UNIVERSITY OF SOUTHERN QUEENSLAND

LIFE CYCLE ENERGY USE AND GREENHOUSE GAS EMISSIONS OF AUSTRALIAN COTTON: IMPACT OF FARMING SYSTEMS

A dissertation submitted by

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ABSTRACT

Over the past two decades, the Australian cotton production practices have undergone considerable changes, including the introduction and widespread applications of Genetically Modified (GM) cotton varieties, and the clear trend towards conservation farming, better water use efficiency and sustainable production. In this project, the energy consumption and greenhouse gas emissions (GHG) of Australian cotton production chain – from field to the shipping port – is evaluated. Most of the Australian cotton is exported, and only 2% is milled locally for textile.

In this study, Life Cycle Assessment (LCA) framework for Australian cotton production is developed. An Excel-based software model is also implemented and used to calculate and profile the cotton production system energy consumption and greenhouse gas emissions. These include direct and indirect energy inputs for both on-farm and off-farm operations, as well as related soil emissions due to soil biological activities and the applications of nitrogen-based fertilisers. By analysing farm energy inputs separately for each farming practice, the developed model was demonstrated to reliably calculate total and individual energy consumption and greenhouse gas emissions for different operations, thus allowing for the comparison between different farming practices, and identifying more efficient and sustainable farming systems.

A farm survey was first conducted to gather necessary field data for the model inputs. The energy consumption and relevant greenhouse gas emissions for different
operations were subsequently calculated and profiled. In addition, sensitivity analysis was carried out to quantify the impacts of new technologies and improved farming practices.

The findings of fifteen case studies based on the available data at two surveyed farms (Bremner and Keytah) showed that for each bale of cotton delivered to the port, the total energy consumption was in 4.3 – 12.6 GJ/bale range, with an average of 10.1 GJ/bale. The related GHG emission was between 0.38 and 0.92 tonnes CO$_2$e/bale of cotton. The indirect on-farm energy use (mostly the embodied energy for the purpose of manufacturing farm fertiliser chemicals and machinery for use in cotton farming) was the most significant component (average 77%), consuming on average 7.7 GJ/bale. This was followed by direct on-farm energy consumption (11%). In comparison, the direct and indirect off-farm energy consumption and soil emissions were relatively low, around 8-9% and 2-3% respectively.

The energy consumption and GHG emissions of GM and conventional cotton were also compared. Based on the available data and 12 case studies (paddocks) at Bremner farms, it was found that conventional cotton farms on average consume 11.4 GJ of energy per bale, with related emissions of 0.83 tonnes CO$_2$e/bale. This is in comparison to the values of 10.0 GJ/bale and 0.83 tonnes CO$_2$e/bale for GM cotton that accounts for 80-90% of currently grown Australian cotton.

A comparison of the different irrigation system effects was carried out. Based on the available data and 12 case studies (paddocks) at Bremner farms, it was found that cotton farmed under furrow irrigation lead to higher energy consumption and
increased GHG emissions than those based on lateral move irrigation system. This is due to higher fertiliser application rates used in furrow irrigated farms that often lead to higher total energy consumption and GHG emissions, outweighing the energy efficiency of this system. It was found that on average, cotton farm under furrow irrigation requires 10.4 GJ/bale of energy with GHG emissions of 0.88 tonnes CO₂e /bale, compared to 8.7 GJ/bale and 0.86 tonnes CO₂e /bale for cotton produced by the lateral move irrigation method.

The effect of three different tillage systems – zero, minimum and conventional – was also compared. Based on the available data and three case studies at Keytah farms, it was found that on average, total energy consumption and GHG emissions were respectively 4.5, 4.52 and 4.7 GJ/bale, with corresponding GHG emissions of 0.38, 0.39 and 0.41 tonnes CO₂e /bale. Thus, it was found that zero tillage uses the least energy and emits the least GHG emission.

A comparative study conducted between cotton, wool and other chemical synthesis resulted in the finding that cotton is consuming the least energy (46.4 MJ/kg) compared to wool, acrylic, polypropylene, viscose, polyester and nylon.

Combining all the above studies, it was shown that when the cotton is produced with the “optimum” system – employing zero tillage practices in GM cotton field under lateral move irrigation – its total energy consumption and GHG emissions would be reduced to 4.3 GJ and 0.38 tonnes CO₂e per bale. This is a 57% reduction of the average energy use in current farming systems and is mainly due to less embodied energy per hectare associated with farm machinery capital (in Keytah farms).
This project highlights the great importance of reducing the chemical applications (particularly the nitrogen-based fertilisers) and direct energy consumption of cotton farming processes. This will assist the Australian cotton industry to a more sustainable path.
CERTIFICATION OF DISSERTATION

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

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GLOSSARY

This glossary defines and clarifies the use of specific terms within this thesis.

**Cotton**

**Bale**

Unit of ginned cotton weighing 217.72 kilograms (480 lb) of lint.

**GM cotton** is genetically modified to control damage by insects and weed, aiming to reduce the herbicide and pesticide consumption.

**Yield**

The weight of harvested cotton crop per unit of area.

**Energy, Climate Change, and Global Warming**

**Carbon footprint** is the total amount of directly and indirectly produced GHG in support of human activities. It is usually expressed in tonnes of carbon dioxide equivalent (CO2-e).

**Climate change** is the term used to refer to changes in long-term environmental factor trends, such as temperature and rainfall. These changes can be due to natural variability or as a result of human activity.
**Greenhouse gases**

Greenhouse gases that contribute to global warming by absorbing solar radiation. The main contributors are carbon dioxide, methane, nitrous oxide and water vapour.

**Carbon dioxide (CO₂)**

A colourless, odourless and non-poisonous gas that is a natural constituent of the Earth’s atmosphere. Carbon dioxide is a product of fossil-fuel combustion and other processes. It is considered a greenhouse gas, as it traps heat (infrared energy) radiated by the Earth into the atmosphere and thereby contributes to the potential for global warming.

**Energy**

The capability of doing work; different forms of energy can be converted into other forms, but the total amount of energy remains the same.

**Embodied energy**

Embodied energy is defined as the commercial energy (fossil fuels, nuclear, etc) that was used in the work to make any product, bring it to market, and dispose of it. Embodied energy is an accounting methodology which aims to find the sum total of the energy necessary for an entire product lifecycle. This lifecycle includes raw material extraction, transport manufacture, assembly, installation, disassembly, deconstruction and/or decomposition.
**Emissions**

Natural and anthropogenic releases of gases to the atmosphere. In the context of global climate change, they consist of radiatively important greenhouse gases (e.g. the release of carbon dioxide during fuel combustion).

**LCA**

Life cycle assessment (LCA) is a process of compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

**LPG**

The word LPG stands for Liquefied petroleum gas.

**Farming and Tillage Practices**

**Zero tillage**

Zero tillage (sometimes referred to as no-till farming) is a crop growing technique without disturbing the soil through tillage.

**Minimum tillage**

Minimum tillage is the minimum soil manipulation necessary for crop production. It is a tillage method that does not turn the soil over.

**Conventional tillage**

Conventional tillage refers to standard tillage operations for a specific location and crop that prepares land for planting and tends to bury the crop residues.
CTF (Controlled traffic farming)

Controlled traffic farming (CTF) is a management system which is used to reduce the damage to soils caused by heavy or repeated agricultural machinery passing on the land. Rather than “random” traffic in the field, the wheel tracks of all machinery operations are now confined to fixed paths.
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