmers face-to-face with a pre-developed questionnaire and the necessary crop information such as crop rotations, machinery use for the crop, products and rates used for the crop in selected fields was collected and analysed using the computer software Simapro, which can model products and systems from a lifecycle assessment (LCA) perspective. Greenhouse gas emissions from the production of 1 kg of cotton lint and seed on-farm is 0.41 kg CO_2-e and from the production of 1 kg of corn is 0.342 kg CO_2-e. The emissions are dominated by the production and use of nitrogenous fertilisers. Replacing these fertilisers with biologically fixed N using a legume-based system may reduce these emissions.