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_2e/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_2e/bale. This is in comparison to the values of 10.0 GJ/bale and 0.83 tonnes CO_2e/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 CO_2e /bale, compared to 8.7 GJ/bale and 0.86 tonnes CO_2e /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 CO_2e /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 CO_2e 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 (CO_2)

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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Chapter 1 – Introduction

In this chapter the background of this project will be discussed first, highlighting the public concerns over energy consumption and greenhouse gas emissions of Australian agriculture sector. It is followed by description of the project aims, goals and implemented methodology. Finally, the outline of the thesis is given.

1.1 Project Background

1.1.1 Concerns over Greenhouse Gas Emissions and Global Warming

Agricultural products are vital for humanity, providing food and fibre product sustenance. However, all aspects of the agricultural production cycle − from the primary production, through the advanced packaging, to the customers − have significant environmental effects. Australian agriculture sector accounts for 16% of the total national greenhouse gas emissions (Cotton Australia 2008, p. 3).

1.1.2 Carbon Labelling

Recent public concerns over global warming and climate change are re-shaping the society's attitude, raising awareness of environmentally friendly products. As a result, more attention is now placed on the life cycle environmental impacts of food and textile products. Nowadays, consumers are demanding higher standards in their agricultural products. New concepts such as “food miles,” “carbon footprint,” and “carbon labelling” are also being introduced.

1.2 Problem Statements

In Australia and other countries, currently available literature on environmental impact of cotton production is mostly limited to on-farm direct cotton farming processes, without including the full “field to the port” cycle. The main aim of this project is to bridge this information gap, by providing a comprehensive study of the Australian cotton farming system energy consumption and greenhouse gas emissions from field to the port. This will allow both the farmers and the industry to make informed comparisons between different farming systems, so that the most sustainable system can be selected.

1.3 Project Aims

Cotton is a product has been mainly used for textile production. It can be used to manufacture jeans, T-shirts, sheets, as well as yarns. Cottonseed is also a by-product used to produce oil and animal feed.

The aim of this study is to identify, quantify, and compare the energy consumption and greenhouse gas emissions of different cotton production and distribution systems in Australia. The specific objectives of this work are:

- Creation of a comprehensive framework for evaluation of environmental life cycle impact of the different cotton production technologies and systems.

- Collection of field data for evaluation of the impact of new technologies on cotton production. These may include: new crop varieties through the plant breeding programs, shift in agricultural systems, production regions, and plant species.

- Quantification of the impact of new and improved technologies on energy consumption and greenhouse gas emissions.

The more specific objectives of this research are:

- Conducting a LCA analysis of cotton production chain in Australia
  - Development of a LCA framework
  - Data collection
  - Model and software development
- Evaluation of the impact of different farming systems and practices
  - Comparison of genetically-modified cotton (GM) and conventional cotton
  - Irrigation methods and water use efficiency measures
  - Different tillage practices
  - Comparison with wool and chemical synthesis fibres
  - Evaluation of the maximum GHG reductions when all the above “new technologies” are combined

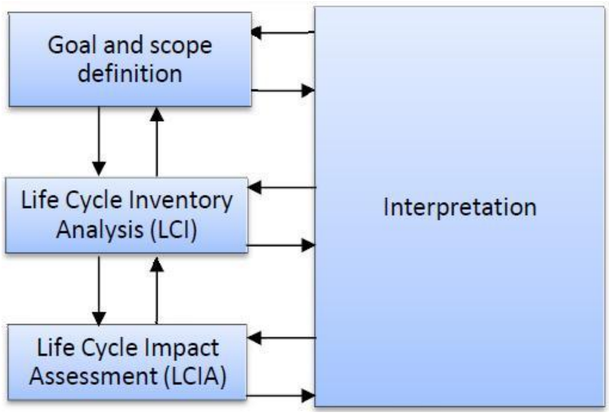
1.4 Overall Project Methodology

1.4.1 Life Cycle Assessment (LCA) Development

In this thesis, a Life Cycle Assessment (LCA) will be undertaken to determine the relative impacts of new technologies on greenhouse gas (GHG) emissions from field to the port. Firstly, carbon footprint for a typical case study will be calculated. Subsequently, the life cycle assessment framework and model will be applied to different technology adoption scenarios. The study will also identify the relative impact of adopting these technologies on GHG emissions.

In this study, the Life Cycle Assessment framework modified from ISO 14040, 2006 (Figure 1.1) will be initially used to define the study goal. It will be followed by the cotton farming life cycle inventory and finally by the impact assessment. A clear and detailed description of the above steps will be given. The developed cotton production Life Cycle Assessment will enable impact of each individual task in on-farm and off-farm applications to be evaluated. This study will be conducted through a combination of LCA, model and software development, and farm surveys.

Life cycle assessment boundaries for this study will be discussed further in model development chapter of this thesis.



Sources: (ISO 2006 & Cotton Research and Development Corporation 2009, p. 16)

Figure1.1: Life cycle assessment framework

1.4.2 Model Development

The LCA model developed in this study will divide the Australian cotton farming system into several detailed component processes (e.g. tillage, irrigation, harvesting), to enable a comprehensive study of each individual process, aimed at determining the energy consumption and its related greenhouse gas emissions.

The model will include the following direct and indirect applications, as well as the relevant soil emissions.

- On-farm direct (e.g. tillage)
- On-farm indirect (e.g. manufacturing of fertilisers and on-farm machinery)
- Off-farm direct (e.g. ginning and shipping)
- Off-farm indirect (e.g. manufacturing of processing machinery and storage facilities)
- Soil emissions (e.g. N_2O emissions from the application of nitrogen fertilizer)

As most of the Australian cotton is produced for export purposes (98% in 2006-07 season) (National Land and Water Resource Audit 2008, p. xi), milling operations are excluded from the calculations in this study.

1.4.3 Farm Surveys

Data collection in this study was conducted through farm surveys that provided information related to both on-farm and off-farm applications. This process was initiated by sending an e-mail to relevant farmers and industry people, providing the relevant background information on the proposed study and an invitation for participation. A questionnaire was also developed (Appendix 1) for face-to-face farmer interviews, which included questions on their on-farm cotton farming application rates, fuel consumption, and the type of machinery they typically use in their cotton production.

1.5 Expected Outcomes

By employing the life cycle assessment (LCA) through the developed model, the following outcomes were generated from this study:

- Energy consumption and greenhouse gas emissions of Australian cotton farming system were identified.
- This study also identified the total energy consumption in cotton farming life cycle, including transport, ginning and all other major off-farm processes.

- Comparison between genetically modified (GM) and Conventional cotton.
- Comparison of different agricultural systems, e.g. different irrigation, tillage and fertilising operations.
- Comparison of cotton with other fibres.

1.6 Outline of the Thesis

This thesis consists of eight chapters. A brief review of each chapter is given below:

Chapter 1

This chapter discusses the project background and problem statements. It further describes the project aims and goals, implemented methodology and the thesis outline.

Chapter 2

The Australian cotton industry overview and a discussion of different farming systems, cotton yields, varieties and post harvest operations are the topic of this chapter.

Chapter 3

This chapter reviews the current literature on energy consumption and greenhouse gas emissions of cotton and other farmed products via their life cycle assessment. Data analysis and calculation methods are also discussed. The concepts of food miles, cotton farming life cycle inventory and related software tools will be also reviewed.

Chapter 4

In this chapter the LCA model development and boundaries for each LCA stage are presented, including on-farm and off-farm, and both direct and indirect energy and emissions calculations. Model framework, required model input data, software design and implementation will also be discussed.

Chapter 5

The Australian cotton farm survey data are presented in this chapter. Data collection covers the on-farm and off-farm stages of cotton production, including both direct and indirect applications. This chapter also describes the data collection methodology used in this study.

Chapter 6

This chapter presents the calculation results for the cotton farming energy consumption and greenhouse gas emissions for each individual case study presented in Chapter 5. This is followed by the evaluation of the energy consumption and emissions of on-farm and off-farm applications for GM and conventional systems.

Chapter 7

This chapter further discusses the results of the above case studies, to facilitate the comparisons between different farming systems and practices. In particular the comparison between Genetically Modified (GM) cotton and conventional cotton, different irrigation systems, tillage practices and cotton with other fibres will be made.

Based on the above analysis, the most efficient system will be identified and compared to the typical Australian cotton farming system to compare the energy consumption and emissions between the "optimal" system and the typical cotton farming practice.

Chapter 8

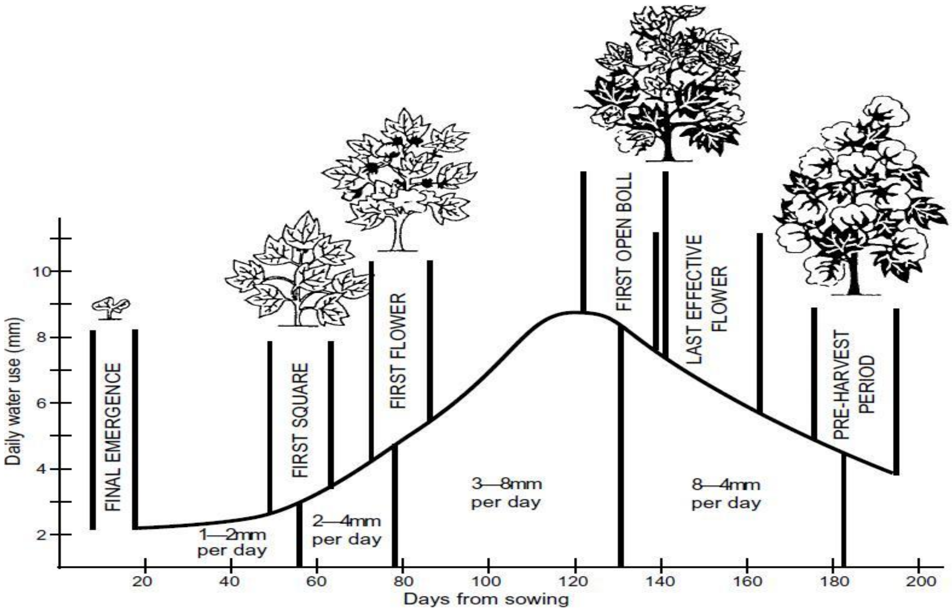
The main conclusions from this research and the recommendations for further research will be presented in this chapter.

Chapter 2 - Overview of Cotton Industry and Practices in Australia

This chapter provides the Australian cotton industry overview, followed by the discussions on different farming systems, cotton yields and varieties, and post harvest operations.

2.1 Cotton Production Processes

Cotton production begins with tillage operations that prepare the field before planting season to optimise the soil condition for seed germination, establishment and growth. Fertilisers are also applied, if used, at this stage to promote seed and crop growth. The following figure shows the cotton growing process stages from planting to harvest.



Source: (Shaw 2002, p. 3)

Figure 2.1: Cotton seasonal calendar

Once the planting process is complete, it typically takes 25 weeks for the bolls to fully open. When the cotton crop is mature and ready for picking, the defoliation process is applied to prepare the cotton crop for harvesting (picking) operation.

Agricultural machinery is essential for cotton production, where some operations such as picking and spraying may also be outsourced to contractor companies. As planting and harvesting operations must be done in a limited time period, the required machinery must be operational and available on request. Thus farmers typically own necessary equipment, as part of their farm assets (Hughes 2002, p. 33).

There are a number of machines used in Australian cotton farming systems; their number and selection varies from one farm to another. Typical machinery requirement for 200 to 400 hectares of cotton farm is estimated to include a tractor with 150 kW power, 8 row (12m) planter, 24 m spray rig, 8000 litres nurse tank, 12 m inter row cultivator, slasher and module tarps, as well as cotton ropes (Hughes 2002, p. 33).

Australian cotton farmers nowadays may employ different tillage operations such as incorporation of stubble mulch, zero tillage and controlled traffic. Energy consumption and environmental effects of these operations may vary significantly.

Irrigation system is another significant issue that plays a great role in cotton farming energy and emissions contribution. In 1996-97, cotton farming water usage accounted for 12% of total Australian nationwide irrigation water usage (Jacobs 2006, p. 10). The irrigation systems may include furrow, sprinkler, and subsurface drip irrigation. It has been estimated that 92% of irrigated cotton in Australia is under furrow irrigation, whilst sprinkler system accounts for 6 to 7% (Chen & Baillie 2007, p. 10).

The furrow irrigation, commonly known as border check irrigation, is one of the most common irrigation types in Australian cotton farming. In this method (Figure 2.2), water is supplied from a dam or another elevated storage area and then flows into the pipelines which are connected to field channels (Jacobs 2006, p. 11).

Figure 2.2: Furrow irrigation − also known as border check irrigation method − in cotton farm

Centre pivot or lateral move is a pressurized irrigation system that includes a number of spans with different lengths of 30 to 50 meters (Fig 2.3).

Figure 2.3: Lateral move (Centre pivot) irrigation system in cotton farm

An alternative irrigation method is sub-surface drip irrigation method. It is estimated that up to 94% water efficiency can be achieved through its implementation. This is a pressurised micro irrigation technique that is usually employed for high profit crops. It also enables the delivery of fertiliser to the crop with higher efficiency than standard fertilising methods. Despite its benefits, high setup and pumping energy costs, together with high maintenance requirements and high level water filtration, make this method a last choice for cotton farmers in Australia (Jacobs 2006, p. 14).

Harvest is the last step in cotton on-farm production, typically carried out by cotton harvesters that can usually harvest up to eight rows in one pass. Once the picking is finished, they are emptied into a boll buggy (tractor mounted bins) and then transferred into a module builder that compresses the cotton into modules. Each rectangular module usually weighs about 13 tonnes and is 11-12 m long, 2.5 m wide and 2.5 m high.

Cotton modules are subsequently transferred by road cartage to a gin in order to separate the fibre and seed. Cotton ginning is a process where cotton seed and external matters (trash) are removed from the lint. Generally, the process involves drying the cotton, removing the leaf trash and dirt, and separating the lint from the seed. It is estimated that 50 to 55 kWh of electricity and 2 to 5 litres of Liquid Petroleum Gas (LPG) are required to gin one bale of cotton (Ismail 2009, p. ii).

After ginning operations, cotton is classified into different quality grades and transported to the port for export.

2.2 Cotton Production in Australia

2.2.1 Brief History

During the 1950s, cotton production in Australia was practically non-existent. The modern industry was initiated in 1961 by two Californian growers who planted a first commercial crop at Wee Waa on the Namoi River, thus starting the "first wave" that lasted for nearly two decades, in which Australian cotton producers were completely dependent on American varieties. The "second wave" that started in the 1980s, came with the development of the Commonwealth Scientific and Industrial Research Organisation (CSIRO)'s cotton breeding program, enabling the gradual introduction of new varieties tailored to Australian conditions. By the 1990s, Australian varieties dominated the market and were delivering improved yields, fibre quality and agronomic characteristics. The Australian cultivars enabled the industry to expand significantly and rapidly. In the last 20 years the cotton planting area has tripled, accompanied by the production growth from 435,000 bales in 1980 to 3 million bales in 2006 – an increase of 700 percent (Australian Cotton Shippers Association, 2009).

Figure 2.4 below shows the cotton production gross and export value between 1960 and 2006. There has been a significant increase, starting from 1980s, in both gross and export values of cotton in Australia, which peaked by 1990s. From the year 2000, the Australian cotton production faced a dramatic drop in its production because of the severe droughts.

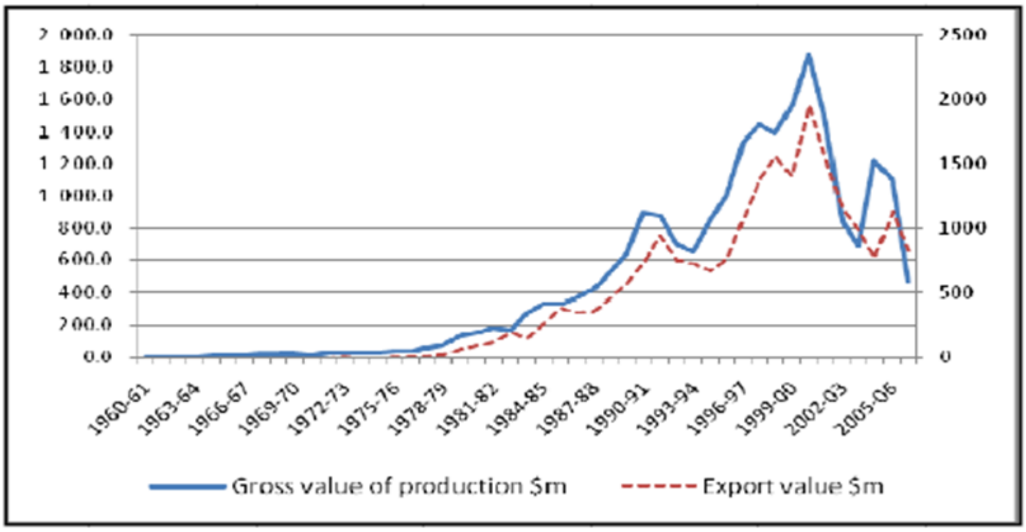


Figure 2.4: Gross and export value of Australian cotton by year from 1960-61 to 2006–07 (Unknown reference)

The following figure describes the trend of Australian cotton lint yield increase in time. It can be seen that drought, pests, wet pick, flood and various diseases significantly impacted the cotton yield improvement over the time. Nevertheless, on average, cotton lint yield increased from 2 bales/ha (435 kg/ha) in 1960s to 8 bales/ha (1741 kg/ha) in 2005.

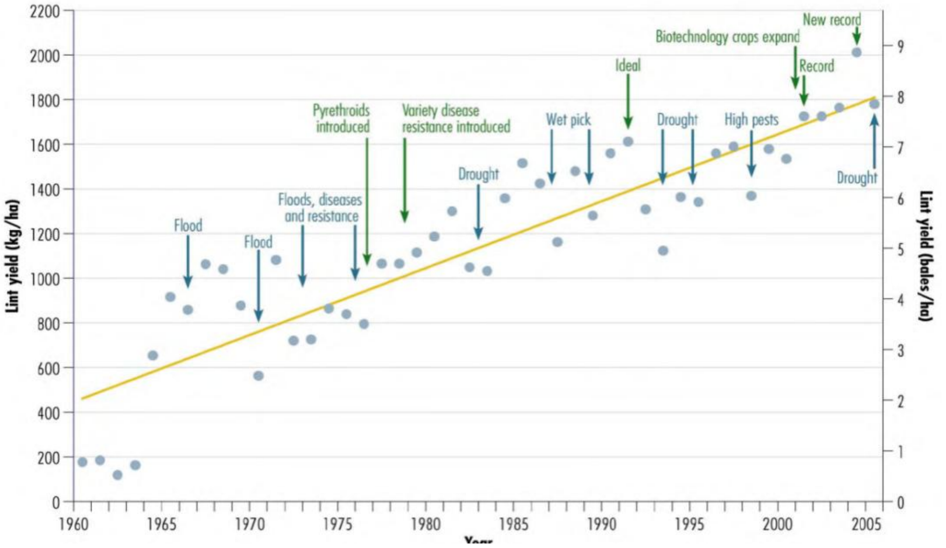
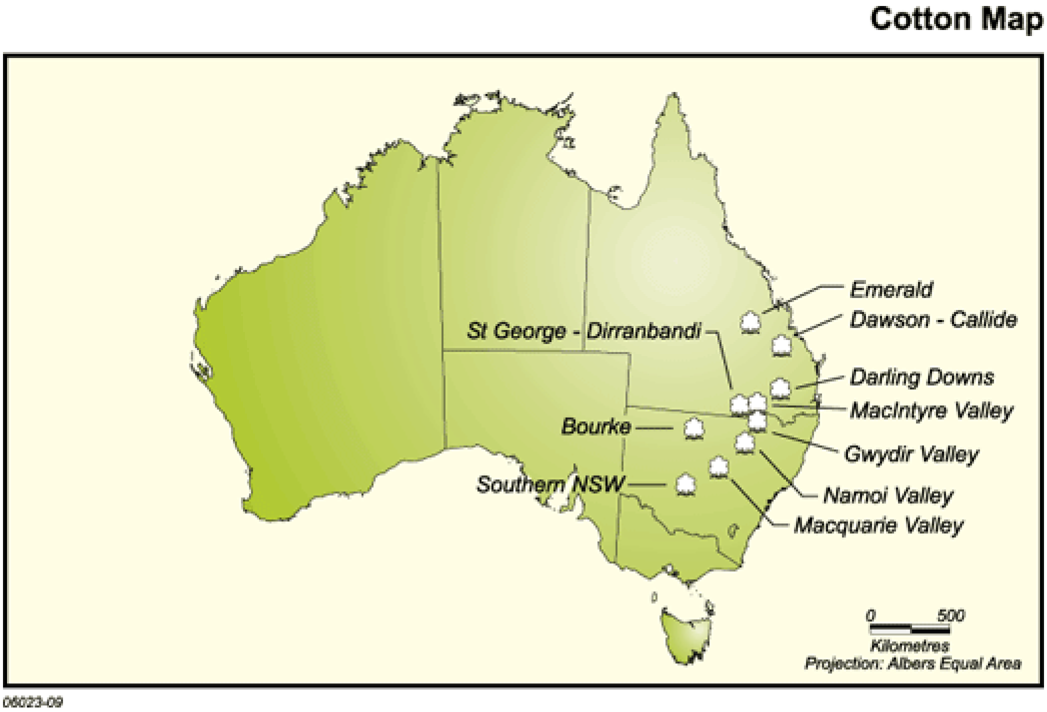


Figure 2.5: Cotton lint yields from 1960 to 2005 for Australia (Unknown reference)

2.2.2 Cotton Growing Regions

In Australia, cotton is farmed mainly in New South Wales and Queensland (Australian Cotton Shippers Association, 2007). On average, 500,000 ha of cotton are planted in Australia annually, yielding more than 3 million 217 kg bales of cotton per year (Australian Cotton Shippers Association, 2007). It is reported that over 80% of Australian cotton is irrigated (Cotton Australia, 2010), with estimated average yield of 7.85 bales/ha (1783 kg/ha).



Source: (ANRA, 2009)

Figure 2.6: Map of Australian cotton regions

2.2.3 Farming Systems and Practices

Cotton, both Genetically Modified (GM) and Conventional varieties (Non-GM), can be planted under different cotton farming systems such as dry-land, irrigated, minimum tillage, no tillage, conventional tillage and many more. Each of these farming systems and practices may be used by Australian farmers based on their cotton paddock history, crop rotations, water and machinery availability and accessibility. Wherever sufficient water supply is available, farmers prefer to plant irrigated rather than dry-land cotton, due to the higher yield potential. Regardless of water supply, cotton growers employ no-till, minimum till or conventional tillage farming operation. However, these tillage operations imply different energy consumption and also affect the soil compaction, leading to different soil irrigation capacity and water retention ability. This affects the choice of irrigation system.

At the moment, Australian cotton industry mainly uses the furrow irrigation. Only four to six percent of total cotton farms are using lateral move irrigation method, whilst less than two percent employ the subsurface drip irrigation method (Raine & Foley 2002, p. 30).

2.2.4 Cotton Variety

There are two main varieties of cotton: Conventional (Non-GM) and Genetically Modified (GM) cotton. Conventional cotton is the variety that is not scientifically modified to increase its tolerance against insects or weed in the field. In contrast, GM cotton is modified for that purpose, therefore reduces the herbicide and pesticide consumption. This, in turn, can lead to reduction in energy consumption and environmental impacts of chemical applications. It has been estimated that 92% of Australian grown cotton was genetically modified (Foster & French 2007, pp. 6-8).

GM cotton varieties were first introduced to Australian farming industry in 1996 (Cotton Australia, 2008). Different GM cotton varieties have been developed for specific purposes. Table 2.1 below shows some of the GM cotton varieties and their primary groups, as either insect resistant or herbicide tolerant:

Table 2.1: Types of common genetically modified (GM) cotton

Insect Resistant Cottons	Herbicide Tolerant Cottons
BT or INGARD® 1996	ROUNDUP READY® 2001
BOLLGARD II® 2003	ROUND UP READY FLEX® 2006
	LIBERTY LINK® 2006

Source: (Agri food Awareness Australia, 2009)

Table 2.2: Description of genetically modified cottons

BT or INGARD®	This variety was developed by CSIRO using a gene owned by Monsanto company. This gene was sourced by bacteria from soil (BT) and enabled the plant to produce the BT gene to kill the main cotton pest, heliothis (cotton bollworm), if it eats the cotton plant's leaves.
BOLLGARD II®	This variety is similar to BT, except that it includes two soil bacteria (BT) rather than one. Genes produce proteins on cotton leaves that kill cotton's main caterpillar when it eats the leaves.
ROUNDUP READY®	The roundup ready cotton makes the plant resistant to the herbicide glyphosate. This enables the farmers to have broader weed management practices, as their crop will be tolerant to herbicide applications against the weeds around the crop.
ROUND UP READY FLEX®	This variety gives growers more flexibility in weed control by extending the period of glyphosate application for weed control purposes. This variety differs from ROUNDUP READY® in that it contains two soil bacteria rather than one, originated from soil.
LIBERTY LINK®	This variety was introduced to the cotton industry in 2006. LIBERTY LINK® cotton is genetically modified cotton to tolerate herbicide and glufosinate ammonium application which marketed as LIBERTY®. Glufosinate ammonium allows farmers to control broader range of leaf weed species and minimize the risks of herbicide resistance.

Source: (Agri food Awareness Australia, 2009)

2.2.5 Cotton Yields

The area under cotton crop changes annually in Australia. It ranged between 150,000 and 535,000 ha per year over the period between 1998-99 and 2006-07 with the average of 321,000 ha per year. About two thirds of Australian cotton is grown in New South Wales (NSW) with the remainder grown in Queensland (QLD) (Fig 2.6). Most of the Australian cotton farms are family owned and operated. Cotton yield is sensitive to available water amount. Reduced water availability can lead to low yield in cotton farms and reduce the cotton production. In 2006-07 (drought year), Australian cotton industry produced 1.3 million bales of cotton harvested from 157,000 hectares, thus yielding 1802 kg (or 7.94 bales) per ha. This number was about 2.5 times of the world average of 747 kg/ha. As explained previously, Australian cotton is mostly grown for export purposes. In 2006-07, this percentage was 98%, equivalent to 487,000 tonnes of raw cotton with the market value of $832 million. Other cotton farming export product is cotton seed. In 2007-08, 152,000 tonnes of cotton seed were sold in the international markets for stock feed and alternative uses, with the market value of $46 million (National Land and Water Resource Audit, 2008).

2.2.6 Postharvest and Distribution

2.2.6.1 Ginning

The ginning operations include cotton fibre cleaning, separating the cotton lint from the seeds, and removing the dirt and leaf. After ginning, the cotton is ready for transport to the milling company for textile purposes. Australian ginning industry is

15 to 37 years old and is relatively modern compared to other countries (Ismail, 2009). It has the operational capacity of up to 100 days per year, on 24 hours a day and 7 days a week basis, if there is a demand in the industry. A typical Australian gin can process 35,000 to 200,000 bales annually (Ismail 2009, p. ii).

In cotton ginning process, all operations, except drying − that uses either the natural gas or LPG as an energy source, are powered by electricity. Nearly all of the ginning machinery used in Australia is made in US. The two major brands are “Lummus” and “Continental Eagle” (Ismail 2009, p. 18).

2.2.6.2 Transportation

There are two stages of “transportation” in Australian cotton industry. The first is the land transport from field to the gin, followed by transfer from cotton gin to the shipping port. It has been estimated that Australian raw cotton export was 221,300 tonnes of raw cotton at the end of 2008 – 09 seasons. Each gin, depending on its location, chooses different cotton transport company. Usually cotton gin company transfers the raw cotton from field to the gin, hence on-farm application stage ends at the cotton-picking point in the field.

2.2.6.3 Milling

A cotton mill is a factory that houses spinning and weaving machinery. As only 2% of Australian cotton is milled locally and the rest is grown for export purposes, this proportionally small section of cotton industry was not included in this study. Australian main cotton export partners by the end of 2008-09 season were China, Indonesia, Thailand, Japan, Korea, Malaysia, India, Hong Kong, Taiwan and Bangladesh (Australian Cotton Shippers Association, 2009). At the destination export countries, milling operations take place for textile purposes, excluded from calculations in this study.

2.2.7 Research Organisations and Activities

There are a number of Australian research organizations actively engaged in cotton research and related studies. The following table lists the main research institutes in Australia and their key working areas.

Table 2.3: List of Australian cotton research organizations

Organization	Major Work Area	Webpage
Commonwealth Scientific and Industrial Research Organization (CSIRO)	Cotton Farming Systems	www.csiro.au
Department of Primary Industries and Fisheries (DPI & F New South Wales (NSW))	Cotton Irrigation, Pest Management	http://www.dpi.nsw.gov.au
Agri Science Queensland (Formerly known as DPI Queensland (QLD))	Planting, Harvesting, Nutrition and GM cotton	http://www.dpi.qld.gov.au
National Centre for Engineering in Agriculture (NCEA)	Production Systems, Irrigation	www.ncea.org.au
Cotton Seed Distributors (CSD)	Cotton Seeds, Varieties	www.csd.net.au

Commonwealth scientific and industrial research organization (CSIRO) is an Australian national science agency and one of the world's leading research organizations. It undertakes research in a broad range of scientific areas, including sustainable agriculture, climate adaptation, farming futures, greenhouse gas management, and carbon storage in land use.

Department of primary industries (DPI) is an organisation based in each Australian state to undertake research projects related to the local industry. Agricultural research is an important part of their work, and they are presently involved in a number of projects related to cotton farming in New South Wales (NSW) and Queensland (QLD), as main Australian cotton producing regions. The major work areas of DPI in cotton farming are irrigation, insect pests, planting, harvesting, and cotton nutrition studies.

National Centre for Engineering in Agriculture (NCEA) is a research organization based at the University of Southern Queensland. A number of research projects, such as energy and emissions of cotton on-farm applications, energy saving in cotton ginning processes and energy use audits for cotton industry, have been undertaken by agricultural engineering research teams at NCEA.

Cotton Seed Distributors (CSD) works closely with CSIRO and applies the modern cotton planting seed technology to produce improved results for cotton growers in Australia. This research organization has been undertaking a number of research studies on summer crops such as cotton, corn, soybeans, sunflowers and sorghum to analyse their gross margin. CSD is mainly engaged in trials of new cotton varieties on dry-land and irrigated cotton farming systems.

2.3 Conclusions

This chapter has provided a review of the cotton production processes and a discussion of different farming systems. A brief Australian cotton history, cotton-growing regions, different farming practices, and cotton varieties have also been described. Cotton yields, post-harvest and distribution activities were reviewed and a number of Australian research organizations that are actively engaged in cotton research were listed in a table at the end of the chapter.

It has been shown that in the 2006-07 cotton farming season, Australian producers exceeded the world yield average of 747 kg/ha by two and half times, yielding 1802 kg (or 7.94 bales) per ha. Nearly 98% of Australian cotton was exported, with the export value of $832 million. A review has also shown that about 80% of total cotton farmlands are irrigated, whilst the rest are dry-land farming systems. Furrow irrigation accounted for 92% of all applied cotton irrigation methods, whilst sprinkler system accounted for only 6% to 7%. It has also been found that the GM cotton occupied 92% of total Australian cotton production.

Chapter 3 - Literature Review

This chapter will firstly discuss the global warming and identify the agricultural emissions sources, followed by the review of the available literature on energy consumption and greenhouse gas emissions of cotton and different products via their life cycle assessment. The concept of carbon footprint and cotton farming related software tools will also be reviewed.

3.1 Global Warming

The greenhouse gas effect that is mainly produced by human activities is adding to the natural earth warming process. Activities such as land clearing, fossil fuel burning and agricultural operations are producing greenhouse gases; and as the number of these activities is increasing, the balance of air and greenhouse gases in the atmosphere is changing. This is affecting the natural earth environment, referred to as climate change. The continuous increase in earth's temperature is also referred as global warming, which is only a component of climate change (IPCC 2007).

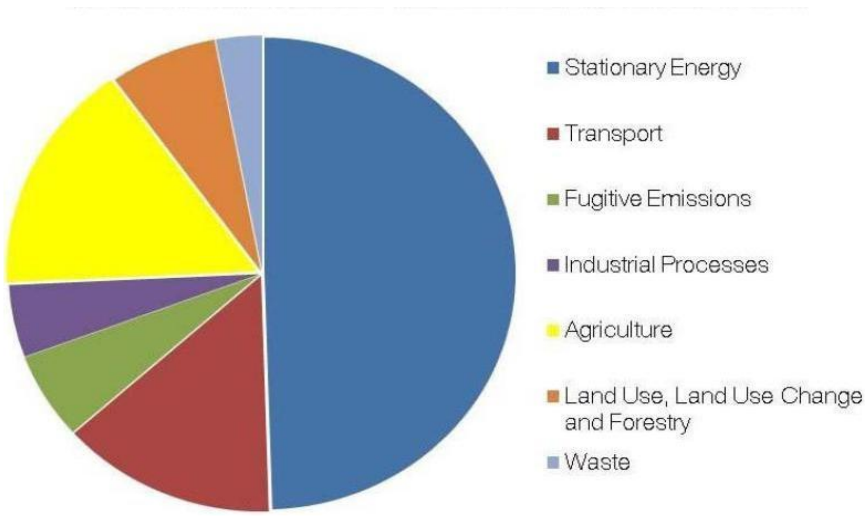
3.2 Sources of Greenhouse Gas Emissions from Agriculture

In addition to carbon dioxide (CO_2), emissions of methane (CH_4), nitrous oxide (N_2O), oxides of nitrogen (NO_x), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC) are produced when dead or living biomass decays, is processed or burned. These emissions are caused by human activities, such as cultivation, fertilising, burning or irrigation applications, and by the introduction of ruminant animals (Australian Greenhouse Office 2004, p. 22).

The above sources have also been identified as the most significant elements that affect the Australian agricultural sector greenhouse gas emissions. Thus due to the growing concerns on climate change and global warming, these emission sources must be targeted in order to reduce greenhouse gas emissions from agricultural systems. The Australian greenhouse office (AGO) is now under supervision of the Department of climate change and energy efficiency (DCCEE).

3.3 Carbon Footprint

Carbon footprint is a carbon-equivalent to various sources of emissions. This value is unique for a specific product and includes various sources of greenhouse gas emissions. Thus, each of these emissions is converted into their carbon dioxide emission equivalent, providing a single total emission measure. This enables an emission comparison of different sources of e.g. CH_4, CO_2, N_2O. The following figure shows the Australia's greenhouse gas emissions by sector in 2006. Agriculture accounted for 16% of total emissions.



Source: (Cotton Australia, 2008)

Figure 3.1: Australian greenhouse gas emissions by sector in 2006

3.4 Energy Consumption and Emissions of Cotton Production and Supply Chain

A number of studies have been carried out to evaluate the cotton production energy consumption and greenhouse gas emissions in Australia and other countries Matlock et al. (2008), Chen and Baillie (2007), Cotton Research and Development Corporation (2009) and Cotton Australia (2008). However, most have neither covered the full cotton farming system life cycle, nor made a comparison between different farming technologies. This section will review the available literature related to cotton farming.

Yilmaz, Akcaoz and Ozkan (2005) collected data from 65 farmers to determine the on-farm energy consumption in the cotton production chain in Turkey. The study also analysed the effect of farm size. It was found that cotton farming in Turkey used a total of 49.73 GJ/ha of energy. Diesel energy consumption was the biggest component (31.1%), followed by fertiliser and machinery. It was also found that 21.14 (GJ/ha) out of 49.73 GJ/ha total energy consumption of cotton farming in Turkey could be attributed to direct energy input, and the remaining 28.59 (GJ/ha) to indirect energy input. This research, however, only covered the on-farm phase of cotton farming, which showed that the indirect component was higher than the direct one in on-farm cotton farming in Turkey.

In another study, Chen and Baillie (2007, p. 8) divided the cotton farming energy consumption into six processes of fallow, planting, in-crop operations, irrigation, harvesting and post harvesting operations. Through this study, on-farm direct operation energy consumption and related emissions were determined and compared to other crops. An on-farm energy calculator EnergyCalc was also developed. It was found that total energy inputs in Australia were strongly influenced by different application methods and management systems, and varied from 3.7 to 15.2 GJ/ha of primary energy, equivalent to 275 – 1404 kg CO_2e of greenhouse gas emissions per ha.

In the same study, irrigation was found to contribute 40-60% to the total energy costs (wherever water is pumped). Use of harvesters accounted for 20% of overall direct on-farm energy consumption. It was further found that 10% saving on fuel usage was achievable by moving from conventional to minimum tillage, whilst cotton energy consumption was still more than 100% higher than for other crops.

The model also showed that irrigation water management had significant effect on energy consumption, especially when pressurised spray irrigation or double pumping systems were used. This research was again limited to on-farm direct energy and greenhouse gas emissions, excluding ginning, drying, and other off-farm activities. Another major limitation of the EnergyCalc energy calculator tool is that it heavily relies on published data from other countries.

Matlock et al. (2008, p. 1) used Life Cycle Assessment (LCA) to quantify the required energy for cotton production over global cotton practices. They developed a model by dividing cotton agricultural operations into different phases. The LCA model also quantified embodied energy in various farm operations, such as direct mechanical, animal and human energy used to produce cotton. This study also calculated embodied energy in fertilisers, mechanical components and manure.

In this study, four general farming stages of field preparation, planting, field operations and harvesting were measured and the average embodied energy for global cotton production was quantified. The results varied from 5.6 GJ (North America East) to 48 GJ (South America, Non-Mechanized) per tonne of cotton. The latter value was higher than the North America East because cotton growers in the South America used medium level of irrigation, whilst the North American farmers do not. It was also found that the energy consumption values were heavily dependent on irrigation water, the amount of fertiliser used and cotton farming yield. The detailed numbers for each region are presented in Appendix 2.

It was found that energy consumption varies significantly depending on a range of factors. In most cases, fields producing lower yields were found to consume more energy compared to those with higher yields. Therefore, it was suggested that the most evident approach to decrease energy consumption in cotton production is to increase the yield. It was concluded that by increasing cotton yield and decreasing irrigation, more energy efficient cotton farming system could be achieved.

International Cotton Advisory Committee (2008, p. 2) analysed the cost of energy used in cotton supply chain to deliver the lint to mill customer. In this study three types of costs were analysed:

a) Direct cost – diesel, electricity and natural gas.

b) Indirect cost – Energy used to produce fertilizers and pesticides to use in cotton farming.

c) Embedded Cost – for instance energy used to produce agricultural equipment and ginning machines.

The methodology used in this study was Life Cycle Assessment (LCA), shown in Appendix 3. This study analysed the data from Africa, USA, India and China. Energy cost share from farm to mill was calculated as given in Table 3.1:

Table 3.1: Planting, ginning and logistics energy share in cotton supply chain

Item	% Energy share in Supply Chain
Plantation	30 to 65%
Ginning	6 to 20%
Logistics (Transportation)	25 to 55%

Source: (International Cotton Advisory Committee 2008, p. 15)

It was found that the most significant energy costs were related to logistics (average 40%) and cotton plantation (45%). The energy cost in finished textiles influenced retail prices by 10%.

It was concluded that cotton uses less energy compared to wheat and corn. Therefore, increase in energy prices has lesser effect on cotton textile price. It was also found that a 30% increase in energy costs would increase cotton textile prices by 1.35 US cents/kg, equivalent to 5% of cotton sales prices. Furthermore, it was suggested that environmental regulation and pollution control in USA led to higher consumption of energy, as highest energy consumption was found to be in the USA, followed by

Africa/India. This study provides literature that enables comparison of cotton farming energy consumption between other countries and Australia.

A recent study (Cotton Research and Development Corporation, 2009) at Queensland University of Technology (QUT) focused on the Life Cycle Assessment of a 100% Australian-Cotton T-Shirt. The environmental impacts of cotton and polyester T-shirt production, use and disposal stages have been compared. It was found that throughout the life of a T-shirt made and sold in Australia, almost 75 per cent of its carbon footprint is caused by machine washing and drying at home, implying the importance of reducing energy consumption by hanging clothes out on a washing line to dry instead of using a tumble dryer.

Further evidence implied that a cotton T-shirt is more environmentally friendly compared to a polyester T-shirt (Table 3.2).

Table 3.2: Greenhouse gas emissions of cotton and polyester T-shirt

Product type	Emissions (kg CO_2e /kg textile)
Cotton	26
Polyester	31

Source: (Cotton Research and Development Corporation 2009, p. 71)

The above values imply that production of 1000 polyester T-shirts would result in the emissions of 1.25 tonnes of CO_2 equivalent, compared to one tonne for cotton T-shirt. This study also estimated that on average 200 kg N/ha of fertiliser is applied on cotton farms. A number of methods were subsequently recommended to reduce the cotton T-shirt production chain greenhouse gas emissions.

- Reduce the use of the chemicals, as their manufacturing process relies on fossil fuels. Try to use more natural fertilisers and pesticides.

- Use alternative energy sources to fossil fuel.

- Apply minimum tillage and no-till systems.

Through the results of this study, data for cotton and polyester T-shirt emissions for different T-shirt production industry sectors are presented in the following table.

Table 3.3: Greenhouse gas emissions of cotton and polyester T-shirt by production levels

Production level	Cotton (kg CO_2e/kg textile)	Polyester (kg CO_2e/kg textile)
Fibre production	3.2	8.9
Textile manufact.	22.6	22.6
Use and disposal	370.1	370.1

Source: (Cotton Research and Development Corporation 2009, p. 22)

The reliability of these results has also been validated through Monte-Carlo simulation, which concluded that in 95% of the time, cotton T-shirt production is emitting less GHG compared to the polyester T-shirt production. This confirmed the reliability of the current numbers and showed that cotton fabric is less greenhouse gas emitting compared to polyester fabric.

Limitations of this study included:

- Currently 98% of Australian cotton is produced for export purposes and only 2% is milled locally. However this study was primarily focused on the 2% local milling data.

- Transport of seeds and chemicals and farm machinery manufacturing energy consumption and emissions are not included in this study.

- As this study excludes the transport to the ports, it was not possible to calculate the energy consumption and related emissions arising from gin to the port transport, or energy and emission values to manufacture transport vehicles.

- The study was also heavily dependent on previously published data.

Cotton Australia (2008, p. 3) briefly reviewed the cotton production and its implications on climate change. It was found that cotton industry emitted 0.2 million tonnes of CO_2 equivalent emissions in 2005. These estimates only covered on-farm activities and excluded embodied energy consumption.

Jacobs (2006, p. 35) conducted a study entitled "Comparison of life cycle energy consumption of alternative irrigation systems" that compared the energy consumption and the greenhouse gas emissions of the border check (furrow), centre pivot (lateral move) and subsurface drip irrigation systems. It was found that the subsurface drip irrigation method was the highest energy user and accounted for 10.5 GJ/ha/year, whilst centre pivot was the highest greenhouse gas emitting irrigation system, producing 94376 kg CO_2e per year or 1467 kg CO_2e/kWh. As the study was conducted in Australian state Victoria, where electricity is generated by high polluting brown coal, the impact on the above findings was significant. But in some case (e.g. in Tasmania) electricity companies use hydraulic renewable energy sources to generate the electricity. While the energy usage to generate the energy will be the same from different locations, the emissions will be very different. The following table shows the main results of this study.

Table 3.4: Energy usage and the relative greenhouse gas emissions of different irrigation systems

Irrigation System	Energy Consumption (GJ/ha/year)	Greenhouse Gas (kgCO_2e/year)
Furrow	4.6	39 – 28783
Lateral move	6.2	129 – 94376
Subsurface drip	10.5	122 - 89546

Source: (Jacobs 2006, p. 35)

Further results suggested that the total life cycle energy related to furrow irrigation was 75% of the total in lateral move and 50% in subsurface drip. Hence, it was concluded that when low price water is available, furrow irrigation is the most cost effective irrigation system. However, if the water prices are subject to increase, the lateral move would be preferred choice.

Raine and Foley (2002, p. 30) compared several cotton irrigation systems in Australia and found that different surface irrigation systems in cotton farming showed variable performances. Grower’s survey data implied that water use efficiency for surface irrigation ranged from 0.6 to 1.6 bales per ML. Furthermore, the average yield for growers using lateral move irrigation method was 0.5 bales/ha, lower than in flood irrigated cotton farms. The study therefore concluded that the most cost effective option would be the further development of currently employed surface irrigation systems.

Ismail (2009, p. ii) submitted a dissertation on assessment of energy for cotton gins in Australia. The author reported that the benchmark electricity consumption ranged between 44 and 66 kWh per bale, compared to Australian national average of 52.3 kWh. This is equivalent to 188.28 MJ per bale or 0.86 MJ/kg of cotton. The greenhouse gas emissions factor in this study was found to be 60.38 kgCO_2e per bale for the ginning operation or 0.27 kg CO_2e/kg of cotton.

Alcorn (2008, p. 50) estimated the greenhouse gas emissions of different controlled traffic farming systems. The following table shows the fuel requirements for different tillage systems.

Table 3.5: Fuel requirements of farming operations in different tillage systems, L/hectare

Tillage type	Chisel plough	Cultivator (L/ha)	Seeder (L/ha)	Sprayer (L/ha)	Header (L/ha)	Fuel use (L/ha)	Emissions kg CO_2e/ha
Min. till	9.8	6	5	1.4	8	36.2	99.6
Zero till	9.8	0	5	1.4	8	21.9	60.1
Cont. tr.	0	0	3	0.7	6	11	30.5

Source: (Alcorn 2008, p. 50)

After calculating the herbicide manufacturing energy and their application rates, Alcorn (2008, p. 51) estimated the total emissions of cropping systems for different tillage methods of minimum, zero and controlled traffic tillage (Table 3.6).

Table 3.6: Cropping system effects on greenhouse gas emissions

System	Diesel $KgCO_2e/ha$	Herbicides prod. Kg CO_2e/ha	N production Kg CO_2e/ha	Total Kg CO_2e/ha	Soil emissions Kg CO_2e/ha
Min-till	99.6	12.7	205	362.3	633
Zero till	60.1	50.8	245	405.9	760
Controlled traffic	30.5	38.1	196	304.6	434

Source: (Alcorn 2008, p. 51)

It can be seen from the above table that employing the controlled traffic farming system reduces the emission rates compared to zero and minimum tillage operations. In terms of diesel usage, zero till is emitting double, whilst minimum tillage is emitting three times more than controlled traffic system.

Herbicide and fertiliser manufacturing emissions were found to be the greatest in zero tillage, whilst the lowest emissions were related to minimum tillage. As the above data are general values, further research focusing on Australian cotton farming system is recommended.

Blackburn and Payne (2004, p. 59) published a report on “life cycle analysis of cotton towels”, in which it was assumed that cotton fibre growing used 9.35 kWh or 33.6 MJ of energy for dyed 600g 100% cotton towel. This excluded the water and chemical consumption, as well as transportation.

It has also been found that in total life cycle assessment of a cotton towel, growing stage contributed only 4% to the total energy consumption, whilst product manufacturing processes and consumer use accounted for 19% and 76% respectively.

Chen and Baillie (2009, p. 2) reviewed the previous available studies of cotton and different crops. The following table summarizes their findings on various on-farm energy consumptions for direct and indirect farming operations.

Table 3.7: Energy consumption of cotton for different countries

Energy consumption Direct (MJ/ha)	Energy consumption Indirect (MJ/ha)	Total energy consumption (MJ/ha)	Country
3700 - 15200	-	-	Australia
-	-	82600	Greece
21140	28590	49730	Turkey

Source: (Chen and Baillie 2009, p. 2)

This study has also reviewed the available energy monitoring and calculation hardware.

Chen and Baillie (2009, p. 4) also found that choice of production systems and a particular farming method performance impacted energy consumption. It was estimated that 40 – 60% of total on-farm direct energy consumption can be related to irrigation. Furthermore, by adjusting the gear selection and engine speed, energy saving of up to 30% for the same type of machinery can be achieved. By improving the hydraulic system and pump, further 30 – 40% reduction would be possible. This study concluded that there is a strong need in the industry to develop a model to calculate the energy consumption in agriculture. This may be conducted through software design, or easy to use toolkits such as training materials.

Asare et al. (2006, p. 4) reviewed conceptual, screening and detailed life cycle assessment history and divided the cotton supply chain into eight different phases of growing, harvesting, ginning, fabric production, sewing, transportation, recycling and disposal. Through this study it has been shown that the organic and conventional cotton both use approximately the same amount of energy and have the same impact on transportation emissions.

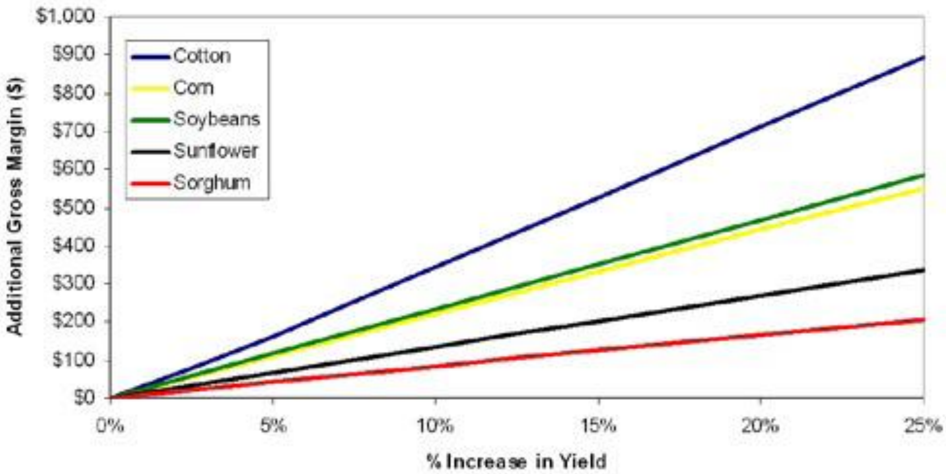
Cotton Seeds Distributors (2008, p. 1) conducted a gross margin analysis for summer crops. This analysis included cotton, corn, soybeans, sunflowers, and sorghum. Data were collected for each of the above-mentioned crops on their irrigation water levels, nitrogen requirement and commodity prices. The following table shows the average water requirements per hectare for all five crops.

Table 3.8: Irrigation water requirement for Australian summer crops

Product	Water requirement per hectare
Cotton	7.25 ML
Corn	7.15 ML
Soybeans	6 ML
Sunflowers	3.90 ML
Sorghum	3.80 ML

Source: (Cotton Seeds Distributors 2008, p. 1)

It was concluded that cotton had the highest variable costs, as well as the highest returns, as demonstrated by the gross margin analysis in Figure 3.2. Fertilizer cost is another significant factor that affects the product inputs. Thus sorghum, corn and sunflowers were affected the most, as the fertiliser inputs represent about one third of their variable costs. It was also shown that the increase in yield may increment the variable costs as well as product returns. The following figure shows the price and yield increase relationship for five irrigated Australian summer crops.



Source: (Cotton Seeds Distributors 2008, p. 5)

Figure 3.2: Price and yield increase relationship of irrigated summer crops

Cotton Seeds Distributors (2008, p. 6) concluded that if the effect of water availability is excluded from the assessment, cotton planting in Australia makes economic and logical sense, with the highest yield per mega litre of irrigation water. This study has shown that cotton was the most cost-effective crop option for the farmers and the industry on both per hectare and per mega litre basis.

3.5 Life Cycle Assessment for Energy Consumption and Emissions of Other Products and Systems

This section will review the available data on life cycle assessment of energy consumption and emissions of other products such as dairy systems and maize. These data will enable comparison of cotton energy uses and emissions against different products.

To evaluate the sustainability for dairy systems in New Zealand, Wells (2001, p. 1) showed the effect of each agricultural process on total energy inputs. Energy input participation in the national average, non-irrigated and irrigated dairy farms were calculated. He also collected data related to farm machinery usage by different farming systems and concluded that:

- Total energy inputs for a dairy farm were 18 GJ for each milking hectare on annual basis (Wells 2001, p. 1).
- Average total energy inputs were approximately 22 MJ/kg of milk solids (Wells 2001, p. 1).
- Using fertilisers, particularly nitrogen-based, and electricity for irrigation pumping and milk solids production were the main causes of variations in energy uses amongst individual farms (Wells 2001, p. 1).
- The gross CO_2 emissions from energy consumption of dairy farming systems were estimated to be 1.1 tonnes CO_2 per effective milking hectare or 1.4 kg CO_2e/kg of milk solids (Wells 2001, p. 1).

Grant and Beer (2008, p. 375) published a paper on "Life cycle assessment of greenhouse gas emissions from irrigated maize and their significance in the value chain." This study showed that the average total life cycle greenhouse gas emissions for different uses of maize are: 12.32 tonne CO_2e/ha for corn chip manufacture, 7.65 tonne CO_2e/ha for starch production, and 8.66 tonne CO_2e/ha for ethanol production. In the case of corn chip manufacture, it was also found that pre-farm emissions comprised 6% of the total life cycle emissions, on-farm activities 36%, whilst post-farm activities contributed to the remaining 58%.

The main methodology used in this study was Life Cycle Assessment (LCA) which divided the farming system into more detailed production processes. This enabled the researchers to determine the energy consumption and related greenhouse gas emissions more effectively for each stage. Data from this study may be useful to compare Australian cotton farming energy consumption with other Australian crops, such as maize.

The LCA study showed that the emissions from nitrogen based fertiliser application in on-farm phase of maize production were the single biggest source of emissions. Furthermore, post farm (off-farm) applications for production of oil and energy, packaging and transport accounted for most of the greenhouse gas emissions. This study showed that applying different techniques such as soil tillage, fertiliser management and crop rotation can influence the soil carbon and greenhouse gas emissions.

Biswas, Barter & Carter (2008, p. 206) have conducted the study of global warming potential of wheat production in Western Australia. They developed a life cycle assessment of one tonne of wheat delivered to the shipping port in south Western Australia. This study included the farm machinery usage, fertiliser and chemical production emissions for on-farm phase, as well as pre-farm mining and processing activities. Grain storage and transportation for the off-farm wheat production phase was also included.

It was concluded that the LCA is a useful technique for estimating the greenhouse gas emissions from farm to port. Greenhouse gas emissions were found to be 304 kg CO_2e for one tonne of wheat, which was about 38% percent less than the IPCC emissions factor (Biswas, Barter & Carter 2008, p. 206).

The authors also reported that the pre-farm phase accounted for 45 %, compared to 44% and 11% of emissions arising from the on-farm and off-farm stages of wheat production processes respectively. Fertiliser production was found to be the biggest contributor with 35% participation in the pre-farm and post-farm activity emissions. The recommendation of this study was to calculate and use the regional and farm survey data to evaluate the soil N_2O emissions (Biswas, Barter & Carter 2008, p. 206).

The United States Agency International Development USAID (2009, p. 9) collected the data on energy consumption for various transport methods. The results are presented in the following table:

Table 3.9: Energy used by different transport systems

Method of transport	Energy consumption (MJ/MT km)
Passenger car (diesel powered)	13.4 – 23.2
Aerial transport (500 km)	10.2
Aerial transport (6000 km)	6.8
Vans below 3.5 MT	8.04
Trailers above 20 MT	0.86
Trains with diesel fuel with 790 MT capacity	0.56
Ship 3500 MT capacity	0.3
Ship 4000 MT capacity	0.18

Source: (United States Agency International Development USAID 2009, p. 9)

The study further concluded that passenger cars carrying smaller load, use more energy compared to trucks or bigger vehicles. It was found that train carriage is consuming about 65% less energy compared to the trailer transport method.

Australian Climate Change Education Network (2007, p. 1) has conducted a research to calculate energy consumption and greenhouse gas emissions caused by transportation. They found that the transport accounted for almost 15% of total Australian greenhouse gas emissions and 22% of Australian CO_2 emissions.

The results confirmed that there is a significant increase in the transport vehicle emissions, due to their rapidly increasing number. For long journeys, using public transport instead of driving, as well as using electricity as a transportation energy source was recommended. Electricity was deemed the most environmentally friendly option, as it can be generated from renewable energy sources. In addition hybrid cars can further reduce their energy consumption by reusing the energy generated from brakes. The following table shows the energy consumption and the emissions for various transport methods.

Table 3.10: Energy consumption and emissions of different fuel types

Fuel Type	Energy (MJ/L)	Energy (MJ/kg)	Emissions (kgCO_2e/GJ)
Petrol	34.2	46.4	80
Aviation Kerosene	36.8	46.4	3.15 per kg
LPG	25.6	49.6	68.3
Diesel	38.6	45.6	78.2
Ethanol	23.4	29.6	-

Sources: (IPCC 1996 & Australian Climate Change Education Network 2007, pp. 1-2)

Regarding the product related energy consumption, a study by Chen and Baillie (2009, p. 2) reported the following findings:

Table 3.11: Energy consumption of various crops for different countries

Crop	Energy consumption Direct (MJ/ha)	Energy consumption Indirect (MJ/ha)	Total energy consumption (MJ/ha)	Country
Tomato	53400	53300	106700	Turkey
Pasture	14600	3600	18200	New Zealand
Pea	-	-	2500 - 5400	Canada
Rice	-	-	64890	USA
Maize	4700 - 500	-	-	Europe

Wheat	-	-	16000 - 32000	Greece
Wheat	2500 - 4300	-	-	Europe

Source: (Chen and Baillie 2009, p. 2)

Oecotextiles (2009, p. 2) calculated the energy profile for the textile industry and they found that embodied energy consumption of different textile products varies significantly, ranging from 102 MJ/kg of textile for Flax production and fabrication, to 342 MJ/kg of produced Nylon. These variances were mainly caused by the different materials and energy used in the production chain of each individual textile product. Table 3.12 shows the energy consumption of flax, conventional cotton, wool, polypropylene, polyester, acrylic, nylon and viscose fibre, and fabric production.

Table 3.12: Energy consumption in production of fibre and fabric for different textile products

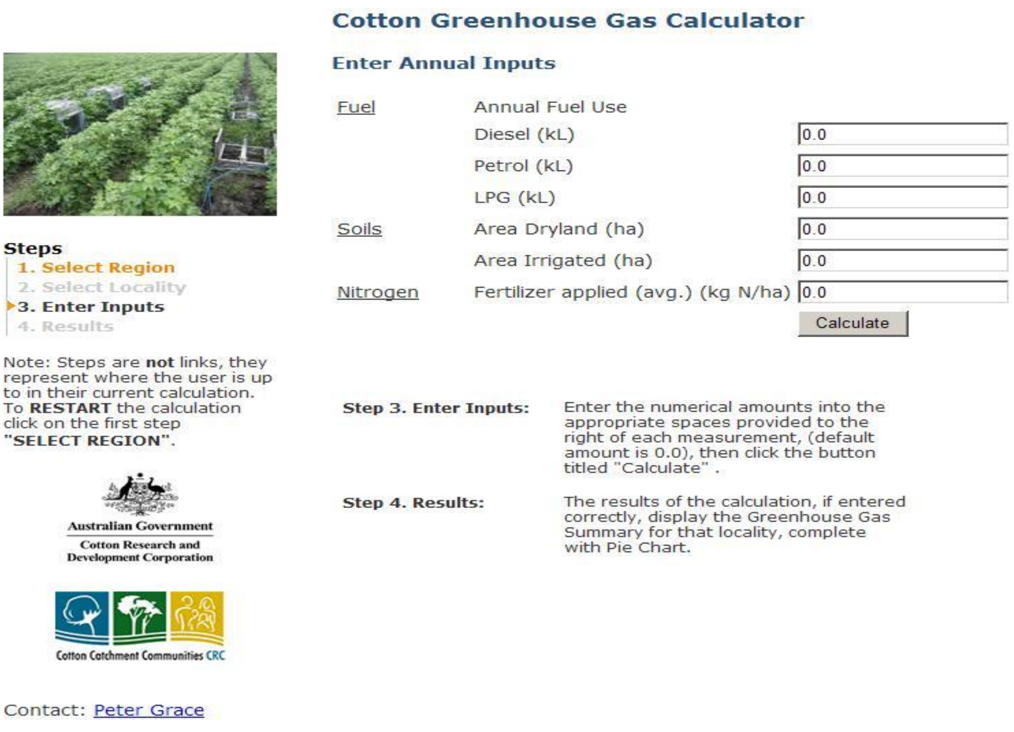
Textile product	Energy usage to produce per kg of fibre (MJ)	Energy usage to process per kg of fabric (MJ)	Total energy uses per kg of fibre prod. +Fabric (MJ)
Flax	10	92	102
Convent'l cotton	55	92	147
Wool	63	92	155
Polypropylene	115	92	207
Polyester	125	92	217
Acrylic	175	92	267
Nylon	250	92	342
Viscose	100	92	192

Source: (Oecotextiles 2009, p. 2)

3.6 Software Tools

This section provides a review of available software tools developed in previous studies that calculate the cotton farming energy consumption and/or greenhouse gas emissions.

Cotton greenhouse gas calculator (Institute for Sustainable Resources, 2007) is an online tool that calculates the cotton on-farm energy and greenhouse gas emissions by selecting the region where the farm is located. This tool is limited to only six inputs of diesel, petrol, LPG, area dry-land, area irrigated, and fertiliser applied. The following figure shows the input page of this online calculator:

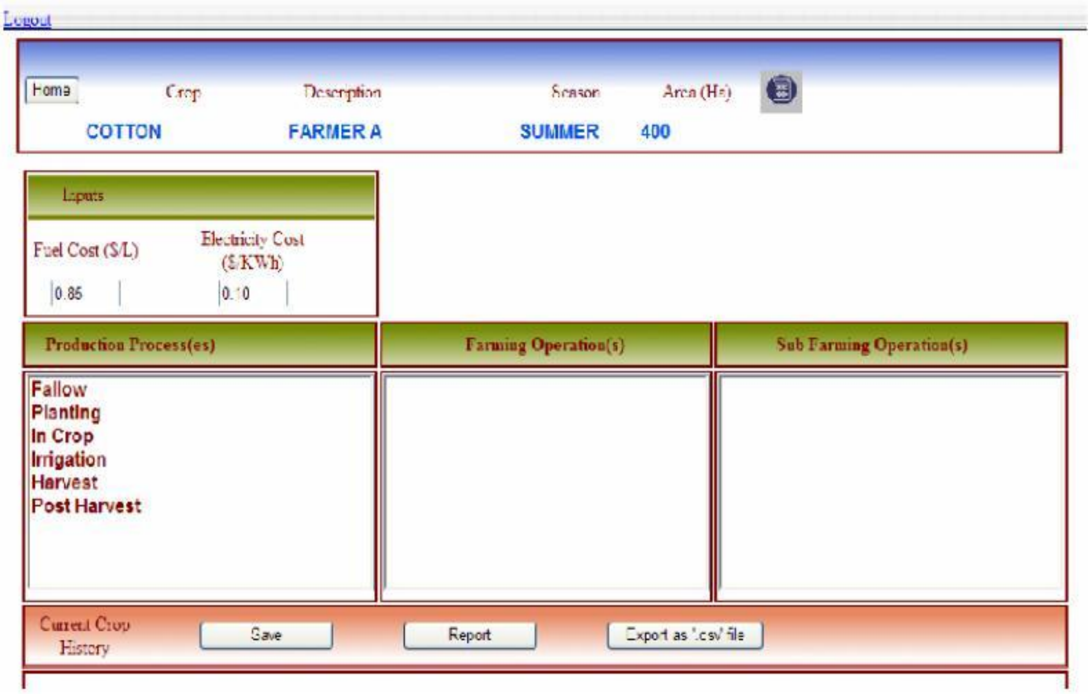


Source: (Institute for Sustainable Resources, 2007)

Figure 3.3: Cotton greenhouse gas calculator

As stated above, this software is limited to six simple inputs and only covers the cotton on-farm applications. It excludes the transport, ginning and all other off-farm activities.

ENERGYCALC, reviewed previously, is a software that calculates the cotton on-farm energy consumption and related greenhouse gas emissions by dividing cotton on-farm applications into six broad stages: fallow, planting, in-crop, irrigation, harvesting and post harvest operations. The following figure shows the ENERGYCALC software data input page.



Source: (Chen and Baillie 2007, p. 18)

Figure 3.4: ENERGYCALC software for assessment of cotton on-farm energy requirements

As discussed in Section 3.4, ENERGYCALC is heavily dependent on previous research, thus needs to be further developed and improved with more reliable data.

3.7 Conclusions

This chapter has reviewed the available literature on energy consumption and greenhouse gas emissions of cotton and other farmed products via their life cycle assessment. It has been shown that most previous studies were limited to on-farm direct applications, whilst some overseas studies on cotton and other products included off-farm applications. However, the latter findings were either limited or unreliable, or did not apply to the Australian energy consumption and the related emissions for the full cotton farming life cycle. This identifies the need for further research to calculate the energy consumption and the emissions of Australian cotton from field to the port.

Chapter 4 - Model Development

This chapter will describe the cotton farming life cycle inventory, model development, each on-farm and off-farm stage boundaries, as well as direct, indirect energy, and relevant emissions calculations. The model framework, required input data, software design and implementation will also be discussed.

4.1 Introduction

The model in this thesis is an assessment tool for the energy used by different cotton farming phases from field to the port and their relevant emissions. The model is based on life cycle assessment (LCA), discussed in the literature review. LCA divides the cotton farming system into a number of on-farm and post-farm stages, and enables calculation of energy consumption and emissions for each stage separately. Thus, if data for each application is available, total energy and emissions for a farming system can be derived. This study did not cover the emissions from crop residue but covered the N_2O emissions from the soil.

The first step in model development is the establishment of LCA framework. In this thesis, the developed LCA framework in Figure 4.1 will be adopted, which identifies connections between different on-farm and off-farm operations, and includes both direct and indirect energy consumption.

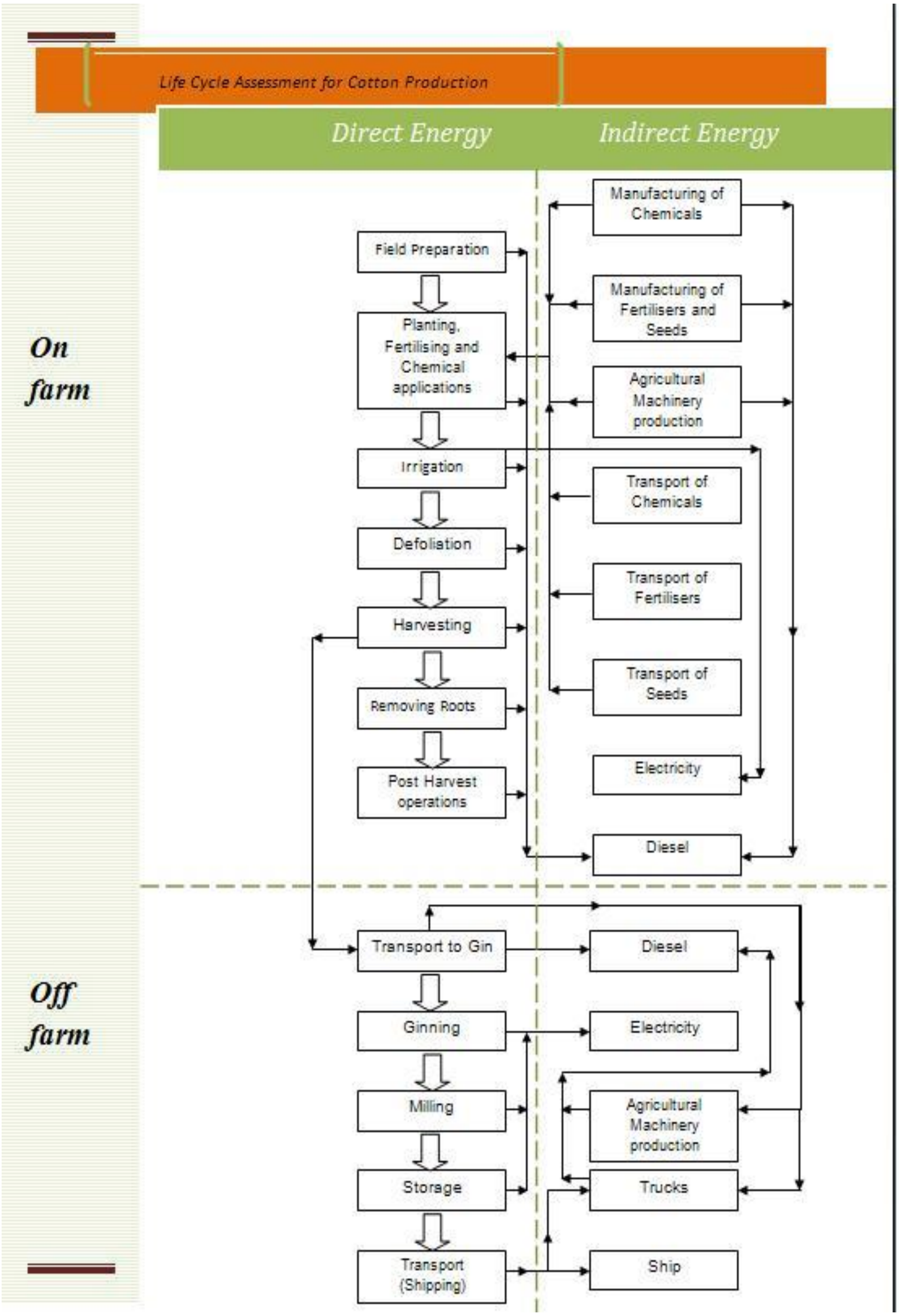


Figure 4.1: Developed life cycle assessment (LCA) of cotton farming: from field to the port

4.2 Life Cycle Assessment (LCA) Boundaries

This study only includes the cotton production processes from field to the port. The possibility of recycling cotton fibres is not considered. The emissions and value contribution of cotton by-products are also not included.

Calculations related to on-farm direct activities in this study incorporate energy consumption and emissions from all agricultural operations including irrigation. The latter however excludes the energy used to transfer water from another location to the farm.

On-farm indirect energy and greenhouse gas emissions calculations incorporate manufacturing and transport of seeds, chemicals and fertilisers; excluding embodied human input in these processes. However, the energy used to manufacture agricultural machinery and implements is included.

Off-farm direct component will include the energy and the emissions of cotton ginning and transport from field to the gin and from gin to the port. The milling operations are excluded, as only 2% of Australian cotton is milled and used locally.

Off-farm indirect calculation stage will consider the manufacturing processes contributions for heavy, light trucks and motor bikes, as well as the impact of ginning company building.

4.3 Model Framework Implementation

This model is implemented in an Excel spreadsheet with embedded macro programming system. Microsoft Excel software is widely used in different scientific programs, ranging from medical systems to engineering. It makes the studies much easier by simplifying the calculations, establishing relations, gathering charts and smart arts.

The Excel model is based on LCA framework and divided into the following stages: on-farm direct, on-farm indirect, off-farm direct and off-farm indirect plus soil emissions. General boundaries for each of these stages are described as below:

4.3.1 On-farm Direct Applications

These activities start from tillage operations and finish at crop destruction. They include field preparation, planting, in crop operations, irrigation, harvesting and some post harvest operations. Sub sections of each activity are described in Table 4.1.

Table 4.1: Detailed activities for cotton on-farm direct applications

Field Preparation	**Tillage (L of Diesel)**
	Harrowing (L of Diesel)
	Weeding (L of Diesel)
	Fertilising (L of Diesel)
Planting	Tillage (L of Diesel)
	Harrowing (L of Diesel)
	Planting (L of Diesel)
	Weeding (L of Diesel)
	Fertilising (L of Diesel)
In Crop Operations	Weeding (L of Diesel)
	Fertilising (L of Diesel)
	Spraying (L of Diesel)
Irrigation	Furrow or Flood (ha/year)
	Centre Pivot (ha/year)
	Sub-Surface Drip (ha/year)
Harvest	Harvesting (L of Diesel)
	Infield Operations (L of Diesel)
Post Harvest	Crop Destruction (L of Diesel)

By using specific energy and emissions conversion rates, the total energy consumption and related GHG emissions for each of the sections detailed in the Table 4.1 are estimated, as shown by the equation below:

Total used energy (GJ) = units used × energy conversion rate

Thus total energy consumption is a product of the number of units applied and the relevant conversion factor sourced from Australian Department of Climate Change, Energy Sector. Clearly, each of these factors may change with the fuel sources and industry locations.

The equation below gives total greenhouse gas emissions as a function of the units used and specific Australian Greenhouse Office (AGO) Factors, both highly dependent on industry location and their energy source (e.g. fossil fuel, renewable energy).

Total GHG emissions (kg CO_2 equivalent) = units used × emissions conversion rate AGO factor (kg CO_2 equivalent /unit)

4.3.2 On-farm Direct Inputs

Diesel

Diesel is often the only source of energy consumption and emissions in field preparations, planting, in crop operations, harvest and post harvest activities. Carbon oxidation released during the fuel burning activity causes the release of CO_2 emissions, dependent on carbon content of fuel (Saunders, Barber & Taylor 2006, p. 33).

Industrial diesel fuel energy consumption is calculated as 39.6 MJ/L of diesel, equivalent to 0.07 kg CO_2e/MJ of energy (National Greenhouse Gas Inventory committee 2007, p. 11). On the other hand, Saunders, Barber and Taylor (2006, p. 33) used a value of 35.4 MJ/L for New Zealand and UK energy consumption, and the emissions of 0.068 kg CO_2e/MJ and 0.065 kg CO_2e/MJ respectively. The reason for this difference in CO_2 emissions was due to different energy sources used to produce diesel in these countries (Saunders, Barber & Taylor 2006, p. 33).

Wells (2001, p. 25) estimated the CO_2 emissions of diesel consumption to be 0.0741 kg CO_2e/MJ of energy to produce diesel, based on the carbon emission rate of 0.020

kg C/MJ published by IPCC (1996). The value of 0.0067 kg CO_2e/MJ must be added to the number above for fugitive emissions and, thus the overall diesel emission rate of 0.0808 kg CO_2e/MJ was calculated for on-farm applications.

Australian Climate Change Education Network (2007, p. 1) suggested the emissions of 38.6 MJ/L or 45.6 MJ/kg of diesel used in Australia. However, this study did not indicate a value for on-farm applications emissions in Australian agricultural sector.

Based on the work of Chen and Baillie (2007, p. 14), in this thesis, values of 39 MJ/L and 2.89 kg CO_2e/L of diesel will be used as energy and emissions input conversion rates respectively.

Electricity

Electricity is a common power source in cotton irrigation systems. Depending on water availability and energy costs, either diesel or electric pumps are used. Emissions rate for New Zealand electricity was estimated to be 0.209 kg CO_2e/kWh with the energy conversion rate of 8.18 MJ/kWh (Wells 2001, p. 25). Chen and Baillie (2007, p. 14) adopted the emissions of 1.051 kg CO_2e/kWh and energy uses of 36 MJ/kWh in Australia. This variance in emission rates is due to variability in electricity supply systems in different countries and regions. In this thesis 1.051 kg CO_2 and 36 MJ per kWh will be used for emissions and energy consumption conversion rates respectively. These results are summarised in Table 4.2.

Table 4.2: Diesel and electricity conversion rates with relevant emissions

Energy Type	Energy Coefficient	Emissions Conversion Rate
Diesel	39 MJ/L	2.89 kg CO_2e/L
Electricity	36 MJ/kWh	1.051 kg CO_2e/kWh

Tillage

Tillage is series of soil preparation operations, including subsoiling, discing, chisel ploughing or harrowing. Tillage operations are usually employed before the cotton planting stage, to prepare the seedbed and promote the seed germination by creating a suitable growing environment (Chen & Baillie 2007, p. 6). Tillage operations require high energy input, as the soil manipulation is cost and labour intensive. In this study, tillage and its related calculations exclude energy consumption and emissions of labour or related sub products. Nowadays, various tillage operations are employed and the most common three types are Zero, Minimum and Conventional tillage.

Harrowing

Harrowing is performed during tillage wherever necessary. It is performed by an implement attached to a tractor, thus using diesel as the main power source. Two most common types of harrowing in cotton farming are power harrowing and light harrowing/rolling, depending on soil condition.

Planting

Planting consists of placing the seed into the specific depth and covering it with soil. For cotton production, two main types of planting methods are employed − conventional and direct drilling. As planters are tractor implements, diesel is the only power source in this operation.

Weeding

Weeding consists of manual or machine based operations which result in removal of unwanted weed plants from the cotton lands. It is expensive when done manually due to the high labour cost. In most Australian cotton farms the weeding operations are mechanised, unless the crop rows are narrow. Thus, diesel is the only energy source, as manual weeding is excluded from this study.

Fertilising and Spraying

Crop maintenance requires a series of applications, e.g. weed control, fertilising and pesticide treatments. Based on plant height and row width, boom or shielded spaying systems can be employed. Chemicals can be applied by ground or aerial spraying, both using fuel as energy source. In this thesis, fertilising and spraying exclude the production chain of implements or chemicals, as they are included in indirect applications.

Aerial Spraying

Aerial spraying may be used in cotton farming, to ensure crops are protected throughout the season. This method is often recommended due to ground water safety, soil and crop protection, saving, avoidance of off-target spray etc.

Australian Climate Change Education Network (2007, pp. 1-2) estimated the aviation kerosene energy consumption as 36.8 MJ/L or 46.4 MJ/kg of fuel and emission of 3.15 kg CO_2e/kg or 4 kg CO_2e/L. However, as – according to the Royal Commission on Environmental Pollution (2002, p. 9) report− the emissions are released directly into the atmosphere, the areal exhaust was found to be 2.7 times greater than the ground fuel emissions. This finding is excluded from the present study, as aerial spraying is typically done at the elevation of 20 – 40 m from the agricultural ground.

Figure 4.2: Aerial spraying

The following table shows the energy and emissions conversion rates for aerial spraying which will be used in this study.

Table 4.3: Energy consumption and emissions from aerial spraying

Type of Application	Energy Conversion Rate	Emissions Conversion Rate
Aerial Spraying	36.8 MJ/L	4 kg CO_2e/L

Fuller (2009, p. 1) has estimated that aerial spraying is using 200 L of fuel per hour in Darling Downs in southern Queensland, Australia. Thus, based on average aerial spraying application efficiency of 1.8 ha/min, 1.85 L of fuel per hectare is used.

Irrigation

Cotton in Australia can be planted dry-land (rain growth) or irrigated. The most common type of cotton irrigation in Australia is the furrow or flood irrigation system, followed by sprinkler or centre pivot systems. It has been estimated that 92% of total irrigated cotton production systems in Australia are under furrow irrigation. It is typically powered by diesel engines or electric motors (Chen & Baillie 2007, p. 10). Based on irrigation method and its power source, diesel or electricity impact factors can be applied to calculate the energy consumption and emissions from irrigation operations.

Jacobs (2010. p. 35) calculated the energy consumption for life cycle analysis of Border Check (Furrow Irrigation) to be 4.6 GJ/ha/year and 6.14 GJ/ha/year for Centre Pivot (Lateral move) systems. These values covered initial and recurring embodied energy, as well as operational components and decommissioning.

Australian irrigation systems are often dependant on electricity, where Chen and Baillie (2007, p. 14) estimated the emission factor of 1.051 kg CO_2 equivalent per kWh of electricity. Based on this emission factor, the values of 0.292 kg CO_2/MJ/ha/year for furrow irrigation and 0.278 kg CO_2e/MJ/ha/year for lateral move will be used in this study.

The following table shows the energy consumption and emissions conversion factors for various irrigation systems employed in this thesis.

Table 4.4: Energy and emissions conversion rates for different irrigations systems

Type of Irrigation	Energy Conversion Rate	Emissions Conversion Rate
Furrow	4.6 GJ/ha/year	0.292 kg CO_2e/MJ/ha/year
Lateral move	6.2 GJ/ha/year	0.278 kg CO_2e/MJ/ha/year

The following figure shows the developed model sample input page for 300 ha typical GM cotton on-farm direct applications.

	A	B	D	F
1	Operation Unit	Unit Used	Total Used Energy (MJ)	GHG Emissions (KgCO2)
2	Field Preparation			
3	Tillage (L of Diesel)	30	1170	86.7
4	Harrowing (L of Diesel)		0	0
5	Weeding (L of Diesel)		0	0
6	Fertilising (L of Diesel)		0	0
7	Planting			
8	Tillage(L of Diesel)	5	195	14.45
9	Harrowing(L of Diesel)	20	780	57.8
10	Planting(L of Diesel)	5	195	14.45
11	Weeding(L of Diesel)		0	0
12	Fertilising(L of Diesel)	5	195	14.45
13	In Crop Operations			
14	Weeding(L of Diesel)		0	0
15	Fertilising(L of Diesel)	5	195	14.45
16	Spraying(L of Diesel)	5	195	14.45
17	Irrigation			
18	Furrow or Flood (ha/year)	1	4600	1343.2
19	Centre Pivot (ha/year)		0	0
20	Sub-Surface Drip (ha/year)		0	0
21	Harvest			
22	Harvesting(L of Diesel)	45	1755	130.05
23	Infield Operations(L of Diesel)	24	936	69.36
24	Post Harvest			
25	Crop Destruction(L of Diesel)	20	780	57.8
26	Aerial spraying (L of fuel)	9.25	340.4	37
27				
28	Total Direct On farm		11336.4	1854.16

Figure 4.3: On-farm direct applications cover page of the developed model

4.3.3 On-farm Indirect Applications

This section of the developed model calculates the energy consumed by production chains of fertilisers, chemicals, seeds, agricultural machineries and implements, as well as transport of the above-mentioned products. The emission rates for all above elements are also calculated. The following table shows all on-farm indirect applications and their subsections covered by this study.

Table 4.5: List of on-farm indirect applications covered by this study

Manufacturing of Chemicals	Herbicides (L)
	Insecticides (Kg)
	Fungicides (L)
	Plant Growth Regulator (Kg)
	Oil (L)
Manufacturing of Fertilisers	Nitrogen (Kg)
	Ammonia
	Urea
	Manure
	Diammonium Phosphate (Kg)
	Potassium
	Sulphur (kg)
Manufacturing of Seeds (Kg)	
Transport of Chemicals and Fertilisers (kg)	
Transport of Seeds (kg)	
Agricultural Machinery Production	Harvester (kg)
	Silage Feed Wagon (kg)
	Bale Feeder (kg)
	Front End Loader (kg)
	Fertiliser Spreader (kg)
	Sprayer (kg)
	Hay Rake (kg)
	Hay Baler (kg)
	Tractors (kg)
	Farm Implements (kg)
	Plough (kg)
	Discs (kg)
	Cultivator (kg)
	Harrows (kg)
	Roller (kg)
	Drill (kg)
	Trailer (kg)
	Mower (kg)
	Planter (kg)

4.3.4 On-farm Indirect Inputs

Fertilisers

Fertilisers are significant on-farm indirect energy consumption inputs, particularly when nitrogenous fertilisers are used. There are different types of fertilisers e.g. Nitrogenous, Phosphate, Potassium, Sulphur and compound fertilisers. The formula used in this study to calculate the energy consumption and emissions to produce a unit of fertiliser is given below:

[Energy used to produce 1 kg materials × consumed material's weight (kg)]

Based on consumption rate for each fertiliser in cotton farming, total manufacturing energy and emissions can be calculated.

Nitrogenous Fertilisers

Wells (2001, p. 26), as well as Saunders, Barber and Taylor (2006, p. 34), used the energy rate of 65 MJ/kg and emissions of 3 kg CO_2e/kg for unit of nitrogenous fertilisers. The values of 57 MJ/kg for energy consumption and 3.15 kg CO_2e/kg as emissions from Nitrogen based fertilisers were used in practice (Cotton Incorporated, 2009). In this study, conversion rates of 65 MJ/kg and 3 kg CO_2e/kg or 0.05 kg CO_2e/MJ are adopted.

As about 40 - 50% of urea's weight is nitrogen. Lewis (1982) estimated a value of 36.1 MJ/kg of Urea manufactured. This was supported by Mudahar and Hignett (1982) who adopted the value of 36.6 MJ/kg. In this thesis 33.8 MJ/kg will be used for the manufacturing energy consumption of Urea. Carbon dioxide emissions arising from Urea manufacture, based on IPCC (1996) recommendations, were estimated to be 1.8 kg CO_2e/kg NH_3 and this value is used in this study.

Although the "manufacturing" of feedlot manure does not require any fossil fuel energy inputs, the collection, transportation and spreading do. As the feedlot manure consists of 5% Nitrogen (Wylie 2007, p. 4), the “embodied” energy in this thesis was arbitrarily assumed to be 5% of that of nitrogenous fertiliser. Because of the rapid advance in this subject, other more precise emission factors may exist but were not always employed in this thesis.

Phosphate Fertilisers

Leach (1976) used the rate of 13.8 MJ/kg of phosphate in his study, whilst Cotton Incorporated (2009, p. 28) recommended 7 MJ/kg to produce phosphate fertilisers in the United States with the relevant emissions of 0.62 kg CO_2e/kg or 0.08 kg CO_2e/MJ. The reason for this difference could be due to the source of energy used in phosphate fertilisers production processes. Saunders, Barber and Taylor (2006, p. 34) adopted a value of 15 MJ/kg for phosphate manufacturing processes. In this study, a rate of 15 MJ/kg of P is used as the model conversion rate to produce phosphate based fertilisers. The emissions conversion rate of 0.06 kg CO_2e/MJ, as recommended by Wells (2001, p. 27), will also be used in this study.

Potassium

Mudahar & Hignett (1987) estimated 3.8 MJ/kg to be the average energy used in the world to manufacture potash. In another study, Dawson (1978) estimated the value of 9.7 MJ/kg of K, compared to 7 MJ/kg estimated by Cotton Incorporated (2009, p. 28), required to produce potassium fertilisers in the United States ,with the relevant emissions of 0.44 kg CO_2e/kg or 0.06 kg CO_2e/MJ. This study will use the values of 10 MJ/kg and 0.06 kg CO_2e/MJ for energy and emissions respectively.

Sulphur

Dawson (1978) adopted the value of 5.3 MJ/kg of Sulphur, whilst Mudahar and Hignett (1987) used the rate of 7.4 MJ/kg. In this study, 5 MJ/kg and 0.06 kg CO_2e/MJ will be used for energy and emissions conversion rates respectively. The following table summarises the energy required to produce various fertilisers and their relevant emissions.

Table 4.6: Energy consumption and emissions to manufacture fertilisers

Fertiliser Component	Energy Use (MJ/kg)	Emission Rate (kg CO_2e/MJ)
N	65	0.05
P	15	0.06
K	10	0.06
S	5	0.06
Feedlot Manure	3.25	0.0025

Manufacturing of Seeds

Cotton Incorporated (2009, p. 28) was a study on life cycle inventory of cotton farming in United States. It employed the rates of 33 MJ and 2.38 kg CO_2e to produce a kg of cottonseeds in the United States. In contrast, a much lower value of 11.8 MJ/kg was estimated by Singh (2002) to produce cottonseeds in Indian cotton farming. In the present study, 33 MJ/kg and 2.38 kg CO_2e/ kg of cottonseeds will be used as energy and emissions conversion rates. The following table summarises energy and related emissions factors employed in this study.

Table 4.7: Energy consumption and emissions to manufacture cottonseeds

Type of Application	Energy Use (MJ/kg)	Emissions Coefficient (kg CO_2e/ kg)
Manufacturing of Seeds	33	2.38

Transport of Chemicals and Seeds

Transport of Chemicals and Seeds starts with the collection from manufacturing companies and ends at on-farm delivery point, thus it is highly dependent on the distance between the farm and the product manufacturing companies. The main energy source is diesel, used by trucks or light vehicles for transport purposes.

Saunders, Barber and Taylor (2006, p. 43) estimated transport energy consumption and emissions from Italy to the UK based on the consumption rate of 0.0102 litres of diesel per tonne km. This number was based on a fully loaded truck with maximum weight of 44 tonnes, which is the limit of European Union on international transport. This is equivalent to 0.46 MJ per tonne km, based on Australian diesel energy coefficient from the Table 4.2 for the stated quantity of diesel.

The CO_2 emissions are adopted to be 0.046 kgCO_2e/tonne km, based on the Australian carbon emissions for diesel consumption recommended by Australian Greenhouse Gas Office (AGO), as previously described in Table 4.2. The following table summarises the adopted values for transport of seeds and chemicals.

Table 4.8: Transport of chemicals and seeds energy coefficients and emissions conversion rates

Type of Application	Energy Conversion Rate	Emissions Conversion Rate
Transport of Chemicals	0.46 MJ per tonne km	0.046 kgCO_2e/t-km
Transport of Seeds	0.46 MJ per tonne km	0.046 kgCO_2e/t-km

Agricultural Machinery Production

The cotton farming agricultural machinery includes tractors, harvesters and related implements, e.g. plough and fertiliser spreader. The model developed in this study will use the energy coefficients and relevant emissions to estimate the total life cycle energy and emissions related to the manufacture of cotton farming machinery per cotton farming season.

This includes the energy used in smelting, steel oxidation process, repair and maintenance costs (allowance), and freight from producing countries to destinations, but excludes the human resources.

Tractors and Harvesters

Tractors are used in most farming systems. Typically for a 300 ha cotton farm in Australia, one 150 – 200 kW-powered tractor is required. To calculate the amount of energy used in tractor manufacture, embodied energy in raw materials and fabrication energy need to be determined. Dawson (1977, 1978) estimated an average of 162.5 MJ/kg was required to manufacture tractors and harvesters in New Zealand.

In another study, Doering (1980) adopted a value of 70 MJ/kg for United States agricultural machinery and Stout (1990) used a value of 85 MJ/kg as an international value.

McChensey, Sharp & Hayward (1978) used an energy conversion factor of 90 MJ/kg and added 60% for repair and maintenance costs over the total working life of tractors and harvesters, resulting in 144 MJ/kg. This value is close to 159 MJ/kg suggested by Roller et al. (1975). In this study the value of 160 MJ/kg of tractors and harvesters is used, which includes the repair and maintenance cost of machinery.

For equivalent carbon dioxide emissions, it was assumed that fossil fuel energy emissions coefficient is 0.07 kg CO_2e/MJ. However, IPCC (1996) advised an additional 1.6 kg CO_2e/kg for oxidation of coke during smelting process. As steel is the main element of tractors and harvesters, multiplying 160 MJ/kg by 0.07 kg CO_2e/MJ and adding 1.6 kg CO_2e/kg for oxidation yields the final value of emissions adopted in this study. Thus 12.8 kg CO_2e/kg of vehicle mass and 0.08 kg CO_2e/MJ of energy will be used in this thesis.

Farm Implements

Farm implements are usually tractor powered. Dawson (1977, 1978) estimated an energy coefficient of 75 MJ/kg for New Zealand, and Wells (2001, p. 35) adopted 80MJ/kg for energy consumption to produce the implements in the USA. In this thesis, energy coefficient of 80 MJ/kg of farm implement weight and the relevant CO_2 emissions of 7.2 kg CO_2e/kg or 0.09 kg CO_2e/MJ are adopted. The assumed implement working life is 20 years.

The following equation is employed in this study to calculate the energy consumption and emissions from manufacturing of agricultural machinery and implements:

[Energy used to produce 1 kg of machinery / (Life period (years) × Total number of paddocks which machinery are used)] × Machinery or materials weight (kg)]

The following table shows the energy and carbon dioxide emissions conversion rates to produce agricultural machinery.

Table 4.9: Tractor and farm implements production energy and emissions conversion rates

Machinery Type	Energy Conversion Rate	CO_2e Emissions	Work Life (years)
Tractors	160 MJ/kg	12.8 kg CO_2e/kg	15
Farm Implements	80 MJ/kg	7.2 kg CO_2e/kg	20

4.3.5 Off-farm Direct Inputs

Trucking

Trucks are often used for cotton bale pick up and transfer to the ginning points in each agricultural region. After ginning operations, trucks typically pick up and transfer the export-ready cotton to the shipping port, which is the end point of the cotton life cycle assessment in this study. Various types of trucks are used in this process, each consuming the energy in different rates. Transport produces 15% of all Australian greenhouse gas emissions. Based on transportation report of Australian Climate Change Education Network (2007, p. 2), trucks and cars as road transport account for 89% of the transport produced emissions in Australia.

Cotton Incorporated (2009, p. 28) reported average values of 113 MJ/ha and 9.09 kg CO_2e/ha respectively of energy consumption and related emissions for cotton transport from field to the gin.

Saunders, Barber and Taylor (2006, p. 44) used 0.419 MJ/tonne km as transport energy coefficient for international transport between Italy and UK, based on the estimate that 0.01202 litres of diesel is used for transport per tonne km of dairy products. In this study, CO_2e coefficient for trucking operations was found to be 0.027 kg CO_2e/tonne/km.

It is reasonable to assume that cotton transportation accounts for the same energy rates as that of cottonseeds or chemicals transport, which is previously reviewed in this chapter. This is equivalent to 0.46 MJ/tonne/km, based on Australian diesel energy coefficient given in Table 4.2.

Accordingly, the adopted CO_2 emission is 0.046 kgCO_2e/tonne/km, based on the carbon emissions for diesel usage reported by Australian greenhouse gas office, as previously described in Table 4.2. The reason for this difference between European and Australian values is due to different sources of energy used during fuel production. Furthermore, fuel consumption rates may vary from one vehicle to another.

The following table summarises the adopted energy and emissions values for cotton transportation from field to the gin point. Obviously, the final model outputs will also highly be dependent on the distances between the farm, ginning company and the port.

Table 4.10: Energy consumption and emissions of cotton trucking (from field to gin)

Type of Application	Energy Conversion Rate	Emissions Conversion Rate
Transport of Cotton	0.46 MJ per tonne km	0.046 kgCO_2e/t-km

Ginning

Ismail (2009, p. ii) measured the Australian cotton ginning processes energy consumption and greenhouse gas emissions for various gin companies and calculated the Australian national average as 52.3 kWh per bale and the corresponding 60.38 kg of CO_2e emissions. Based on estimated 217.72 kg of cotton per bale and 1 kWh is equivalent to 3.6 MJ, in this study the energy of 0.86 MJ/kg and its related emissions 0.27 kg CO_2e/kg were used.

Cotton Incorporated (2009, p. 28) estimated the value of 1572 MJ/ha based on 933 kg/ha of fibre, approximately half the Australian average in 2006-07. This number equals to 1.68 MJ/kg of cotton fibre. They estimated the emissions to be 47.47 kg C_e/ha (C_e= CO_2 divided by 3.667), equivalent to 174.07 kg CO_2e/ha or 0.186 kg CO_2e/kg of processed cotton. Energy consumption reported by Cotton Incorporated (2009, p. 28) was found to be nearly double the Australian average, due to the low yield, as in 2006-07 Australian yields was nearly 100% higher than that of USA.

In this thesis, energy coefficient value of 0.86 MJ/kg and emissions conversion factor of 0.27 kg CO_2e/kg of processed cotton will be used as conversion rates in modelling. The following table summarises the above numbers. No allocation for cotton by-products has been included in this thesis.

Table 4.11: Energy consumption and emissions of cotton ginning processes

Type of Application	Energy Conversion Rate	Emissions Conversion Rate
Ginning	0.86 MJ/kg Cotton	0.27 kg CO_2e/kg Cotton

4.3.6 Off-farm Indirect Inputs

Manufacturing of Transport Machinery

Heavy Vehicles, Light Trucks, Utilities and Motor Bikes

This category includes transport vehicles used to transfer cotton from field to the gin or from gin to the port dock. As their manufacturing processes is using energy, the method previously employed in this chapter to calculate the energy required to manufacture agricultural machinery will also be used in this section.

Wells (2001, p. 35) estimated that manufacturing process of heavy vehicles, light trucks, utilities and motor bikes requires 160 MJ/kg of their weight, equivalent to 12.8 kg CO_2e/kg of machinery mass. Average working life is assumed to be 15 years for heavy and light trucks, and 10 years for motorbikes. The total value, calculated by multiplying the vehicle mass by energy or emission rate, must be further divided by their average working life and farming seasons to derive seasonal equivalent.

Saunders, Barber and Taylor (2006, p. 42) estimated that trucks and vehicles are comprised of 95 percent steel and 5 percent rubber. In New Zealand, steel production uses 32 MJ/kg, whilst the rubber consumes 110 MJ/kg. Thus the authors estimated the final value of 65.5 MJ/kg as energy conversion rate for heavy vehicle, light vehicle and motorbike production.

Wibberley et al. (2000) estimated the emission value of 2.1 CO_2e/kg to produce Australian steel. By adding 1.6 kg CO_2e/kg for oxidation processes, the final value of 3.7 kg CO_2e/kg is derived and is adopted in this study for Australian steel production. When expressed in terms of manufacturing energy, Saunders, Barber & Taylor (2006, p. 42) adopted a carbon dioxide emission of 0.09 kg CO_2e/MJ for these vehicles.

For carbon dioxide emissions from heavy, light vehicle and motorbike production system, 0.07 kg CO_2e/MJ was adopted as the fossil fuel energy emissions coefficient. As before, IPCC (1996) advised adding further 1.6 kg CO_2e/kg for oxidation of coke during smelting process. As the main vehicle construction element is steel, CO_2 emissions are calculated by multiplying 160 MJ/kg by 0.07 kg CO_2e/MJ and adding 1.6 kg CO_2e/kg for oxidation. Thus, the final values of 12.8 kg CO_2e/kg of vehicle mass or 0.08 kg CO_2e/MJ of energy are used in this thesis.

Each of the above-mentioned energy values must further be divided by vehicle average working life and calculated for the number of days (2 days per year) used for cotton farming transport purposes. In this thesis a value of 160 MJ/kg for energy consumption is employed over the total vehicle life. This is equivalent to 10.67

MJ/kg for heavy and light vehicles, and 16 MJ/kg for motorbikes. The following table shows the energy and emissions coefficients for heavy, light vehicle and motorbike manufacturing chain.

Table 4.12: Energy consumption and emissions from heavy, light vehicle and motorbike production

Type of Application	Energy Conversion Rate	Emissions Conversion Rate
Heavy, Light Vehicles	10.67 MJ/kg per year	0.08 kg CO_2e/MJ
Motor Bikes	16 MJ/kg per year	0.08 kg CO_2e/MJ

Buildings

Buildings involved in the cotton life cycle typically include the gin factory or cotton storage sheds, as energy consumed to build a shed or gin adds the greenhouse gas emissions.

Wells (2001, p. 37) estimated that 590 MJ of energy is required to build one m^2 of farm buildings with related emissions of 0.1 kg CO_2e/MJ over the 20 years of working life.

Table 4.13 shows the values used in this thesis for building energy and emissions conversion factors.

Table 4.13: Energy consumption and emissions for building construction

Type of Application	Energy Conversion Rate	Emissions Conversion Rate
Buildings	590 MJ/m^2	0.1 kg CO_2e/MJ

Lubricants

Lubricants are used in machinery parts. IPCC (1996) recommended a value of 40 MJ/litre of lubricants, whilst Wells (2001, p. 24) stipulated that every delivered MJ of energy equals to 1.23 MJ of primary energy value. Thus an extra 23% energy must be added to the above value, yielding the total 49.2 MJ/litre to be used for lubricant energy consumption. The related CO_2 emissions are assumed to be 0.0367 kg CO_2e/MJ, based on the IPCC guidelines for carbon emissions of 20 g C/MJ (73.3 gCO_2/MJ) and 50% oxidation during lubricant usage. Thus the total emission for lubricant usage was found to be 0.0434 kg CO_2e/MJ.

Australian Greenhouse Office (2004, p. 6) estimated the energy value of 40.8 MJ/litre and emissions factor of 0.0814 kg CO_2e/MJ for full fuel cycle of Australian fuel oil.

Saunders, Barber and Taylor (2006, p. 31) analysed the lubricant production energy consumption rate and adopted the value of 38.5 MJ/litre for consumer energy. With 23 percent allowance of lubricant production and transport in New Zealand, the total rate of 47.4 MJ/litre of primary energy was derived.

The same authors estimated the energy consumption for lubricant production to be 38.5 MJ/litre for consumer energy and 44.8 MJ/litre of primary energy in the UK. Related CO_2 emissions of 0.0359 kg CO_2e/MJ and 0.0332 kg CO_2e/MJ of primary energy are adopted for New Zealand and UK respectively.

In this study, values of 40.8 MJ/litre and 0.0814 kg CO_2e/MJ provided by Australian Greenhouse Office (AGO) will be used as model conversion rates for lubricant fabrication energy and emissions calculations. The following table summarises the above values.

Table 4.14: Energy consumption and emissions of lubricants consumption

Type of Application	Energy Conversion Rate	Emissions Conversion Rate
Lubricants	40.8 MJ/litre	0.0814 kg CO_2e/MJ

4.3.7 Soil Emissions

Soil emissions (carbon dioxide released from soil) are one of the main emission sources from cotton farming and arise mainly during tillage applications. In addition, nitrous oxide (N_2O) is released from the nitrogen based fertiliser application. The amount of emissions from the tillage and fertiliser application highly depends on the farm location, as different soils contain different values of carbon and moisture.

Navarro and Grace (2009, p. 7) estimated the soil emissions as 376 kg CO_2e/ha, based on average 200kg/ha application of nitrogen based fertilisers in Australian cotton farming systems. In this thesis, as a first approximation, a value of 300 kg

CO_2e/ha will be adopted. The following table shows the soil emissions conversion factor used in this study arising from these applications. Crop residues had not been included in this study.

Table 4.15: Soil emissions from tillage and nitrogen based fertiliser application

Type of Application	Emissions Conversion Rate
Soil emissions	300 kg CO_2e/ha

4.4 Software Design and Implementation

One of the main aims of this project is to develop a framework and a software tool to assess Australian cotton energy consumption and greenhouse gas emissions (GHG) from field to the port. As outlined previously, the software is divided into five basic sections of on-farm direct, on-farm indirect, off-farm direct, off-farm indirect, and soil emissions, and will therefore have a layered structure as shown in Figures 4.1, 4.3 and 4.4.

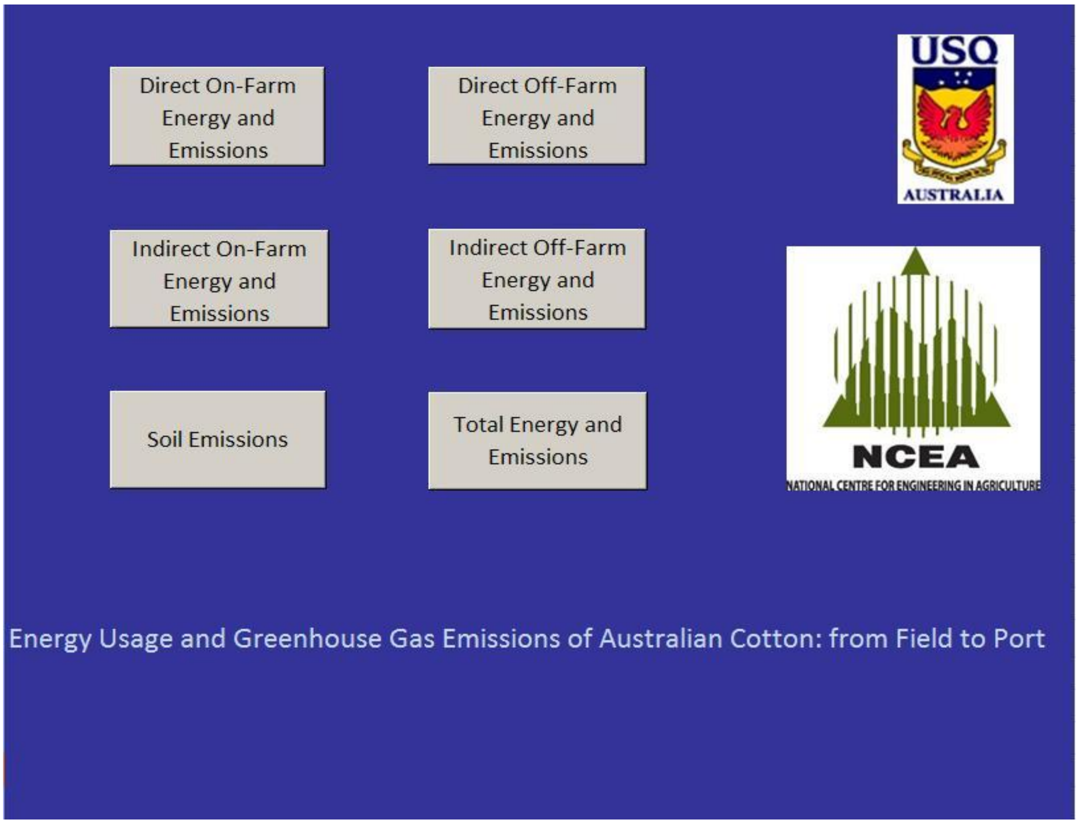


Figure 4.4: The main page of the developed model

In summary, the software calculates the energy uses and GHG emissions by units of activities (Fig. 4.3). For this purpose, the Excel based model relies on the built-in energy and emissions conversion rates from various sources, as described in previous sections of this chapter.

The developed software is self-explanatory and easy to use. To enter the data into the software, the user selects the appropriate on-farm or off-farm section, and inputs the specific number of unit operations performed in that section. The calculator will then be able to automatically convert the input data into estimated energy use and greenhouse gas emissions based on the default conversion rates built into the software.

The developed software can give an excellent feedback on both the energy consumption and greenhouse gas emissions for each farming section separately, or as a whole. This will enable the Australian cotton industry to monitor and potentially reduce their energy consumption and carbon footprint from their agricultural systems.

4.5 Conclusions

This chapter has presented a framework for assessment of Australian cotton energy consumption and greenhouse gas emissions (GHG) from field to the port. The relevant conversion rates for different cotton production stages through its supply chain have been determined. An Excel-based model has also been implemented to calculate and profile the energy consumption and greenhouse gas emissions of cotton production systems. These include both the direct and indirect energy inputs for both on-farm and off-farm operations, as well as related soil emissions due to soil biological activities.

By itemizing farm energy and resource inputs from each operation, it has been shown that the developed model is capable of calculating both the total and individual energy consumption and relevant greenhouse gas emissions for different operations, thus allowing for the comparison between different farming systems. These will be further discussed in the following chapters.

Chapter 5 - Farm Survey Data

This chapter presents the Australian cotton farm survey data, including the on-farm and off-farm stages of cotton production chain, and both direct and indirect applications. Data collection methodology used in this study will also be introduced.

The data collection incorporated application rates for various farming operations and off-farm applications, such as transportation. In particular, detailed information from two farms was obtained and further used as input in the developed Excel based model to demonstrate the calculations of energy consumption and greenhouse gas emissions. A total of 15 case studies (paddocks) will be presented. The data for case studies 1 to 12 were collected from the 1^{st} farm and the values for case studies 13 to 15 were gathered from the 2^{nd} farm.

5.1 Data Collection Methods

Data collection in this study was based on the farm surveys (farmer interviews and records) in addition to other published data. Farm interviews were a part of farm survey process and for this purpose interview forms were designed and shared with farmers. A copy of the developed interview forms can be found in Appendix 1.

5.1.1 Farmer Interviews

These interviews took place in a face-to-face form by previous appointment made via telephone or e-mail. At the beginning of each farm survey, a two-hour period was allocated for interview, during which the questionnaire was given to the farmer. The designed questionnaire included the application rates for different farming operations and irrigation water consumption, as well as machinery used in their farms. During this interview, farmer opinions about further improvements and recommendations were also recorded.

5.1.2 Interview Questionnaire Design

The developed farmer interview questionnaire consisted of two main sections of on-farm direct and indirect inputs. The first section included on-farm fuel consumption in applications such as tillage, fertilising, planting, and spraying. Farmer was also asked to identify the irrigation type, water usage and energy source. In the second part of the questionnaire, seed, fertilisers and chemicals consumption rates were covered. The machinery used at cotton paddock for on-farm and off-farm purposes and the average mass of each machine were also included. The last questionnaire section provided the farmer with an opportunity to offer suggestions and recommendations.

The section below presents the detailed applications list and fuel usage rates collected for further input into the developed Excel-based model to calculate the energy consumption and greenhouse gas emissions of that particular paddock.

5.1.3 On-farm Direct Applications

Tillage

Tillage operations usually include the hilling, cultivation and rolling activities in cotton farming.

Harrowing

In this section of the questionnaire, harrowing application in field preparation and prior to planting was covered, and fuel consumption data was collected from farmers for use as input in the developed model.

Weeding

Fuel consumption in the weeding operations was collected only if machine based physical weeding was applied in the cotton field.

Planting

During the face-to-face interview with cotton farmers, the amount of diesel used by tractor during planting session of the cotton farming was collected.

Fertilising and Spraying

In this section of the questionnaire fuel consumption rates for different fertilising and spraying applications were collected for inputs into the Excel-based model to calculate the energy consumption and emissions of these on-farm operations. Each collected fuel consumption rate is multiplied by the number of times the applications were repeated.

Harvesting and Crop Destruction

During farm surveys, diesel usage of these on-farm applications was collected to be used for energy and emissions calculations.

Irrigation

At the last stage of the direct on-farm applications farm survey, irrigation type, energy source, water usage and the amount of energy used for the cotton irrigation was collected.

5.1.4 On-farm Indirect Applications

During this phase of cotton farming the amount of chemicals, fertilisers and seeds used in the cotton production was recorded. This enabled the calculation of energy consumption and relevant emissions of fertilisers and seed production processes. The seed and chemical transport energy and emissions, based on their average mass, were also recorded. In addition, wherever applicable, the following specific inputs were also collected.

Table 5.1: List of chemicals and seed to calculate the usage amount in cotton farming

Herbicides (L)	Urea (kg)
Insecticides (kg)	Phosphate (kg)
Fungicides (L)	Potassium (kg)
Plant growth regulator (kg)	Sulphur (kg)
Oil (L)	Seeds (kg)
Nitrogen based fertilisers (kg)	Feedlot manure (kg)

Agricultural Machinery Usage

During face-to-face interviews, farmers were required to identify the machinery used in their cotton farming and provide the average machinery mass where applicable. This data was used to calculate the energy consumption and related greenhouse gas emissions from manufacturing of agricultural machinery related to each cotton-farming season.

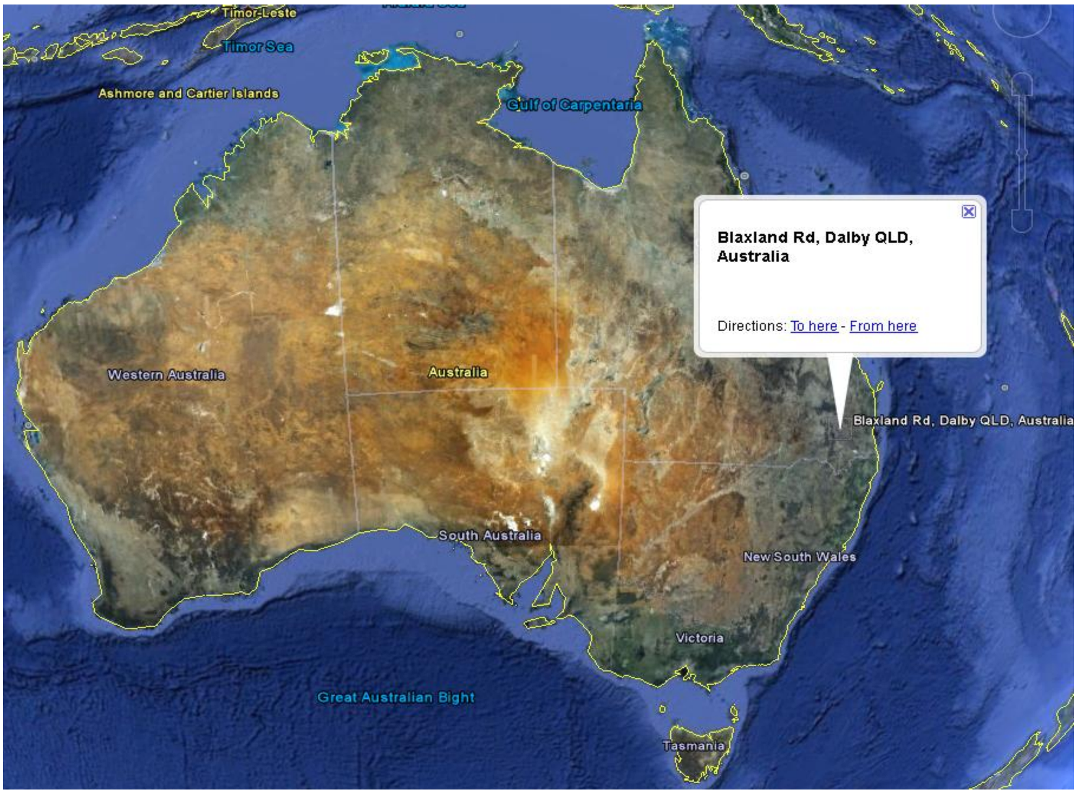
5.1.5 Computer Based Data Collection Based on Farmers' Records

To convert farm survey data into exact model inputs in this thesis, values produced by computer based data collection software PAM ver. 6.7.0 were used. Many Australian cotton farmers are using this tool to calculate and monitor their application rates and costs. This software collects the application data for seeding, planting, chemical applications, fertiliser applications, irrigation, machinery operation, manual tasks and harvest information with details and the date, type of application, application rates and total costs.

5.2 Farm Surveys

5.2.1 Farm Number 1, Werrina Downs (Queensland, Australia)

Bremner farms are family owned. The fields are located on Toowoomba – Dalby Warrego highway, 20 km away from Dalby in south eastern region of Queensland State, Australia. The following map shows the location of the Bremner cotton farms on Australian map.



Source: (Google earth maps)

Figure 5.1: Bremner Farms Location, Dalby, Queensland, Australia

Bremner farms are a complex of 12 combined cotton paddocks under different cotton varieties and farming practices. The paddock description may be found in Appendix 4. The following table lists their main details.

Table 5.2: Cotton varieties for each paddock in Bremner farms

Paddock	Area	Cotton Variety	Description
01 WD	8.7 Ha	Sicot 80BRF	Combination of Bollgard II® and Roundup Ready Flex®
04 WD	32.4 Ha	Sicot 80BRF	Combination of Bollgard II® and Roundup Ready Flex®
	2 Ha	Sicot 80 RRF	Roundup Ready Flex®
05 WD	63.6 Ha	Sicot 75	Conventional
07B WD	4.4 Ha	Sicot 80BRF	Combination of Bollgard II® and Roundup Ready Flex®
01 JK	6.4 Ha	Sicot 80 RRF	Roundup Ready Flex®
02 JK	66.2 Ha	Sicot 80 RRF	Roundup Ready Flex®
03 JK	60.4 Ha	Sicot 80L	Liberty Link®
08 TM	42 Ha	Sicala 45B	Bollgard II®
09 TM	32.1 Ha	DP412B	Bollgard II No Herbicide Traits
13A	23.4 Ha	Sicot 70BRF	Combination of Bollgard II® and Roundup Ready Flex®
13 B	24.8 Ha	Sicot 71BRF	Combination of Bollgard II® and Roundup Ready Flex®

Source: (Appendix 5)

Data were collected for on-farm phases of all 12 paddocks. Each paddock's cotton farming applications are provided in detail in Appendix 5. All data collected from the Bremner farms are related to the 2009 – 2010 cotton farming season.

The ginning company used by this farm is Dunavant Ginning, Dalby, located just 10 km of the Bremner farms. The distance from the ginning company to the Brisbane port for trucking purposes is estimated to be 206 km. The average distance between the chemical, fertiliser and seed manufacturing companies and the cotton field is assumed to be 200 km in this study. Ginning company buildings in this thesis are assumed to be 3000 m^2 over the 30 years of average life, equivalent to 100 m^2 per year. By assuming that this ginning company handles the cotton products from 50 different farms per year, the value of 2 m^2 will be used for the case studies.

The following data were collected from face to face interview with Kim Bremner at Bremner Farms and PAM 6.7.0 reports generated by the farmer. In this chapter, Case study 1 will be used as the base case for the remaining 11 case studies in Bremner farms, as it employed GM cotton under conventional tillage and furrow irrigation which is the most common Australian farming system.

Only the full list of fuel consumption and machinery for case study 1 is presented below, whilst the information for case studies of 2 – 12 is given in Appendix 6. The paddock description, cotton seed and yield, as well as chemicals and herbicide usage rates will be described for each paddock separately. Following case study details have also included the irrigation water consumption.

5.2.1.1 Case Study 1 - 12

Case study 1

Paddock: 01 WD

Area: 8.7 Ha

Variety: Sicot 80BRF

Cottonseeds for plantation: 13 kg/ha

Yield: 2187.59 kg per ha

Herbicide: 21.7 L/ha

The chemicals and fertilisers consist of Temik, Sprayseed 250, Roundup ready dry, Dimethoate, Bollgard license, RRFlex license, Gesagard 500, Diuron flowable, DC trate, Rounup CT, Shield, Pulse, Bulldock dual, Dropp liquid, Canopy and Prep. The full list of chemicals and fertilisers used by other paddocks can be found in Appendix 5.

Nitrogen fertilisers: 300kg/ha of Urea

Other fertilisers: 6.4 kg/ha

Manure: 8 tonnes/ha

Irrigation water: 3.3 ML/ha of furrow irrigation

Required 13 runs of tractor in total for all applications

Fuel consumption rates were estimated by the farmer in the earlier stage, and are available in Appendix 7.

Table 5.3: Fuel consumption rates by case study 1

On-farm Operation	Fuel Consumption	Repeating Times	Total Fuel Usage Per ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	5 times	9.25 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Table 5.4 presents the machinery used with the corresponding average mass. As the same machinery types are used in all paddocks, the following equation is used to calculate the energy consumption and emissions from manufacturing of agricultural machinery and implements.

[Energy consumed or emissions to produce 1 kg of machinery / (Life period (years) × Total number of paddock which machinery are used)] × Machinery or materials weight (kg)]

Table 5.4: List of machinery used in Case study 1

Machinery Description		Average Mass
Pioneer 8m Rake		2000 kg
Wallaby Spreader		3000 kg
Agroplow 4m		2000 kg
Rotary Hoe		2500 kg
Lillistons		4500 kg
Light Roller		2000 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
8m Spray Bar		1000 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	**John Deere 4450**	5831 kg
	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg

Source: (Appendix 5)

Heavy vehicles used in this study are assumed to transport cotton from the field to the ginning company and from the gin to the port for export, covering total distance of 216 km. Motorbikes, heavy and light vehicles are used for transportation purposes in Bremner farms. As these vehicles may also be used for transporting other goods, it is arbitrarily assumed that 10% of their energy is allocated to this farm.

Case Study 2

Paddock: 04 WD

Area: 32.4 Ha

Variety: Sicot 80BRF

Cottonseeds for plantation: 13 kg/ha

Yield: 2196.36 kg per ha

Herbicides: 21.8 L/ha

Nitrogen fertilisers: 300kg/ha of Urea

Other fertilisers: 21 L/ha fertiliser

Irrigation water: 4.2 ML/ha of furrow irrigation

Required 12 runs of tractor in total for all applications

From the above data, it can be seen that, data from this paddock was very similar to case study 1 but did not use the feedlot manure and the irrigation water usage was lower (about 0.9 ML/ha).

Case Study 3

This case study employed the Round Up Reday Flex® that required less herbicide and more insecticides. Thus, the Combination of Bollgard II® and Roundup Ready Flex® in the previous case studies must account for lower herbicide rates. Even though different varieties are used, the herbicide application rate in case studies 1 and 3 is the same. The farmer stated that the same application rates were used on some paddocks due to history of each paddock and previous season's crop selection.

Area: 2 Ha

Variety: Sicot 80RRF

Cottonseeds for plantation: 12 kg/ha

Average harvested cotton is estimated to be 2100 kg per ha

Herbicides: 21.7 L/ha

Nitrogen fertilisers: 300kg/ha of Urea

Other fertilisers: 10 L/ha fertiliser

Irrigation water: 4.2 ML/ha of furrow irrigation

Required 11 runs of tractor in total for all applications

From the above data, it can be seen that this paddock was very similar to case study 2 but used significantly less of other fertilisers.

Case Study 4

Paddock: 05 WD

Area: 63.6 Ha

Variety: Sicot 75 Conventional

Cottonseeds for plantation: 11 kg/ha

Yield: 2579.65 kg/ha

Herbicides: 37.35 L/ha

Nitrogen fertilisers: 8900 kg/ha of feedlot manure

Other fertilisers: 9.472 L/ha fertiliser

Irrigation water: 3.2 ML/ha of furrow irrigation

Required 12 runs of tractor in total for all applications

This case study showed the data for conventional cotton that used less cottonseed and irrigation water compared to previous paddocks. The data from this case study used to compare GM and non-GM cotton farming systems.

Case Study 5

Area: 4.4 Ha

Variety: Sicot 80BRF

Cottonseeds for plantation: 13 kg/ha

Yield: 1682.73 kg/ha

Herbicides: 25.2 L/ha

Nitrogen fertilisers: 300kg/ha of Urea

Irrigation water: 4.3 ML/ha of furrow irrigation

Required 9 runs of tractor in total for all applications

It can be seen that the yield in this paddock was significantly lower and consumed fewer herbicides, whilst using more water compared to case study 4.

Case Study 6

Paddock: 01 JK

Area: 6.4 Ha

Variety: Sicot 80RRF

Cottonseeds for plantation: 13 kg/ha

Yield: 2258.91 kg per ha

Herbicides: 34.61 L/ha

Nitrogen Fertilisers: 400kg/ha of Urea

Manure: 1 tonne of feedlot manure

Irrigation water: 3.5 ML/ha of furrow irrigation

Required 12 runs of tractor in total for all applications

From the above data, it can be seen that this paddock required more nitrogenous fertilisers and less irrigation water compared to paddock 5.

Case Study 7

Paddock: 02 JK

Area: 66.2 Ha

Variety: Sicot 80RRF

Cottonseeds for plantation: 13 kg/ha

Yield: 2468.49 kg per ha

Herbicides: 34.85 L/ha

Manure: 10 tonnes/ha

Other fertilisers: 18 L/ha

Irrigation water: 4.5 ML/ha of furrow irrigation

Required 16 runs of tractor in total for all applications

This case study used no nitrogen-based fertilisers. But consumed more water and feedlot manure compared to case study 6.

Case Study 8

Paddock: 03 JK

Area: 60.4 Ha

Variety: Sicot 80L

Cottonseeds for plantation: 13.46 kg/ha

Yield: 2390.15 kg per ha

Herbicides: 42.105 L/ha

Nitrogen fertilisers: 400 kg/ha Urea

Manure: 9 tonnes of feedlot manure/ha

Other fertilisers: 17 L/ha

Irrigation water: 6.00 ML/ha of furrow irrigation

Required 13 runs of tractor in total for all applications

This paddock consumed significantly more water, nitrogen fertilisers, herbicides and manure compared to all previous paddocks.

Case Study 9

Paddock: 08 TM

Area: 42 Ha

Variety: Sicala 45B Bollgard II

Cottonseeds for plantation: 13 kg/ha

Yield: 2246.6 kg per ha

Herbicides: 25.456 L/ha

Nitrogen fertilisers: 450 kg/ha Urea

Irrigation water: 6.00 ML/ha of furrow irrigation

Required 10 runs of tractor in total for all applications

This paddock had very high water, herbicide and nitrogenous fertiliser requirements compared to case studies 1-7, but did not consumed feedlot manure.

Case Study 10

Paddock: 09 TM

Area: 32.1 Ha

Variety: DP412B Bollgard II

Cottonseeds for plantation: 13 kg/ha

Yield: 2723.61 kg per ha

Herbicide: 23.694 L/ha

Nitrogen fertilisers: 150 kg/ha Urea

Irrigation water: 4.00 ML/ha of furrow irrigation

Required 8 runs of tractor in total for all applications

Clearly this paddock consumed low amount of nitrogen-based fertilisers and did not used feedlot manure.

Case Study 11

Paddock: 13A

Area: 23.4 Ha

Variety: Sicot 70 BRF

Cottonseeds for plantation: 13 kg/ha

Yield: 2566.24 kg per ha

Herbicide: 24.387 L/ha

Nitrogen fertilisers: 250 kg/ha Urea

Other fertilisers: 7 L/ha

Irrigation water: 4.05 ML/ha of Lateral move irrigation

Required 8 runs of tractor in total for all applications

The above data showed that this paddock consumed less urea and no feedlot manure. In contrast to previous case studies that used furrow irrigation, the irrigation type in this paddock was lateral move.

Case Study 12

Paddock: 13B

Area: 24.8 Ha

Variety: Sicot 71BRF

Cottonseeds for plantation: 13 kg/ha

Yield: 2755.65 kg per ha

Herbicide: 24.487 L/ha

Nitrogen fertilisers: 250 kg/ha Urea

Other fertilisers: 7 L/ha fertiliser

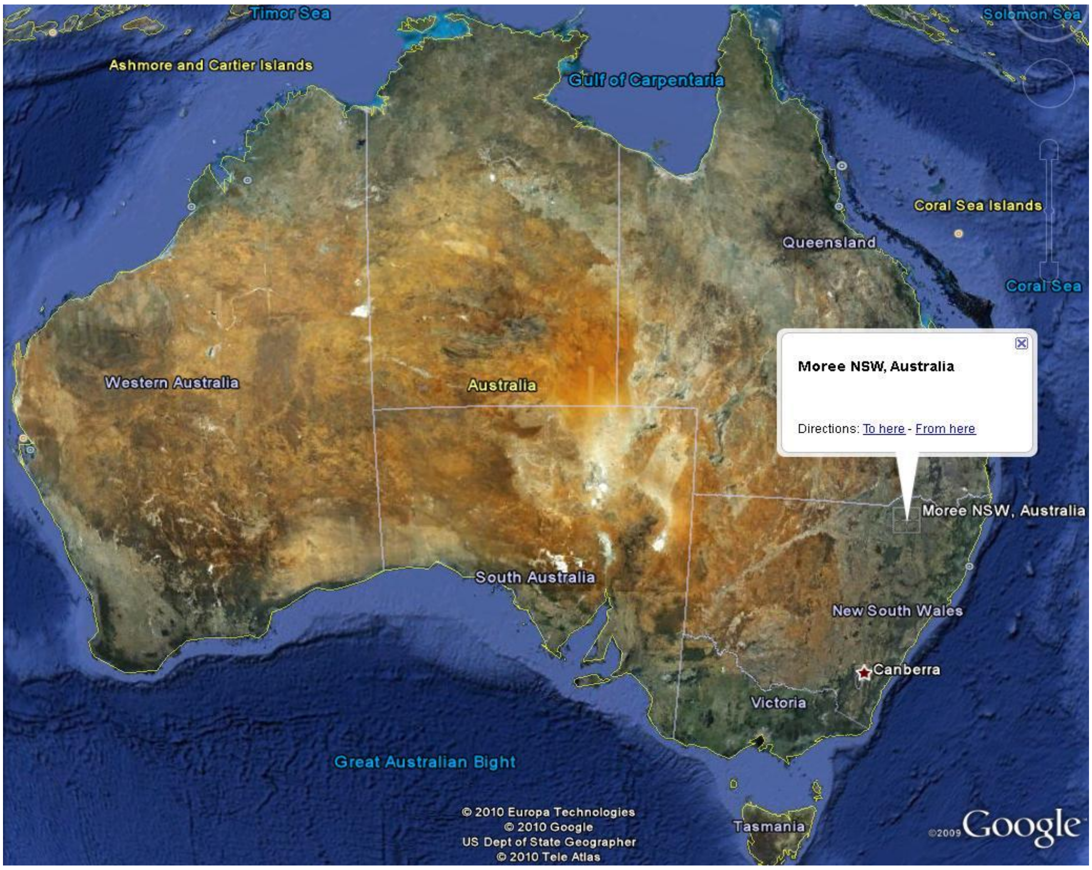
Irrigation water: 4.05 ML/ha of Lateral move irrigation

Required 8 runs of tractor in total for all applications

This case study also employed lateral move irrigation system. It did not used feedlot manure and consumed less nitrogen fertiliser compared to case studies 1-10 that were under furrow irrigation.

5.2.2 Farm Number 2, Keytah Case Studies

Keytah farms are a complex of three 5200 ha areas of cotton fields, located in Moree, New South Wales (NSW), Australia. This region of the NSW is the main cotton production area in Australia. The following map shows the location of Keytah farms on the Australian map.



Source: (Google maps)

Figure 5.2: Keytah farms on Australian maps located at Moree, NSW

As on-farm indirect data from farmers were not available, in this study, chemicals, fertilisers and cotton planting seed rates for all three tillage practices of zero tillage, minimum tillage and conventional tillage are assumed to be the same as in case study 5, described earlier. On-farm direct energy consumption and emissions for case studies 13 – 15 are shown in Appendix 8. GM cotton varieties were planted in Keytah farms. No yield data were available for this farm thus Australian average yield values were used in calculations. Keytah farms are larger than Bremner farms, therefore has a lower stock of machinery per ha.

5.2.2.1 Case Study 13 – 15, Different Tillage practices

Case study Zero Tillage

This part of the field study employed the zero tillage practices

Total area planted under cotton with zero tillage: 5200 ha

Cottonseeds for plantation: 13 kg/ha

The average yield out of first 12 case studies in this thesis will be used: 2368 kg/ha

Herbicides: 25.2 L/ha

Nitrogen fertilisers: 300kg/ha of Urea

Irrigation water: 7ML/ha of furrow irrigation

Required 11 runs of tractor in total for all applications

This case study used significantly more irrigation water compared to Bremner farms.

Table 5.5: List of machinery used in case study 13

Machinery Description		Average Mass
Agroplow 4m		2000 kg
Rotary Hoe		2500 kg
Lillistons		4500 kg
Light Roller		2000 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
8m Spray Bar		1000 kg
24m Boom Sprayer		1200 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	**Case IH MX 305**	9790kg
	Case IH MX 275	9784 kg
	Case IH MX 210	9390 kg
	Caterpillar MT 765	13390 kg
	Caterpillar MT 855	19922 kg
	Caterpillar MT 865 B	20096 kg

Source: (Appendix 8)

Case Study 14 - Minimum Tillage

This part of the field study employed the minimum tillage practices.

Total area planted under cotton with minimum tillage: 5200 ha

Cottonseeds for plantation: 13 kg/ha

The average yield out of first 12 case studies in this thesis will be used: 2368 kg/ha

Herbicides: 25.2 L/ha

Nitrogen fertilisers: 300kg/ha of Urea

Irrigation water: 7ML/ha of furrow irrigation

Required 14 runs of tractor in total for all applications

Again, this case study used significantly more irrigation water compared to Bremner farms.

Case Study 15 - Conventional Tillage

This part of the field study employed the conventional tillage practices.

Total area planted under cotton with conventional tillage: 5200 ha

Cottonseeds for plantation: 13 kg/ha

The average yield out of first 12 case studies in this thesis will be used: 2368 kg/ha

Herbicides: 25.2 L/ha

Nitrogen fertilisers: 300kg/ha of Urea

Irrigation water: 7ML/ha of furrow irrigation

Required 16 runs of tractor in total for all applications

As above, this case study also used significantly more irrigation water compared to Bremner farms. In this thesis, the results of case studies 13 – 15 are used to compare the energy consumption and the emissions of different tillage practices.

5.3 Typical Cotton Farming Practices in Australia

Nowadays genetically modified (GM) cotton varieties consist of more than 90 per cent of total cotton plantation in Australia (Cotton Australia, 2008). Border check irrigation system, which is one of furrow irrigation systems, is also the most common irrigation method, accounting for 92% of irrigation employed in Australian cotton farming (Chen & Baillie 2007, p. 10). Most of the farmers are also employing conventional tillage. Thus, the term of Australian typical cotton farming practices used in this thesis refers to the GM cotton farm under furrow and conventional tillage in this study.

Data from 12 surveyed paddocks in the Bremner farms were also used to determine the average yield for Australian cotton farming in the case studies, deriving the value of 2368.72 kg/ha (10.9 bale/ha). The above value will be used as the base rate for all calculations in Chapters 6, 7 and 8 of this thesis.

5.4 Conclusions

This chapter has discussed the methodology of farm data collection. A survey questionnaire form has been designed for farmer interviews. The real on-farm data from two farms located in Queensland and NSW, as main Australian cotton planting regions, have been collected for further calculations in fifteen case studies. The data presented here will further be used in Chapter 6 as model inputs to calculate the Australian cotton energy consumption and relevant greenhouse gas emissions from field to the port.

Chapter 6 – Results of Case Studies

6.1 Introduction

This chapter presents the calculations of the cotton farming energy consumption and greenhouse gas emissions for each individual case study outlined in Chapter 5. Data provided in Chapter 5 will be used as the model inputs to calculate the energy and greenhouse gas emissions of each paddock separately.

The key research data and the difference between the GM and non-GM cotton farms will be identified. Significant findings of each individual farm survey and their results will be compared, and direct effects of farming stages on total cotton farming energy consumption and emissions will be determined.

Calculated model results will identify the energy and emissions for on-farm direct, on-farm indirect, off-farm direct and off-farm indirect stages separately. These data will be further used to identify the percentage contribution of each stage in total life cycle energy consumption and emissions of cotton production chain in Australia.

6.2 Results of Case Studies

6.2.1 Results of Case Studies 1 – 12

Case Study 1

By applying the values for case study 1 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

Table 6.1: Energy and emissions values from the model for case study 1

ON-FARM DIRECT ENERGY CONSUMPTION:	11570.40	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION :	103865.40	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION :	2089.79	MJ
OFF- FARM INDIRECT ENERGY CONSUMPTION :	10728.43	MJ
Total On-farm Energy Consumption:	115435.80	MJ
Total off-farm Energy Consumption :	12818.23	MJ
Total Energy Used in Cotton Production Per Year/ha:	128254.10	MJ
ON-FARM DIRECT EMISSIONS:	1871.50	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	5954.19	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	611.49	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.27	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	7825.69	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1528.77	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year/ha:	9654.46	Kg CO_2e

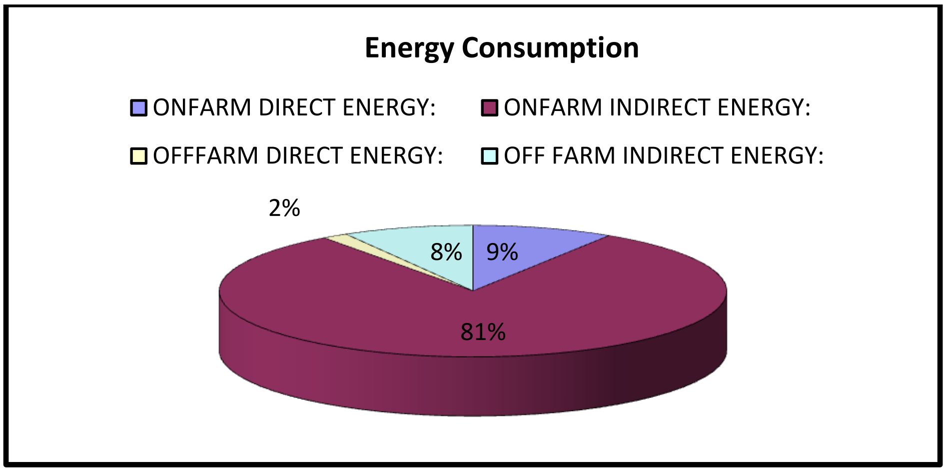


Figure 6.1: Energy consumption share for case study 1

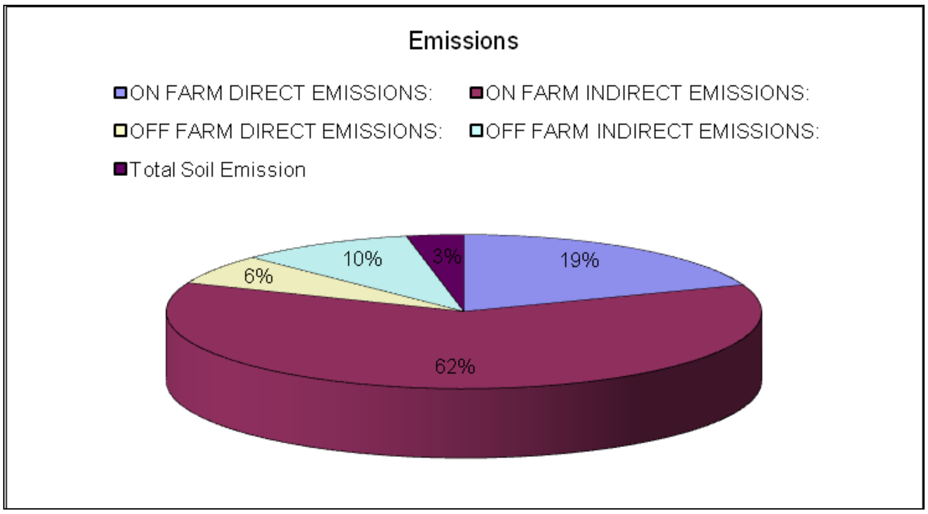


Figure 6.2: Emissions share for case study 1

The results of case studies 2 – 12 may be found in Appendix 9. Some are also discussed in Sections 6.3 - 6.6 of this chapter.

6.2.2 Results of Case Studies 13 - 15

Case Study 13

The on-farm direct energy consumption rates and the relevant greenhouse gas emissions calculated in Appendix 8 were used for on-farm direct stages of the developed model. The energy share and greenhouse gas emissions rates for this case of GM cotton under furrow irrigation with zero tillage are calculated as:

Table 6.2: Energy and emissions values from the model for case study 13

ON-FARM DIRECT ENERGY CONSUMPTION :	12440	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION :	21900.28	MJ
OFFFARM DIRECT ENERGY CONSUMPTION :	2310.281	MJ
OFF FARM INDIRECT ENERGY CONSUMPTION :	10728.43	MJ
Total On-farm Energy Consumption :	34340.28	MJ
Total off-farm Energy Consumption :	13038.71	MJ
Total Energy Used in Cotton Production Per Year/ha:	47378.99	MJ
ON FARM DIRECT EMISSIONS:	934.91	Kg CO_2e
ON FARM INDIRECT EMISSIONS:	1324.38	Kg CO_2e
		Kg CO_2e
OFF FARM DIRECT EMISSIONS:	666.74	Kg CO_2e
OFF FARM INDIRECT EMISSIONS:	917.27	Kg CO_2e
TOTAL ON FARM EMISSIONS:	2259.30	Kg CO_2e
TOTAL OFF FARM EMISSIONS:	1584.01	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year/ha:	4143.31	Kg CO_2e

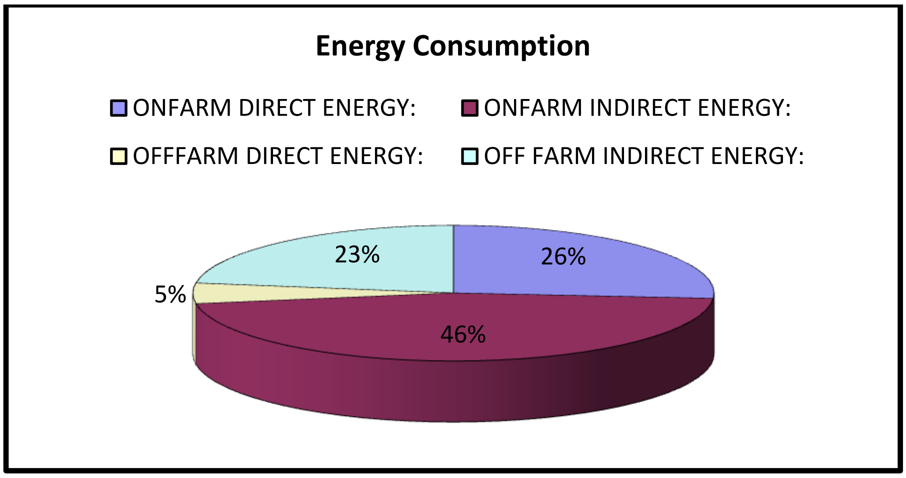


Figure 6.3: Energy consumption share for case study 13

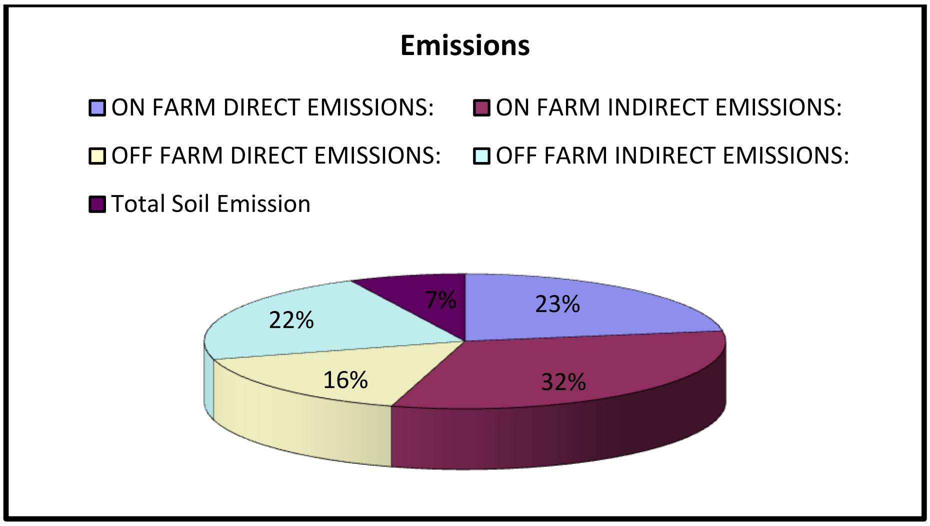


Figure 6.4: Emissions share for case study 13

Case Study 14

The principle described above was also applied to this case. Thus the on-farm direct energy consumption rates and the corresponding greenhouse gas emissions values, calculated in Appendix 8 were used for on-farm direct stage of the developed model. The energy share and greenhouse gas emissions rates for this case of GM cotton under furrow irrigation with minimum tillage are calculated as:

Table 6.3: Energy and emissions values from the model for case study 14

ON-FARM DIRECT ENERGY CONSUMPTION:	14330	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	21900.28	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	2310.28	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	36230.28	MJ
Total off-farm Energy Consumption:	13038.71	MJ
Total Energy Used in Cotton Production Per Year/ha:	49268.99	MJ
ON-FARM DIRECT EMISSIONS:	1076.91	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	1324.38	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	666.74	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.27	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	2401.30	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1584.01	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year/ha:	4285.31	Kg CO_2e

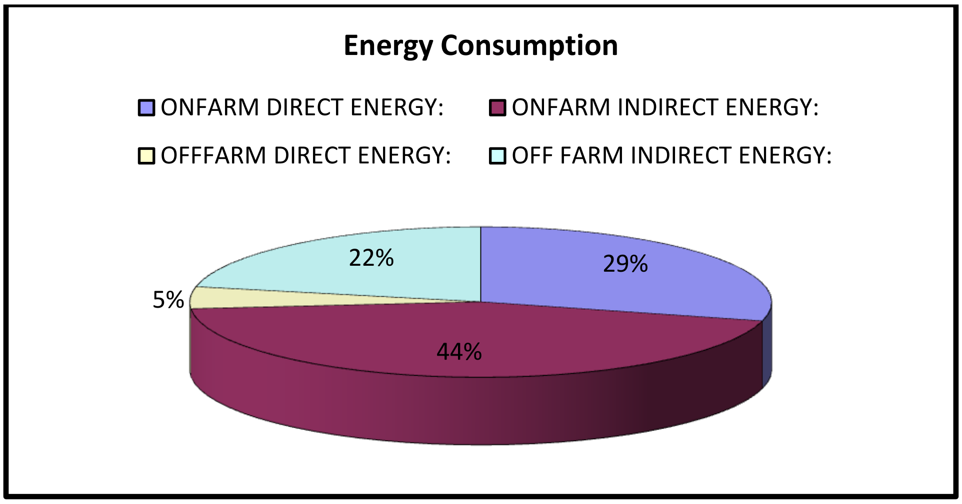


Figure 6.5: Energy consumption share for case study 14

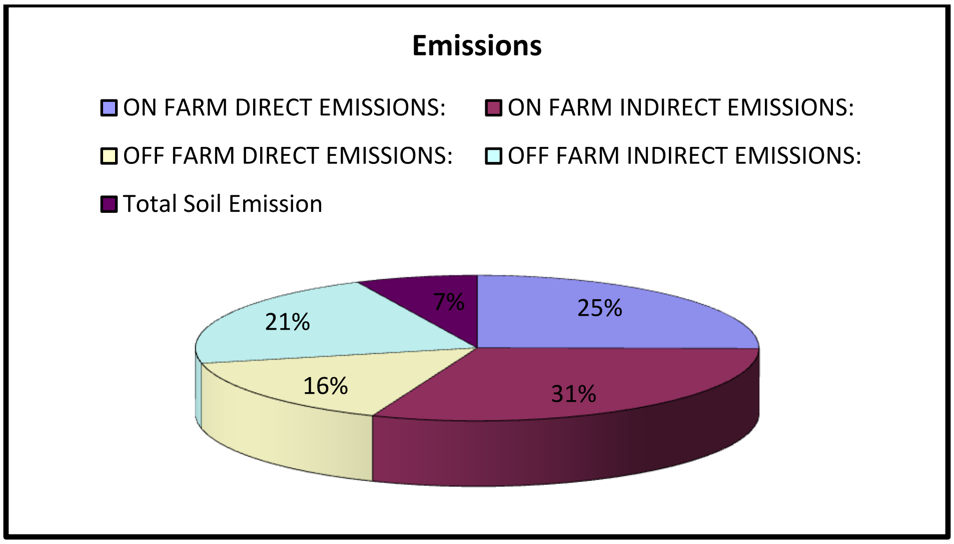


Figure 6.6: Emissions share for case study 14

Case Study 15

As above, the on-farm direct energy consumption rates and the relevant greenhouse gas emissions values calculated in Appendix 8 were used for on-farm direct section of the developed model. Thus, the energy share and greenhouse gas emissions rates for the case of GM cotton under furrow irrigation with conventional tillage are calculated as:

Table 6.4: Energy and emissions values from the model for case study 15

ON-FARM DIRECT ENERGY CONSUMPTION:	16323	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	21900.28	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	2310.28	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	38223.28	MJ
Total off-farm Energy Consumption:	13038.71	MJ
Total Energy Used in Cotton Production Per Year/ha:	51261.99	MJ
ON-FARM DIRECT EMISSIONS:	1226.46	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	1324.38	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	666.74	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.27	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	2550.85	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1584.01	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year/ha:	4434.87	Kg CO_2e

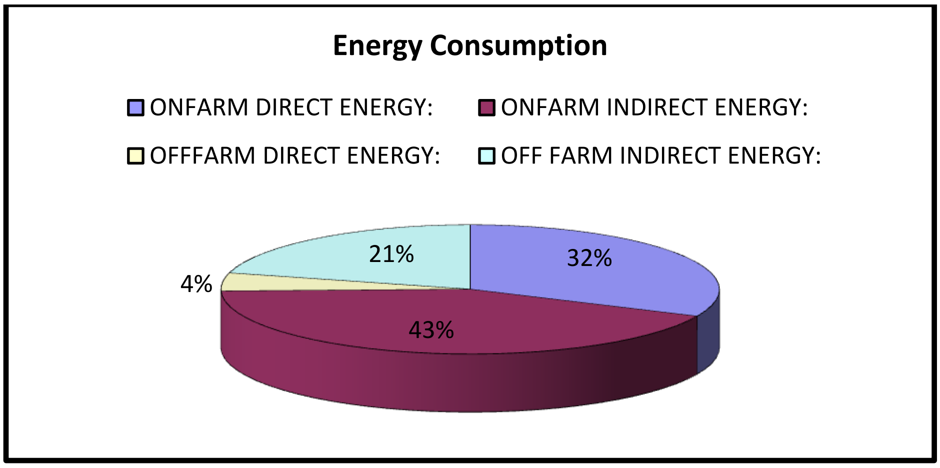


Figure 6.7: Energy consumption share for case study 15

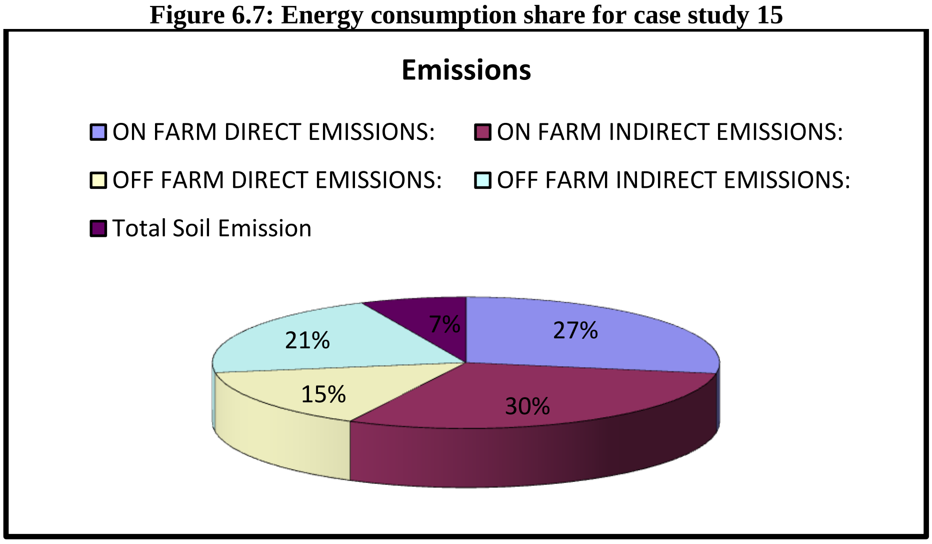


Figure 6.8: Emissions share for case study 15

6.3 Energy Consumption of Conventional Cotton

In this section, the conventional cotton farming system energy consumption will be presented and discussed. The results will also be presented on a per hectare basis. In particular, the results of the case study 4 will be studied, as it was the only paddock under conventional cotton farming. It was found that on-farm direct energy consumption accounted for 11.9 GJ/ha, of which the main contribution (6.6 GJ/ha) was related to on-farm applications, such as tillage and spraying, followed by irrigation (4.6 GJ/ha) under furrow irrigation method.

On-farm indirect energy consumption was measured as 98.9 GJ/ha. About 53.6 GJ/ha of this value was used to manufacture tractors and harvesters used in this particular case study. This value was inclusive of repair and maintenance costs over the machinery working life. Second biggest proportion of used energy (40 GJ/ha) was related to the fertiliser manufacturing, which significantly contributed to the conventional cotton farming total energy consumption.

Conventional cotton farming system off-farm direct applications accounted for 2.5 GJ/ha of energy, in which cotton ginning was found to be the biggest contributor, with a value of 2.2 GJ/ha.

Cotton off-farm indirect applications consumed 10.7 GJ/ha, in which manufacturing of heavy transport vehicles accounted for 6.6 GJ/ha. The energy used for building the ginning and storage buildings accounted for about 3 GJ/ha of the total. The breakdown of energy consumption for different parts of conventional cotton production chain is shown in Figure 6.9 below.

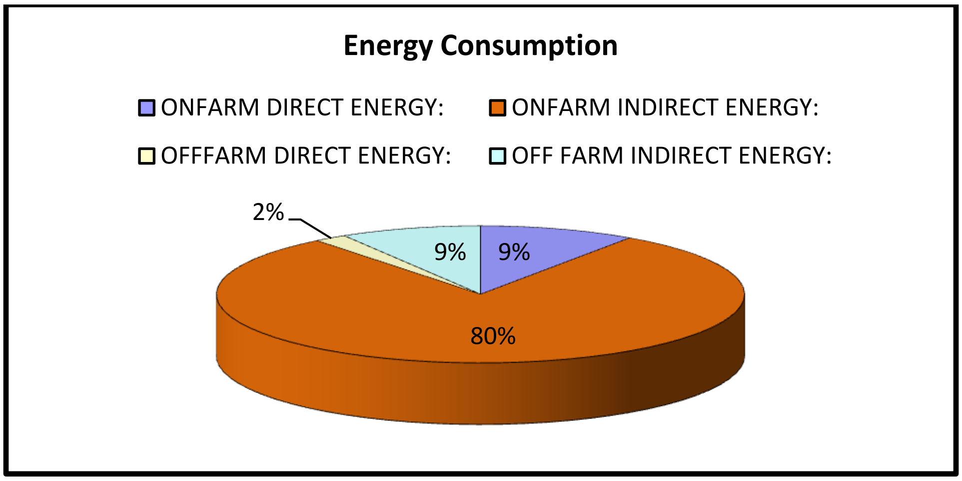


Figure 6.9: Energy Consumption Share of Conventional Cotton

6.4 Greenhouse Gas Emissions (GHG) of Conventional Cotton

The conventional cotton farming system GHG emissions are the focus of this section. In line with the previous section, the results on a per hectare basis will also be presented. The model results showed that cotton farming emissions from on-farm direct applications accounted for 1.9 tonnes CO_2e/ha, of which 1.4 tonnes CO_2e /ha were the emissions related to furrow irrigation system and the remaining 0.5 tonnes CO_2e /ha were the result of other on-farm applications such as fertilising, tillage and aerial spraying.

The highest greenhouse gas emissions value (5.5 tonnes CO_2e /ha) was related to the on-farm indirect applications. Emissions resulting from agricultural machinery production processes were 4.3 tonnes CO_2e /ha, whilst manufacturing of fertilisers, particularly Urea based fertilisers, accounted for some 0.8 tonnes CO_2e /ha.

Off-farm direct emissions for the conventional cotton farming accounted for 0.7 tonnes CO_2e /ha, mainly due to electricity used by ginning machinery applications.

Transportation emissions, from field to the gin and from the gin to the port for export purposes, only accounted for 0.025 tonnes CO_2e /ha.

Off-farm indirect emissions were evaluated as 0.9 tonnes CO_2e /ha, in which 0.5 tonnes CO_2e /ha were related to the emissions from the heavy transport vehicle manufacturing processes and 0.3 tonnes CO_2e /ha were due to the ginning and storage construction. Total soil emissions for this case study, and all other case studies, were assumed to be 0.3 tonnes CO_2e /ha. Thus this number will be used for other case studies with different farming practices. In total, energy used to produce one hectare of conventional cotton accounted for 396.2 GJ/ha with the related emissions of 25.3 tonnes CO_2e /ha. The breakdown of GHG emissions for different parts of conventional cotton production chain is shown in Figure 6.10 below.

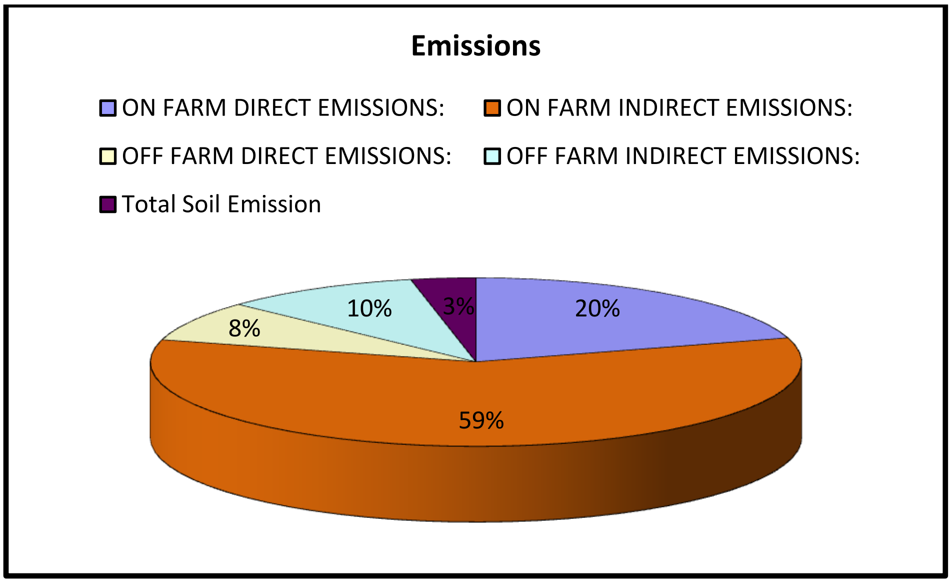


Figure 6.10: Greenhouse Gas Emissions Share of Conventional Cotton

6.5 Energy Consumption of Genetically Modified Cotton

In this section, the GM cotton farming system energy consumption is presented. In line with the previous sections, the results will be presented on a per hectare basis. The values included in this section are the average values derived from 11 different types of GM cotton farming systems that employed different irrigation methods and cotton varieties. These data might be the closest values for a typical Australian genetically modified cotton-farming system.

On-farm direct applications energy consumption of GM cotton farming varied from 11.5 GJ/ha to 13.2 GJ/ha, with the average value of 12 GJ/ha of GM cotton. It has been found that the irrigation type − furrow or lateral move − was the main reason for these differences. Furrow irrigation energy consumption in GM cotton on-farm direct applications was found to be 4.6 GJ/ha, whilst lateral move accounted for 6.2 GJ/ha.

In most cases, it is expected that the beneficial reduction in spraying requirement would be compensated by the increased water requirements of GM crops. However, as Bremner farms employed the same amount of fertilisers and used the same amount of water for both the GM and non-GM cotton, on-farm energy consumption rates were very similar − 12 GJ/ha of GM and 11.9 GJ/ha of non-GM cotton.

On-farm indirect energy consumption in 11 surveyed GM cotton Paddocks ranged from 65.7 GJ/ha to 112.2 GJ/ha, with the average value of 83.7 GJ/ha (7.7 GJ/bale). Reasons for the large difference between different farms were related to the energy used to manufacture fertilisers, particularly urea and feedlot manure, which was used in large quantities per hectare in some of the surveyed paddocks.

The farmer interview information showed that the reason for using varying amounts of urea and feedlot manure in different paddocks was related to the history of each individual paddock. Additional energy consumption difference can be attributed to the varying number of agricultural machinery used in different paddocks as this will change the manufacturing energy consumption.

GM cotton farming off-farm direct energy consumption was determined to range from 1.4 to 2.6 GJ/ha, with the average of 2.1 GJ/ha (0.2 GJ/bale) of harvested cotton for trucking and ginning operations. Negligible difference between various case studies, due to different paddock yields, was observed.

Off-farm indirect GM cotton farming energy consumption accounted for 10.7 GJ/ha (1 GJ/bale) of harvested cotton. This included the energy used to manufacture heavy, light transport vehicles and the ginning company building construction. As it was assumed that all case studies used the same ginning building, thus on average required the same transport distance from ginning company to the same port for export purposes, they accounted for very similar value of 10.7 GJ/ha (1 GJ/bale) of harvested cotton. The breakdown of energy consumption for different parts of GM cotton production chain is shown in Figure 6.11 below.

Energy consumption of agricultural machinery capital followed by fertilisers' capital were found to be the two most energy consuming components of GM cotton farming (Fig.6.12).

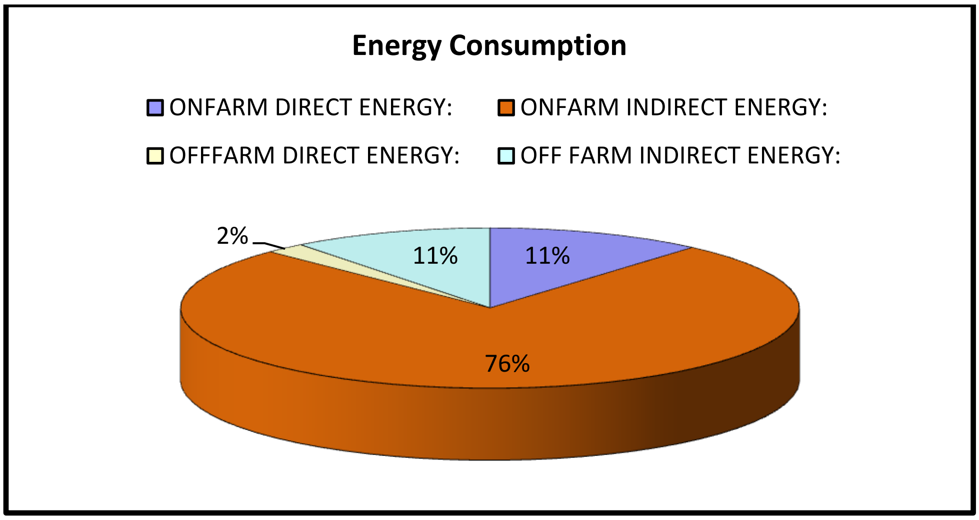


Figure 6.11: Energy Consumption Share of Genetically Modified (GM) Cotton

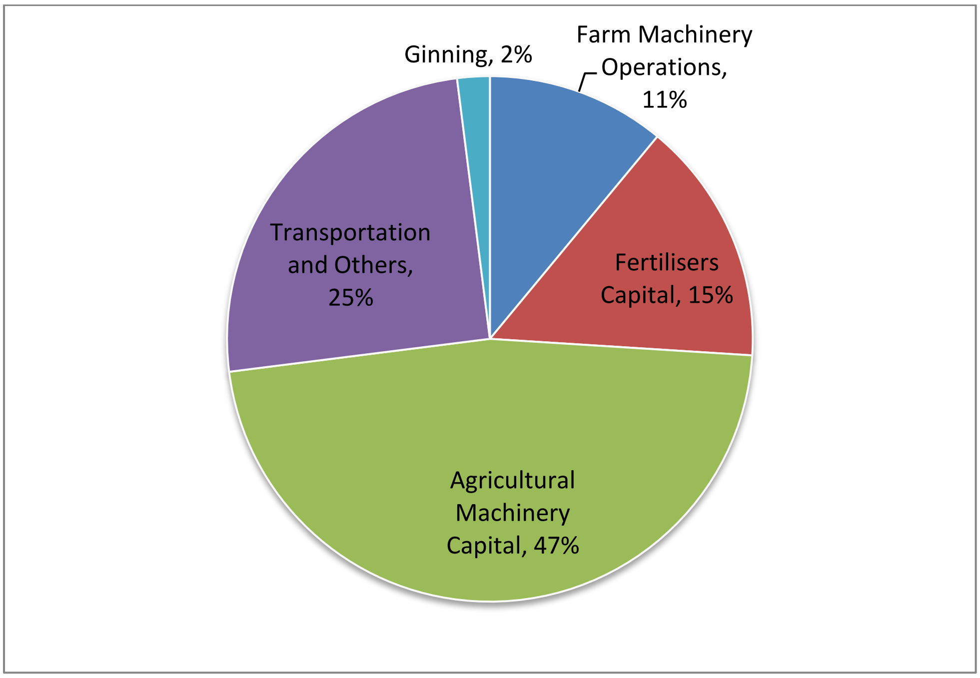


Figure 6.12: Energy consumption share through GM cotton life cycle

6.6 Greenhouse Gas Emissions of Genetically Modified Cotton

This section presents the GM cotton farming system GHG emissions. As before, the results will be presented on a per hectare basis. Greenhouse gas emissions resulting from on-farm direct applications ranged from 1.8 to 2.3 tonnes CO_2e /ha, with the average of 1.9 tonnes CO_2e /ha (174 kg CO_2e /bale). Main emissions sources for on-farm direct applications were the irrigation, followed by the on-farm machinery operations. Irrigation on average accounted for 1.4 tonnes CO_2e /ha (128 kg CO_2e /bale).

It was found that the greenhouse gas emissions for on-farm indirect applications ranged from 5 to 6.3 tonnes CO_2e /ha, with the average of 5.7 tonnes CO_2e /ha (524 kg CO_2e /bale) for the 11 surveyed paddocks. The variance was due to the different amounts of fertilisers applied to paddocks, as well as agricultural machinery and implement production processes, as their usage rates varied across different paddocks.

Greenhouse gas emissions for off-farm direct applications ranged between 0.4 to 0.8 tonnes CO_2e /ha, with the average of 0.6 tonnes CO_2e /ha (55 kg CO_2e /Bale). This variance was due to different yields, which lead to the difference on greenhouse gas emissions of trucking and ginning operations.

Emissions from heavy and light vehicle manufacturing processes, as well as ginning building were calculated as off-farm indirect emissions and accounted for 0.9 tonnes CO_2e /ha. As for energy consumption, this value was nearly constant for all different case studies. As indicated in earlier conventional cotton calculations, the total soil emissions for GM Cotton were assumed to be constant at 0.3 tonne CO_2e /ha. In total, energy used to produce one hectare of GM cotton ranged from 92.4 to 137 GJ/ha, with the average value of 108.6 GJ/ha. The relevant greenhouse gas emissions varied from 8.8 to 10 tonnes CO_2e /ha, with the average of 9.5 tonnes CO_2e /ha (873 kg CO_2e /bale) or 4 kg CO_2e /kg of genetically modified cotton. The breakdown of GHG emissions for different parts of GM cotton production chain is shown in Figure 6.13 below. Greenhouse gas emissions of agricultural machinery capital followed by farm machinery operations were found to be the two most greenhouse gas emitting stages of GM cotton farming.

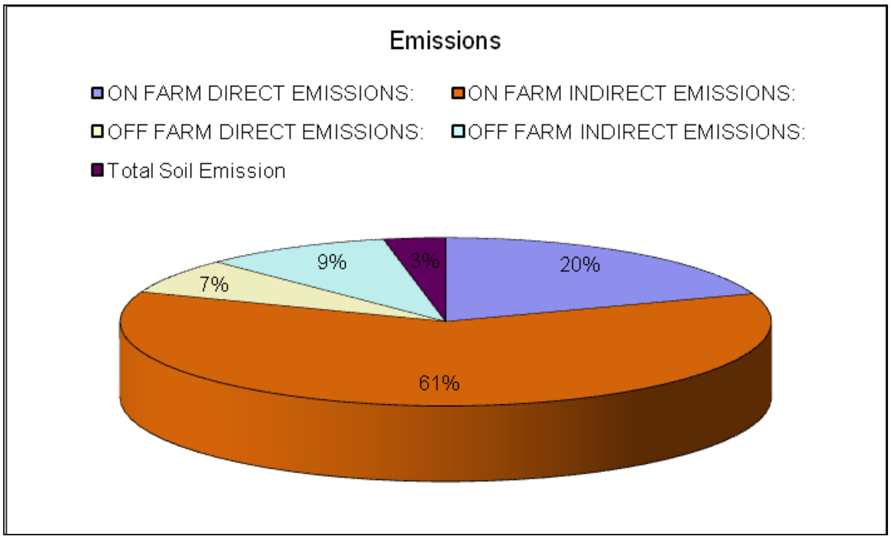


Figure 6.13: Greenhouse Gas Emissions Share of Genetically Modified (GM) Cotton

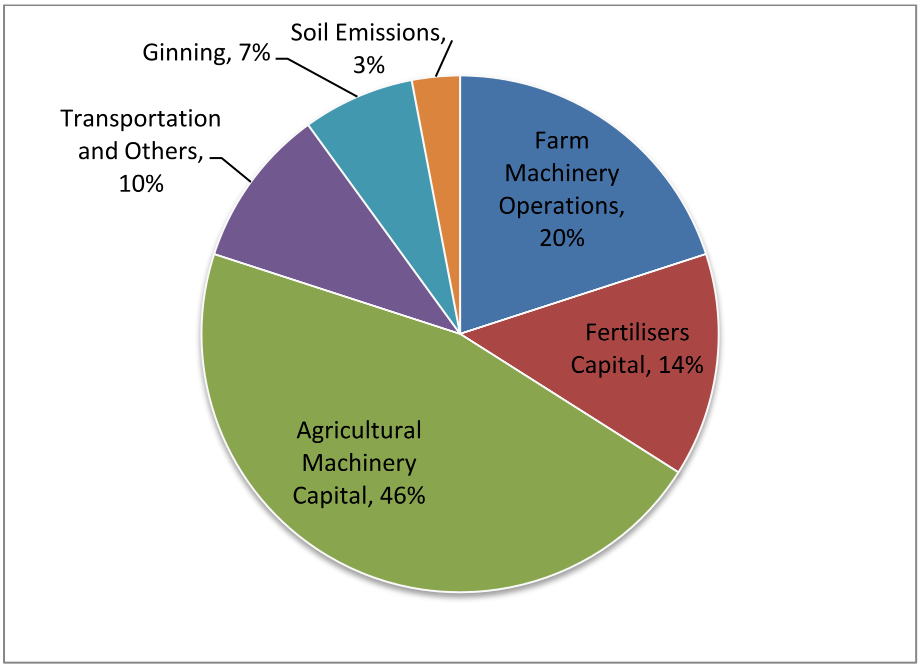


Figure 6.14: Greenhouse gas emissions share through GM cotton life cycle

The lowest GM cotton energy consumption (92.4 GJ/ha) was identified in the case study 2, which was under Sicot 80BRF Combination of Bollgard II® and Roundup Ready Flex® plantation with low urea application rate of 300kg/ha with no feedlot manure and 21.8 L/ha of herbicide application. In contrast, case study 7 showed the highest energy consumption rate of 137 GJ/ha. This paddock was under Sicot 80RRF Roundup Ready Flex® cotton variety plantation and it used more irrigation water (0.3 ML/ha more than case study 2), and consumed 10 tonnes of feedlot manure and 34.9 L/ha of various herbicides. Thus the higher energy consumption is found in cotton farms with higher fertiliser and chemical application rates.

The results of the greenhouse gas emissions followed the same pattern, as the lowest emissions were calculated for the cotton fields with lower fertiliser and chemical application rates, whilst the highest were related to case study 6 that consumed 400 kg urea, one tonne of feedlot manure and 34.61 L of herbicides on per hectare basis.

6.7 Conclusions

This chapter has presented the case study results, calculated using the developed model. Energy consumption and greenhouse gas emissions of each farming stage for conventional and GM cotton have been identified. It has been found that in total, energy used in conventional cotton farming was higher than for GM cotton. However, there were only small differences between the energy consumption and GHG emissions between the conventional and GM crops. The highest GHG emissions (around 60%) related to on-farm indirect applications, due to the energy used to manufacture fertilisers and agricultural machinery. These data will further be used to make comparisons in the Chapter 7 of this thesis.

It has been found that Australian cotton farming system energy consumption and greenhouse gas emissions are mainly affected by the fertiliser and herbicide application rates, as their manufacturing processes along with application energy consumption affected these values the most.

Chapter 7 – Impact of Different Farming Systems and Practices

This chapter will discuss the individual case study results in more detail. This will enable comparisons between different farming systems and practices. Firstly, the comparison between Genetically Modified (GM) and conventional cotton will be made and later different irrigation systems and tillage practices will also be compared, based on the results of case studies detailed in Chapter 6 of this thesis.

Finally, the system identified as the most efficient will be compared against the typical Australian cotton farming system. The term “in average” in this chapter and the Chapter 8 represents the total values divided by the case study numbers not by the area. The average yield in these case studies is 2368.72 kg/ha (10.9 bale/ha).

7.1 Comparison of GM and Conventional Cotton

As calculated in the previous chapter, energy consumption and emissions related to the life cycle of one hectare of conventional cotton from the field to the port accounted for 124 GJ/ha, equivalent to 52.4 MJ/kg or 11.4 GJ/bale, with the relevant emissions of 9 tonnes CO_2e /ha (3.8 kg CO_2e /kg) or 827.5 kg CO_2e /bale.

The corresponding values for Australian GM cotton were calculated to be 108.5 GJ/ha (10 GJ/bale) or (45.8 MJ/kg) of energy, with the relevant greenhouse gas emissions of 9.1 tonnes CO_2e /ha (0.83 tonnes CO_2e /bale) or 3.84 kg CO_2e /kg.

It was found that conventional cotton farming is using more energy (13.5 GJ/ha more) than that of GM cotton, whilst their greenhouse gas emissions were similar. GM cotton data in this study are related to the combination of Bollgard II® and Roundup Ready Flex® and Bollgard II No Herbicide Traits, as well as individual applications of Bollgard II® or Roundup Ready Flex®. The three main reasons for these variances between energy consumptions of GM and non-GM cotton were identified as follows:

- Energy used in production of fertilisers − particularly urea, feedlot manure and herbicides.

- Energy used to manufacture agricultural machinery and implements, as the total energy amount is divided by the farm size. Hence, larger farms will use less energy to manufacture agricultural machinery on per hectare basis.

- Energy consumption varied for different irrigation types employed by individual paddocks. Two of the GM cotton paddocks in these calculations used lateral move irrigation system.

7.2 Comparison of Australian and Overseas Conventional Cotton Energy Consumptions

In this study conventional cotton production energy consumption accounted for 124 GJ/ha, equivalent to 52.4 MJ/kg, excluding milling operations. This was lower than of 147 MJ/kg reported overseas (Oecotextiles, 2009). As discussed in the previous chapter, the quantity of fertilisers used for the cotton production can significantly influence the energy consumption rate. Hence this difference is mainly due to the lower fertiliser rates used in Australian conventional cotton, compared to equivalent overseas farming systems.

7.3 Effect of Irrigation Methods and Water Use Efficiency Measures

7.3.1 Energy Consumption and Greenhouse Gas Emissions in Furrow Irrigation Systems

Furrow irrigation is also referred to as flood irrigation system. The energy consumption in this study, estimated using 10 paddock surveys of mixed varieties of GM and conventional cotton farming practices, was 4.6 GJ/ha (0.42 GJ/bale) for cotton farms under furrow irrigation.

The furrow irrigation greenhouse gas emissions accounted for 1.3 tonnes CO_2e /ha equivalent to 120 kg CO_2e /bale, the above values only included the direct irrigation application emissions.

7.3.2 Energy Consumption and Greenhouse Gas Emissions of Lateral Move Irrigation Systems

Lateral move was another irrigation method employed by Australian cotton farmers. Its energy consumption was 6.2 GJ/ha (570 MJ/bale), with the relevant emissions of 1.7 tonnes CO_2e /ha (156 kg CO_2e/bale).

7.3.3 Comparison of Furrow and Lateral Move Irrigation Cotton Production

The total energy consumption to produce and process one hectare of cotton under furrow irrigation at Bremner farms was 112.9 GJ/ha (10.4 GJ/bale), compared to only 95.3 GJ/ha (8.7 GJ/bale) for lateral move. This difference was due to the significant increase in energy consumption in cotton farms under furrow irrigation that requires higher fertiliser consumption rate. As these findings are inconclusive, further research is recommended to confirm the correlation between the irrigation type and the fertiliser application rate.

Total greenhouse gas emissions arising from production and process stages of cotton farming under furrow irrigation method accounted for 9.5 tonnes CO_2e/ha (0.88 tonnes CO_2e/bale). This demonstrated the effect of higher fertiliser usage on furrow irrigated cotton farms. The corresponding value was 9.4 tonnes CO_2e/ha (0.86 tonnes CO_2e/bale) for cotton farms under lateral move irrigations system.

7.4 Comparison of Energy Consumption and Greenhouse Gas Emissions of Different Tillage Practices

7.4.1 Zero Tillage Practices

On-farm direct energy consumption of zero tillage case accounted for 12.44 GJ/ha, with related greenhouse gas emissions of 0.93 tonnes CO_2e/ha. It has been found that the total energy consumption of GM cotton under furrow irrigation and zero tillage practices at Keytah farms accounted for 47.4 GJ/ha, equivalent to 20 MJ/kg of cotton or 4.5 GJ/bale. The total greenhouse gas emissions of Australian cotton from field to the port was calculated to be 4.14 tonnes CO_2e /ha (379 kg CO_2e/bale), or 1.75 kg CO_2e/kg of cotton fibre delivered to the port.

7.4.2 Minimum Tillage Practices

On-farm direct energy consumption and emissions of minimum tillage case study were 14.3 GJ/ha and 1.07 tonnes CO_2e/ha; more details may found in Appendix 8 of this thesis. The machinery used in case studies 13 − 15 were the same. At Keytah farms, GM cotton energy consumption and greenhouse gas emissions under furrow irrigation with minimum tillage practices were 49.27 GJ/ha, equivalent to 21 MJ/kg of cotton fibre or 4.52 GJ/bale. The minimum tillage cotton farming total greenhouse gas emissions were calculated to be 4.28 tonnes CO_2e/ha (392 kg CO_2e/bale) or 1.8 kg CO_2e/kg of cotton fibre delivered to the port.

7.4.3 Conventional Tillage Practices

The on-farm direct energy consumption and emissions in a conventional tillage cotton farm accounted for 16.3 GJ/ha and 1.22 tonnes CO_2e/ha, with more details available in Appendix 8. Energy required to produce and process a hectare of cotton under conventional tillage operations at Keytah farms was calculated to be 51.26 GJ/ha, equivalent to 22 MJ/kg and 4.7 GJ/bale. The total greenhouse gas emissions in this case were 4.43 tonnes CO_2e/ha (406 kg CO_2e/bale) or 1.83 kg CO_2e/kg of cotton fibre delivered to the port.

7.4.4 Comparison between Different Tillage Practices

Zero tillage with energy consumption value of 20 MJ/kg of cotton delivered to the port used less energy compared to minimum tillage (21 MJ/kg of cotton) and conventional tillage (22 MJ/kg of cotton). It was also found that by employing zero tillage practices up to 24% energy saving was achievable.

In fact, under drought conditions, zero tillage is likely to account for higher yield, but, on the other hand, it may consume more chemicals. As on-farm indirect consumption data were not available (for Keytah farms), this difference could not be calculated in this study. Further research is needed to confirm the energy consumption difference in drought conditions.

Table 7.1: Energy usage and emissions of different tillage practices

Practice	Energy Consumption (MJ/kg cotton)	Greenhouse Gas Emissions (kg CO_2e/kg cotton)
Zero Tillage	20	1.75
Minimum Tillage	21	1.8
Conventional Tillage	22	1.83

7.5 Comparison with the Wool and Chemical Synthesis Fibres

Australian cotton industry, as described previously, employs different varieties of cotton, classified as GM and conventional, and each farm may be under different irrigation and tillage treatments. The average value in 12 surveyed paddocks of the Bremner farms under different farming practices was assumed to represent the total Australian cotton energy consumption and relevant emissions in this section.

This study calculated that the Australian cotton on average consumed 110 GJ of energy to produce a hectare of cotton (10.1 GJ/bale) and its relevant emissions accounted for 9.5 tonnes CO_2e/ha (0.87 tonnes CO_2e/bale) of harvested and processed cotton.

By using the average yield and the total energy consumption and related emissions, it may be concluded that 46.4 MJ of energy was used to produce and process 1 kg of Australian cotton. Greenhouse gas emissions resulting from Australian cotton production chain from field to the port were calculated as 4 kg CO_2e per kg of cotton.

7.5.1 Comparison of Cotton vs. Wool

Oecotextiles (2009) calculated the energy consumption of 155 MJ/kg for wool fibre production, whilst Australian cotton production chain accounted for 46.4 MJ per kg of cotton fibre production and processes, excluding milling applications. This shows that cotton farming uses significantly less energy compared to the wool production and its process chain.

7.5.2 Comparison of Cotton with Polyester and Nylon

Cotton Research and Development Corporation (2009) calculated the value of 8.9 kg CO_2e/kg textile of polyester fibre production. The latter value excludes the transport and some on-farm indirect emissions, such as those arising from agricultural machinery manufacturing processes. Under the assumption that the value reported by Cotton Research and Development Corporation (2009) covers the total polyester fibre production, by making comparison, it can be seen that cotton farming is producing significantly less emissions (4 kg CO_2e per kg of cotton), compared to 8.9 kg CO_2e/kg textile of polyester fibre production.

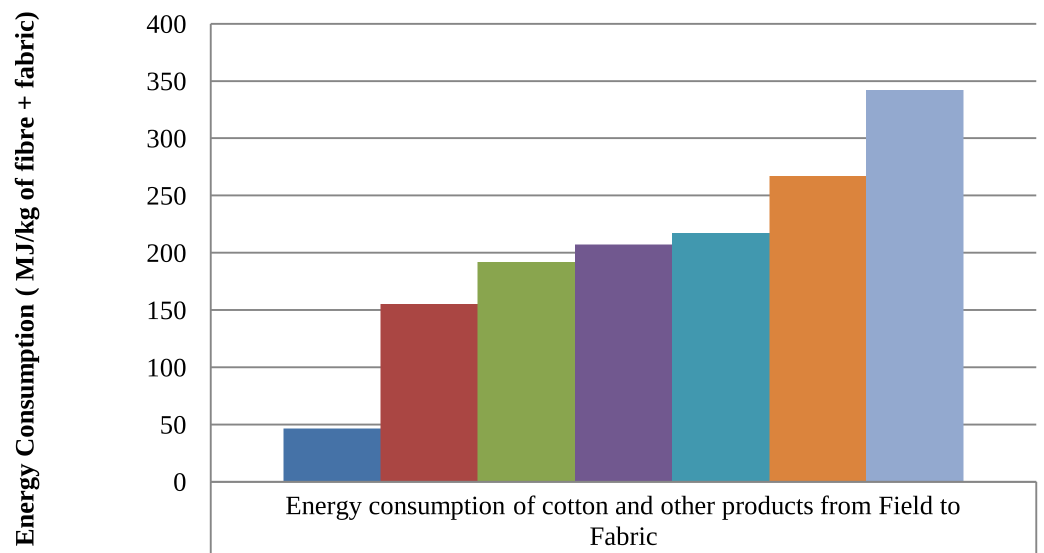
Oecotextiles (2009) determined an energy consumption value of 217 MJ per kg of polyester fibre, including the embodied energy requirements. As, energy of 46.4 MJ per kg of Australian cotton fibre was adopted in this study, this shows that cotton industry requires only 20% of the energy required to produce the same weight of polyester.

Energy consumption to produce 1 kg of nylon was found to account for 342 MJ/kg of nylon fibre (Oecotextiles, 2009). This value was more than seven times that of cotton production.

7.5.3 Comparison of Cotton with Acrylic, Polypropylene and Viscose

Energy used to produce one kg of acrylic, polypropylene and viscose, as calculated by Oecotextiles (2009), valued at 267, 207 and 192 MJ/kg of fibre respectively. As previously described in this chapter, in comparison, Australian cotton uses about 46.4 MJ of energy to produce 1 kg of cotton fibre. It is therefore concluded that cotton is a significantly more energy efficient crop and a lower greenhouse gas emitter, compared to wool and all other chemical synthesises.

The following figure shows the comparison of Australian typical cotton energy versus wool and other chemical synthesis:



	Energy consumption of cotton and other products from Field to Fabric
Cotton	46.4
Wool	155
Viscose	192
Polypropylene	207
Polyester	217
Acrylic	267
Nylon	342

Figure 7.2: Energy consumption of cotton and other products from field to fabric (cotton data excludes milling)

7.6 Reductions of Energy and GHG Emissions when all the "New Technologies" are Combined

It was calculated that by applying zero tillage practices in genetically modified cotton planted area under lateral move irrigation (mainly to improve water use efficiency which is very important for Australia) and low fertiliser application rate, and by employing the agricultural machinery in bigger farms, such as 5200 hectares of cotton land in Keytah case studies, the minimum energy consumption of 47.4 GJ/ha, equivalent to 20 MJ/kg of cotton, was achievable. The above value was less than half of the Australian cotton energy requirement, with the average of 46.4 MJ/kg calculated in this study.

Greenhouse gas emissions for the combination of all new technologies accounted for 4.14 tonnes CO_2e/ha (379 kg CO_2e/bale), or 1.75 kg CO_2e/kg of cotton fibre delivered to the port. This was significantly less than the previously reported 4 kg CO_2e/kg. These reductions are mainly due to less embodied energy and emissions associated with farm machinery capital.

7.7 Conclusions

This chapter has compared the impacts of different farming systems and practices in Australian cotton farming industry. A comparison between conventional and genetically modified cotton, as well as different irrigation and tillage systems, has been made. Their effects on total greenhouse gas emissions and energy consumption were also compared.

Based on the available data and 12 case studies at Bremner farms, it was found that conventional cotton farms in average consume 11.4 GJ of energy per bale, with relevant emissions of 0.83 tonnes CO_2e/bale. This is in comparison with the values of 10.0 GJ/bale and 0.83 tonnes CO_2e/bale for GM cotton. At present, 80 - 90% of Australian grown cotton is of GM varieties.

Furthermore, it was found that furrow irrigated cotton farms lead to higher energy consumption and GHG emissions, compared to lateral move irrigation system. This may be reasonable, as whilst the furrow irrigation directly uses less energy than the lateral move irrigation, higher fertiliser application rates in this system often leads to higher total energy consumption and GHG emissions. On average, 10.4 GJ of energy is required to produce and process a bale of cotton under furrow irrigation with GHG emissions of 0.88 tonnes CO_2e/bale, whilst these values are 8.7 GJ/bale and 0.86 tonnes CO_2e/bale of cotton produced by the lateral move irrigation method.

The effect of 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 relevant GHG emissions of 0.38, 0.39 and 0.41 tonnes CO_2e/bale respectively. Thus, zero tillage uses the least energy and emits the least GHG emissions amongst the three tillage practices.

A comparison between cotton, wool and other chemical synthesis was also conducted, and it was found that cotton is consuming the least energy (46.4 MJ/kg of cotton) in comparison with wool, acrylic, polypropylene, viscose, polyester and nylon.

Finally, a comparison of maximum greenhouse gas emissions reduction when all the new technologies are combined had also been undertaken. 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 CO_2e per bale. This is a 57% reduction of the average energy use in current farming systems.

Chapter 8 – Conclusions and Recommendations for Further Research

In this study Australian cotton energy consumption and the greenhouse gas emissions from the field to the port has been calculated by employing the life cycle assessment (LCA) methodology. A software model has been developed to represent the LCA sections for Australian cotton farming system. Data were collected from twelve Bremner and three Keytah paddocks. Analysis of the field data has been undertaken by using the values from the developed model, as well as sensitive study on cotton varieties and irrigation systems.

It has been found that the major effect on total energy consumption and relevant emissions was related to the fertiliser and herbicide application rates. The energy consumed to manufacture the fertilisers and herbicides, combined with on-farm spraying and fertilising applications were found to be the biggest energy consumer in Australian cotton farming from field to the port.

In the following sections, the comparison of the energy and emission participation of the four main life cycle stages, plus soil emissions, for a “typical” Australian cotton farm will be made. Subsequently the main result summary of comparison between different farming systems and with other crops will be presented. This will enable the cotton industry and the farmers to compare their cotton farming energy consumption and carbon footprint to optimize their practices by knowing the impact of each farming operation separately. Further research suggestions and recommendations will also be given.

8.1 Effect of Cotton Farming Practices and Fertiliser Applications

Cotton farm survey data showed that on average cotton on-farm indirect energy consumption and the related emissions were the highest. They ranged from 65.7 to 112.2 GJ/ha, with the average value of 83.7 GJ/ha (7.7 GJ/bale); and 5 to 6.3 tonnes CO_2e/ha, with the average of 5.7 tonnes CO_2e/ha (524 kg CO_2e/bale) respectively. Key findings on on-farm indirect energy consumption and greenhouse gas emissions are listed below. All values are averages for a typical Australian cotton farm:

- Energy consumed by on-farm indirect applications of cotton farming through its total life cycle on average accounted for about 77 % of total for all surveyed farms. The main contributors were found to be the energy used to manufacture fertilisers and chemicals. The next largest energy consumer section was the manufacturing of agricultural machinery and farm implements with up to 40% contribution.

- Australian cotton greenhouse gas emissions were mainly affected by the on-farm indirect stage, which on average accounted for 66 % of total greenhouse gas emissions arising from cotton production and processing. Emissions due to fertiliser manufacturing were the highest on all farms, followed by the farm machinery production processes.

8.2 Effect of Cotton Varieties

Energy consumption and its related emissions to produce and process conventional cotton from the field to the port accounted for 52.4 MJ/kg with the related emissions of 3.8 kg CO_2e/kg of conventional cotton.

The corresponding values for Australian genetically modified cotton were calculated to be 45.8 MJ/kg and 3.8 kg CO_2e/kg of GM cotton respectively. It was found that conventional cotton farming was using more energy (by 6.6 MJ/kg) than of GM cotton, whilst their greenhouse gas emissions were similar.

In this study energy consumption for conventional cotton production accounted for 124 GJ/ha, equivalent to 52.4 MJ/kg, excluding milling, which is lower than the overseas value of 147 MJ/kg to produce the conventional cotton fabric fibre and weave it into cloth (Oecotextiles, 2009). As discussed in this chapter, the amount of fertilisers used for the cotton production can significantly impact the energy consumption rate, hence this difference is mainly due to the lower fertiliser rates employed on Australian conventional cotton farms, compared to overseas farming systems.

8.3 Effect of Irrigation Systems

Comparison made in Chapter 7 showed that the amongst different cotton farming irrigation systems, total energy consumption of cotton farms under lateral move was found to be the lowest with 95.3 GJ/ha (8.7 GJ/bale), compared to 112.9 GJ/ha (10.4

GJ/bale) for furrow irrigation. As cotton farms under furrow irrigation apply larger quantities of fertiliser, this difference is assumed to be related to this practice.

Production and process stages of cotton farming under furrow irrigation method accounted for the emissions of 9.5 tonnes CO_2e/ha (0.88 tonnes CO_2e/bale). This demonstrates the effect of higher fertiliser usage on furrow irrigated cotton farms, as this value was 9.4 tonnes CO_2e/ha (0.86 tonnes CO_2e/bale) to plant and process one hectare of cotton under lateral move irrigation systems.

Greenhouse gas emissions of different cotton farms under furrow and lateral move irrigation systems were compared and found that lateral move was a superior system in that respect. This was not due to the emissions out of irrigation system itself, but was a result of higher fertiliser usage in cotton farms under furrow irrigation systems.

8.4 Effect of Tillage Practices

It was calculated that over the cotton production total life cycle from field to the port, zero tillage consumed less energy compared to minimum and conventional tillage systems – which was the highest contributor.

Energy saving of up to 13 % was found to be achievable by moving from minimum to zero tillage, whilst cotton farmers replacing conventional by minimum tillage may reduce their energy consumption by 12%. The biggest energy reduction was found to be in system transfers from conventional tillage to zero tillage in which up to 25% energy saving was possible.

8.5 Cotton vs. Wool and Chemical Synthesis Fibres

Australian cotton industry on average consumed 110 GJ (10.1 GJ/bale) of energy to produce a hectare of cotton. Its related emissions accounted for 9.5 tonnes CO_2e/ha (0.87 tonnes CO_2e/bale) of harvested and processed cotton. Australian cotton accounted for lower energy consumption compared to Wool, Polyester, Nylon, Acrylic, Polypropylene and Viscose.

8.6 Maximum Energy and Greenhouse Gas Emissions Reduction

By applying less fertiliser in GM cotton field under zero tillage and lateral move irrigation systems on a big farm (such as 5200 hectares used in the Keytah case studies), it has been shown that energy consumption can be effectively reduced by 57%. This reduction is mainly due to less embodied energy associated with farm machinery capital.

8.7 Recommendations and Further Research

- It can be concluded that in order to reduce energy consumption whilst producing and processing cotton with fewer emissions, the fertiliser application rate needs to be lowered, as it plays the key role in total energy consumption and emissions of Australian cotton farming.

- As Genetically Modified cotton accounted for lower chemical and fertiliser application rates compared to conventional cotton, it is recommended to plant

GM cotton instead of conventional variety to reduce the Australian cotton farming system energy consumption. It is cautioned that this recommendation however does not necessarily apply to other environmental indicators, such as biodiversity and impact of long-term human health.

- As the machinery used in cotton farming systems can handle bigger farm applications, it has been found that bigger farm size would lead to decrease in energy consumption and greenhouse gas emissions, as total energy and emissions values out of machinery manufacturing are calculated on per ha basis, thus lowering the implied value for bigger farms. Alternatively, using contractors for machinery applications could achieve similar results. This can significantly reduce the energy consumption and the related emissions arising from machinery manufacturing, which will affect the total calculations accordingly.

- Further research must be undertaken to establish if there is a direct relationship between irrigation systems and the required fertiliser application rates in cotton farming systems.

- Further study is highly recommended to compare the energy consumption of different tillage practices to confirm the accuracy of energy reduction by moving between zero, minimum and conventional tillage practices. The use of renewable energy such as biodiesel to replace some of the fossil fuel may also need to be explored.

- Research also needs to be broadened to include the other environmental indicators for life cycle assessment.

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Appendices

Appendix 1 – Developed Questionnaire

Questionnaire

On farm direct operations

How much diesel is used during the on farm operations listed below?

1. Tillage

	GM COTTON	NON GM COTTON
Field Preparation		
Planting		

2. Harrowing

Field Preparation		
Planting		

3. Weeding

Field Preparation		
Planting		
In Crop operations		

4. Fertilising

Field Preparation		
Planting		
In Crop operations		

5. Planting

Planting		

6. Spraying

In Crop operations		

7. Harvesting

Harvesting		

8. Infield operations

Harvesting		

9. Crop Destruction

Post Harvest		

10. Irrigation

	Type of irrigation i.e. Furrow	Energy source i.e. electricity, Diesel	Water usage i.e. (l/ha)	Energy unit used i.e. KWh, l
GM Cotton				
Non GM Cotton				

On farm indirect operations

What quantity is used from the units listed below on each farming method?

	GM COTTON	NON GM COTTON
Herbicides (L)		
Insecticides (kg)		
Fungicides (L)		
Plant Growth Regulator (kg)		
Oil (L)		
Nitrogen (kg)		
Ammonia		
Urea (kg)		
Diammonium Phosphate (kg)		
Potassium		
Sulphur (kg)		
Lime		
Seeds (kg)		

Please choose the machinery used during your farming sections from the list below and fill the relevant data.

	Please tick if used	Average mass (kg)	Machinery type if applicable i.e. John Deere 3050
Mower (kg)			
Harvester (kg)			
Silage Feed Wagon (kg)			
Bale Feeder (kg)			
Front End Loader (kg)			
Fertiliser Spreader (kg)			
Sprayer (kg)			
Hay Rake (kg)			
Hay Baler (kg)			
Tractors (kg)			
Farm Implements (kg)			
Plough (kg)			
Discs (kg)			

Cultivator (kg)			
Harrows (kg)			
Roller (kg)			
Drill (kg)			
Trailer (kg)			
Post Rammer (kg)			
Grader Blade (kg)			

Have you seen a change in the numbers of machinery you need for GM cotton and Non GM cotton farming?

( ) Yes ( ) No

What major changes you found while comparing input used i.e. fertiliser, Diesel, between GM Cotton and Non GM cotton farming systems?

Is there any other information that you may note during comparison of GM and Non GM cotton Farming Systems?

Thanks for your time.

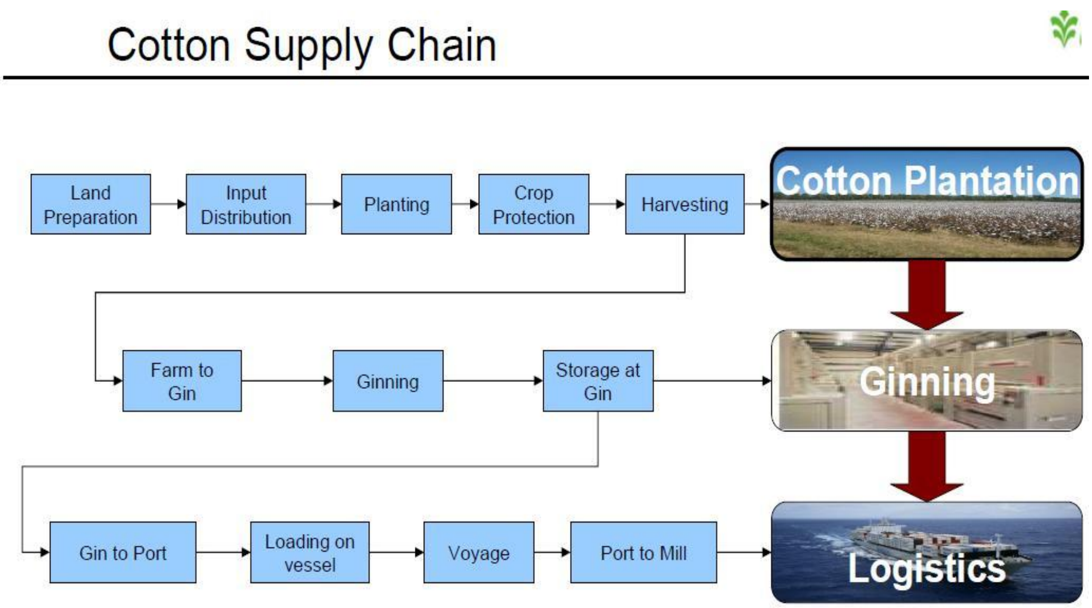
Appendix 2

Energy consumed to produce cotton in different regions (Matlock et al, 2008)

Region	Production Strategy	Irrigation	Fertilizer	Mean (MJ/tonne)	Standard Deviation (MJ/tonne)
North America East	Mechanized	None	High	5,667	962
North America West	Mechanized	High	High	14,081	5,176
South America Mech	Mechanized	Medium	Medium	24,258	6,090
South America Non-Mech	Non-Mechanized	Medium	Medium	48,205	63,488
Australia	Mechanized	High	High	8,249	2,188
Mediterranean - Mech	Mechanized	Medium	High	9,114	3,992
Mediterranean - Non-Mech	Non-Mechanized	Medium	Low	6,901	1,350
Asia - Mech	Mechanized	High	High	13,043	5,658
Asia - Non-Mech	Non-Mechanized	Medium	Medium	9,989	18,275
Africa - Non Mech	Non-Mechanized	High	None	44,942	25,484

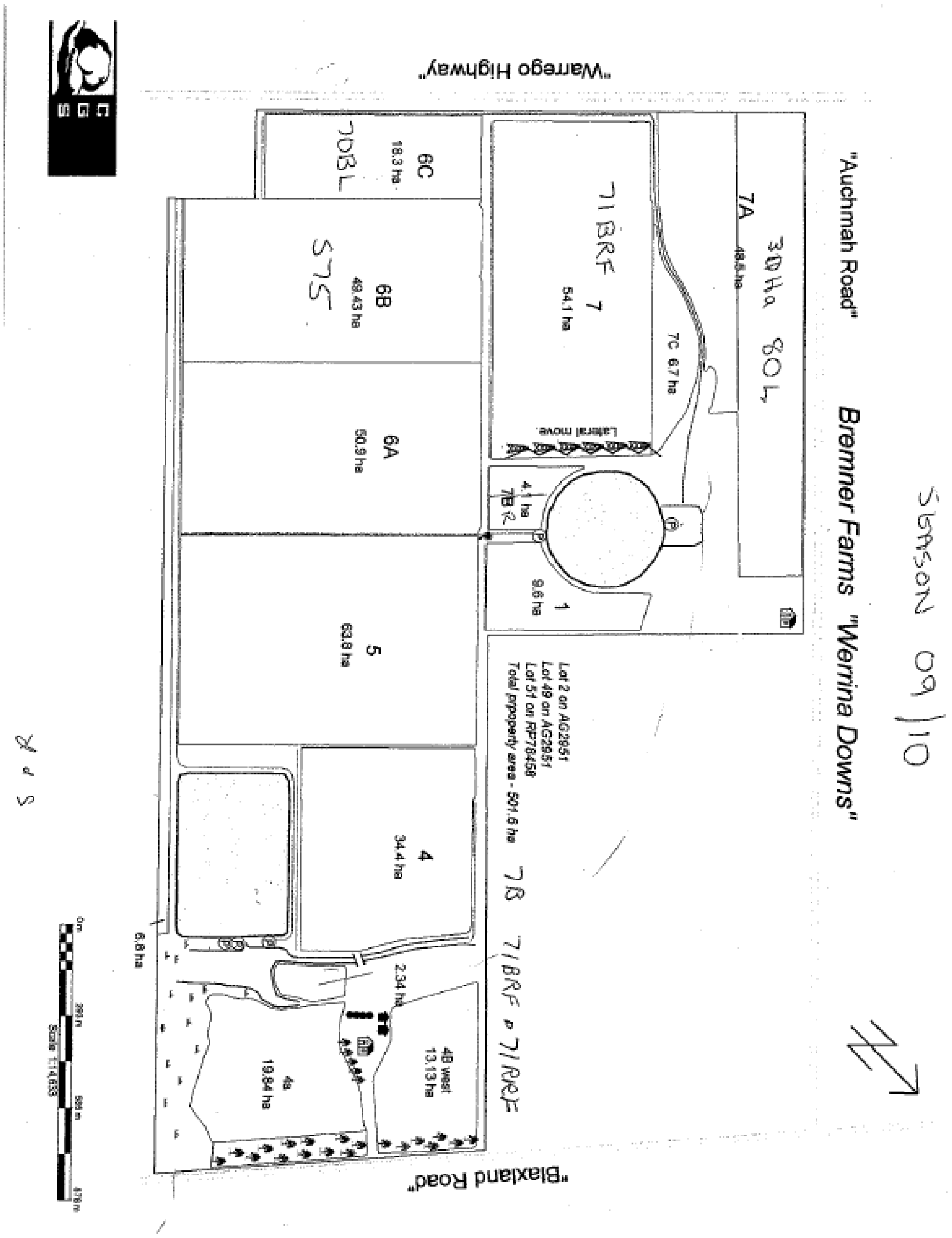
Appendix 3

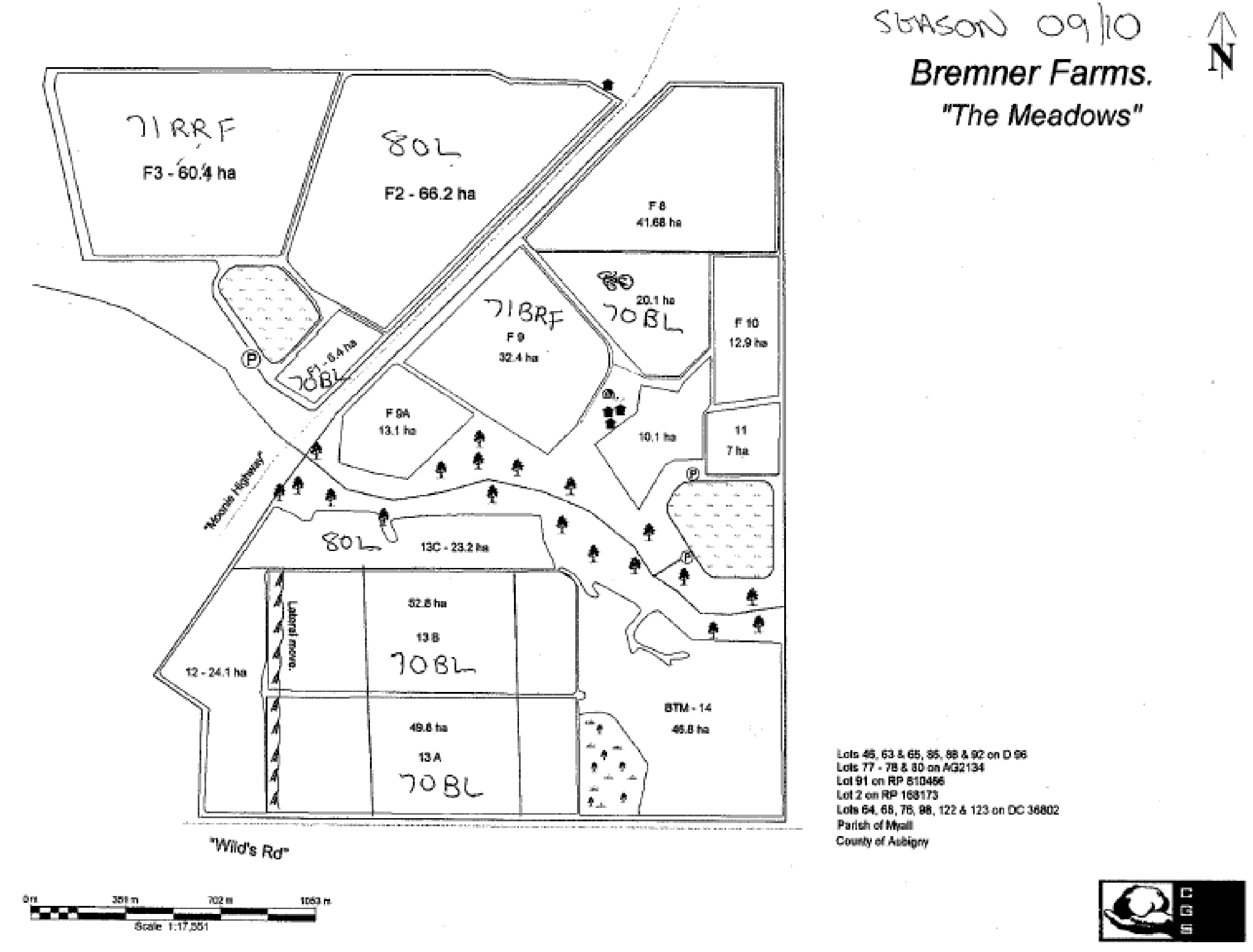
LCA Methodology used in Olam study (International Cotton Advisory Committee, 2008)



Appendix 4

Bremner Farms Local Map




SEASON 09/10
Bremner Farms.
"The Meadows"
N
71RRF
F3 - 60.4 ha
80L
F2 - 66.2 ha
F 8
41.68 ha
20.1 ha
70BL
F 10
12.9 ha
71BRF
F 9
32.4 ha
F1 - 6.4 ha
70BL
F 9A
13.1 ha
10.1 ha
11
7 ha
"Moonie Highway"
80L
13C - 23.2 ha
52.8 ha
13 B
70BL
Lateral move.
12 - 24.1 ha
49.8 ha
13 A
70BL
BTM - 14
46.8 ha
"Wild's Rd"
0 m
351 m
702 m
1053 m
Scale 1:17,551
Lots 46, 63 & 65, 85, 88 & 92 on D 96
Lots 77 - 78 & 80 on AG2134
Lot 91 on RP 810466
Lot 2 on RP 168173
Lots 64, 68, 76, 98, 122 & 123 on DC 36802
Parish of Myall
County of Aubigny
CGS

Appendix 5

Bremner farms raw data

Bremner Farms — Page 1

Annual Crop Summary Report

Farm : *Werrina Downs* — *Season : 2009*

Paddock : 01 WD

Cotton : Sicot 80BRF (B 8.7 Ha) — **Total Area: 8.7 Ha.**

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
Crop Details							
Seeding and Planting							
20/10/2008	8.7	Main Crop	13Kg	7.00	91.00	791.70	
Seeding and Planting		Totals :			$91.00	$791.70	
Crop Details		Totals :			$91.00	$791.70	
Chemical Application							
Chemicals							
20/10/2008	8.7	Temik	3.5Kg	14.25	49.88	433.91	
21/10/2008	8.7	Sprayseed 250	1.5L	12.00	18.00	156.60	
12/11/2008	8.7	Roundup Ready Dry	1.4Kg	23.00	32.20	280.14	
19/12/2008	8.7	Roundup Ready Dry	1.5Kg	23.50	35.25	306.68	
24/12/2008	8.7	Dimethoate	0.5L	8.95	4.47	38.93	
30/12/2008	8.7	Bollgard Licence Fee	1L	315.00	315.00	2740.50	
30/12/2008	8.7	RRFlex Licence Fee	1L	75.00	75.00	652.50	
7/01/2009	8.7	Gesagard 500	1.5L	12.50	18.75	163.13	
7/01/2009	8.7	Diuron Flowable	1.5L	7.25	10.88	94.61	
7/01/2009	8.7	DC Trate	1.5L	4.50	6.75	58.73	
7/01/2009	8.7	Roundup CT	1.5L	7.89	11.84	102.97	
24/01/2009	8.7	Shield	250mL	82.20	20.55	178.78	
24/01/2009	8.7	Pulse	0.042L	34.25	1.44	12.55	
19/02/2009	8.7	Bulldock Dual	0.8L	22.96	18.37	159.80	
18/03/2009	8.7	Dropp Liquid	100mL	88.00	8.80	76.56	
18/03/2009	8.7	Canopy	0.5L	5.00	2.50	21.75	
18/03/2009	8.7	Prep	0.5L	9.00	4.50	39.15	
18/03/2009	8.7	Dimethoate	0.5L	9.15	4.58	39.80	
24/03/2009	8.7	Prep	2L	9.00	18.00	156.60	
24/03/2009	8.7	Dropp Liquid	100mL	88.00	8.80	76.56	
24/03/2009	8.7	Canopy	0.5L	5.00	2.50	21.75	
Chemicals		Totals :			$668.05	$5,811.99	
Fertiliser Application							
Fertilisers							
19/07/2008	8.7	Feedlot Manure	8T	16.00	128.00	1113.60	
31/08/2008	8.7	Urea	300Kg	630.00	189.00	1644.30	
18/12/2008	8.7	FIZ	1L	4.50	4.50	39.15	
Fertilisers		Totals :			$321.50	$2,797.05	
Irrigation							
Irrigation							
29/10/2008	8.7	Cliffies	50mm.		5.00	43.50	
24/12/2008	8.7	Cliffies	80mm.		8.00	69.60	
8/01/2009	8.7	Cliffies	80mm.		8.00	69.60	
16/01/2009	8.7	Cliffies	60mm.		6.00	52.20	
6/02/2009	8.7	Cliffies	60mm.		6.00	52.20	
Irrigation		Totals :			$33.00	$287.10	
Machinery Operation							
Machinery Operations							
2/07/2008	8.7	4450 Tractor					
2/07/2008	8.7	Pioneer 8M Rake			5.00	43.50	
4/07/2008	8.7	4450 Tractor					

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PAM 6.7.0 Report

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
4/07/2008	8.7	Pioneer 8M Rake			5.00	43.50	
19/07/2008	8.7	8300 Tractor					
19/07/2008	8.7	WallabySpreader			5.00	43.50	
18/08/2008	8.7	Agroplow 4M			10.00	87.00	
18/08/2008	8.7	8300 Tractor					
31/08/2008	8.7	8410 Tractor					
31/08/2008	8.7	Rotary Hoe			15.00	130.50	
27/09/2008	8.7	8300 Tractor					
27/09/2008	8.7	Lillistons			5.00	43.50	
29/09/2008	8.7	7420 Tractor					
29/09/2008	8.7	Rollers Light			5.00	43.50	
20/10/2008	8.7	Max E Planter			5.00	43.50	
20/10/2008	8.7	8410 Tractor					
21/10/2008	8.7	7420 Tractor					
21/10/2008	8.7	16M Spray Rig			5.00	43.50	
12/11/2008	8.7	16M Spray Rig			5.00	43.50	
12/11/2008	8.7	4450 Tractor					
18/12/2008	8.7	Lillistons			5.00	43.50	
18/12/2008	8.7	8300 Tractor					
19/12/2008	8.7	7420 Tractor					
19/12/2008	8.7	16M Spray Rig			5.00	43.50	
24/12/2008	8.7	Aircraft(Spray)			16.20	140.94	
7/01/2009	8.7	8M Spray Bar					
7/01/2009	8.7	7420 Tractor			5.00	43.50	
24/01/2009	8.7	Aircraft(Spray)			18.80	163.56	
19/02/2009	8.7	Aircraft(Spray)			17.80	154.86	
18/03/2009	8.7	Aircraft(Spray)			17.80	154.86	
24/03/2009	8.7	Aircraft(Spray)			17.80	154.86	
1/04/2009	8.7	Our Pickers			200.00	1740.00	
Machinery Operations		Totals :			$368.40	$3,205.08	
Manual Task							
Manual Tasks							
3/12/2008	8.7	Crop Scouting			25.00	217.50	
30/04/2009	8.7	Crop Scouting			25.00	217.50	
Manual Tasks		Totals :			$50.00	$435.00	
Harvest Information							
Harvest							
30/06/2009	8.7	01wd2009	19032Kg	2.20			41870.40
Harvest		Totals :	19032.00				$41,870.40

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
Cotton : Sicot 80BRF (B 8.7 Ha)		Totals :			$0.00	$13,327.92	$41,870.40

Water Use Efficiency and Potential Yield details

Available Water : 614.00mm.
$ / Ha / mm : $5.34 / Ha / mm
Total Yield (Modules) : 19032.00 Kg (Lint
Total Yield / Ha : 2187.59 Kg (Lint :
Breakeven Yield / Ha : 696.34 Kg (3.07
Potential Yield : 18.42 Bls / Ha
% of Potential Yield : 52.3%
Water Use Efficiency : 1.57 Bales/Ha/ML

Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$13,327.92	$41,870.40
Net Income or Loss:		$28,542.48

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$1,531.95	$3,280.74
Costs and Net $ per Kilograms :	$0.70	$1.50
Costs and Net $ per Lint Bale :	$0.00	$0.00

Crop Average Harvest Monitoring details

Fibre Length :	0.00
Fibre Strength :	0.00
Gin Turnout % :	0.00
Micronaire :	0.00

* Indicates that Costs/Ha is based on less than the cropped area

Paddock : 04 WD

Cotton : Sicot 80BRF (B 32.4 Ha) **Total Area: 32.4 Ha.**

Crop Details

Seeding and Planting

21/10/2008	32.4	Main Crop	13Kg	6.55	85.15	2758.86
Seeding and Planting		Totals :			$85.15	$2,758.86
Crop Details		Totals :			$85.15	$2,758.86

Chemical Application

Chemicals

21/10/2008	32.4	Temik	3.5Kg	14.25	49.88	1615.95
21/10/2008	32.4	Sprayseed 250	1.5L	12.00	18.00	583.20
13/11/2008	32.4	Roundup Ready Dry	1.5Kg	23.50	35.25	1142.10
19/12/2008	32.4	Roundup Ready Dry	1.5Kg	23.50	35.25	1142.10
24/12/2008	32.4	Dimethoate	0.5L	8.95	4.48	144.99
30/12/2008	32.4	Bollgard Licence Fee	1L	315.00	315.00	10206.00
30/12/2008	32.4	RRFlex Licence Fee	1L	75.00	75.00	2430.00
7/01/2009	32.4	Gesagard 500	1.5L	12.50	18.75	607.50
7/01/2009	32.4	Diuron Flowable	1.5L	7.25	10.88	352.35
7/01/2009	32.4	DC Trate	1.5L	4.50	6.75	218.70
7/01/2009	32.4	Roundup CT	1.5L	7.89	11.84	383.45
24/01/2009	32.4	Shield	250mL	82.20	20.55	665.82
24/01/2009	32.4	Pulse	0.042L	34.25	1.44	46.72
19/02/2009	32.4	Bulldock Dual	0.8L	22.96	18.37	595.12
18/03/2009	32.4	Dropp Liquid	100mL	88.00	8.80	285.12
18/03/2009	32.4	Canopy	0.5L	5.00	2.50	81.00
18/03/2009	32.4	Prep	0.5L	9.00	4.50	145.80
18/03/2009	32.4	Dimethoate	0.5L	9.15	4.58	148.23
24/03/2009	32.4	Prep	2L	9.00	18.00	583.20
24/03/2009	32.4	Dropp Liquid	100mL	88.00	8.80	285.12
24/03/2009	32.4	Canopy	0.5L	5.00	2.50	81.00
Chemicals		Totals :			$671.10	$21,743.48

Fertiliser Application

Fertilisers

2/09/2008	32.4	Urea	300Kg	630.00	189.00	6123.60
18/12/2008	32.4	FIZ	1L	4.50	4.50	145.80
9/01/2009	32.4	Easy N	10L	1.30	13.00	421.20
19/01/2009	32.4	Easy N	10L	1.30	13.00	421.20
Fertilisers		Totals :			$219.50	$7,111.80

Irrigation

Irrigation

22/10/2008	32.4	Main Dam	50mm.		5.00	162.00
25/10/2008	32.4	Main Dam	50mm.		5.00	162.00
24/12/2008	32.4	Main Dam	80mm.		8.00	259.20
9/01/2009	32.4	Main Dam	57.143mm.		5.71	185.14
19/01/2009	32.4	Main Dam	60mm.		6.00	194.40
3/02/2009	32.4	Main Dam	60mm.		6.00	194.40
26/02/2009	32.4	Main Dam	60mm.		6.00	194.40
Irrigation		Totals :			$41.71	$1,351.54

Machinery Operation

Machinery Operations

1/07/2008	32.4	Pioneer 8M Rake			5.00	162.00
1/07/2008	32.4	4450 Tractor				
3/07/2008	32.4	4450 Tractor				

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
3/07/2008	32.4	Pioneer 8M Rake			5.00	162.00	
14/08/2008	32.4	Agroplow 4M			10.00	324.00	
14/08/2008	32.4	8300 Tractor					
2/09/2008	32.4	Rotary Hoe			15.00	486.00	
2/09/2008	32.4	8410 Tractor					
27/09/2008	32.4	8300 Tractor					
27/09/2008	32.4	Lillistons			5.00	162.00	
29/09/2008	32.4	7420 Tractor					
29/09/2008	32.4	Rollers Light			5.00	162.00	
21/10/2008	32.4	Max E Planter					
21/10/2008	32.4	8410 Tractor					
21/10/2008	32.4	18M Spray Rig			5.00	162.00	
21/10/2008	32.4	7420 Tractor					
13/11/2008	32.4	18M Spray Rig			5.00	162.00	
13/11/2008	32.4	4440 Tractor					
18/12/2008	32.4	8300 Tractor					
18/12/2008	32.4	Lillistons			5.00	162.00	
19/12/2008	32.4	18M Spray Rig			5.00	162.00	
19/12/2008	32.4	7420 Tractor					
24/12/2008	32.4	Aircraft(Spray)			16.20	524.88	
7/01/2009	32.4	8M Spray Bar					
7/01/2009	32.4	7420 Tractor			5.00	162.00	
9/01/2009	32.4	Aircraft(Spray)			19.95	646.38	
19/01/2009	32.4	Aircraft(Spray)			19.95	646.38	
24/01/2009	32.4	Aircraft(Spray)			18.80	609.12	
19/02/2009	32.4	Aircraft(Spray)			17.80	576.72	
18/03/2009	32.4	Aircraft(Spray)			17.80	576.72	
24/03/2009	32.4	Aircraft(Spray)			17.80	576.72	
7/04/2009	9.6	Our Pickers			200.00*	1920.00	
Machinery Operations		Totals :			$257.56	$8,344.92	
Manual Task							
Manual Tasks							
3/12/2008	32.4	Crop Scouting			25.00	810.00	
30/04/2009	32.4	Crop Scouting			25.00	810.00	
Manual Tasks		Totals :			$50.00	$1,620.00	
Harvest Information							
Harvest							
30/06/2009	32.4	042009	71162Kg	2.20			156556.40
Harvest		Totals :	71162.00				$156,556.40

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* Indicates that Costs/Ha is based on less than the cropped area

PAM 6.7.0 Report

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
Cotton : Sicot 80BRF (B 32.4 Ha)		Totals :			$0.00	$42,930.60	$156,556.40

Water Use Efficiency and Potential Yield details

Available Water : 701.14mm.
$ / Ha / mm : $5.00 / Ha / mm
Total Yield (Modules) : 71162.00 Kg (Lint
Total Yield / Ha : 2196.36 Kg (Lint :
Breakeven Yield / Ha : 602.28 Kg (2.65
Potential Yield : 21.03 Bls / Ha
% of Potential Yield : 46.0%
Water Use Efficiency : 1.38 Bales/Ha/ML

	Total Costs	Total Income
Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$42,930.60	$156,556.40
Net Income or Loss:		$113,625.80

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$1,325.02	$3,506.97
Costs and Net $ per Kilograms :	$0.60	$1.60
Costs and Net $ per Lint Bale :	$0.00	$0.00

Crop Average Harvest Monitoring details

Fibre Length :	0.00
Fibre Strength :	0.00
Gin Turnout % :	0.00
Micronaire :	0.00

Cotton : S80RRF (A 2 Ha) Total Area: 2 Ha.

Crop Details

Seeding and Planting

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
20/10/2008	2	Main Crop	12Kg	6.54	78.48	156.96	
Seeding and Planting		Totals :			$78.48	$156.96	
Crop Details		Totals :			$78.48	$156.96	

Chemical Application

Chemicals

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
20/10/2008	2	Convoy(Cotogard)	4L D%: 40 C%: 100	12.10	19.36	38.72	
20/10/2008	2	Temik	3Kg D%: 40 C%: 100	14.25	17.10	34.20	
21/10/2008	2	Sprayseed 250	1.5L	12.00	18.00	36.00	
13/11/2008	2	Roundup Ready Dry	1.5Kg	23.50	35.25	70.50	
19/12/2008	2	Roundup Ready Dry	1.5Kg	23.50	35.25	70.50	
24/12/2008	2	Dimethoate	0.5L	8.95	4.47	8.95	
7/01/2009	2	Gesagard 500	1.5L	12.50	18.75	37.50	
7/01/2009	2	Diuron Flowable	1.5L	7.25	10.88	21.75	
7/01/2009	2	DC Trate	1.5L	4.50	6.75	13.50	
7/01/2009	2	Roundup CT	1.5L	7.89	11.84	23.67	
24/01/2009	2	Shield	250mL	82.20	20.55	41.10	
24/01/2009	2	Pulse	0.042L	34.25	1.44	2.88	
19/02/2009	2	Bulldock Dual	0.8L	22.96	18.37	36.74	
24/03/2009	2	Prep	2L	9.00	18.00	36.00	
24/03/2009	2	Dropp Liquid	100mL	88.00	8.80	17.60	
24/03/2009	2	Canopy	0.5L	5.00	2.50	5.00	
Chemicals		Totals :			$247.31	$494.61	

Fertiliser Application

Fertilisers

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
2/09/2008	2	Urea	300Kg	630.00	189.00	378.00	
19/01/2009	2	Easy N	10L	1.30	13.00	26.00	
Fertilisers		Totals :			$202.00	$404.00	

Irrigation

Irrigation

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
22/10/2008	2	Main Dam	50mm.		5.00	10.00	
25/10/2008	2	Main Dam	50mm.		5.00	10.00	
24/12/2008	2	Main Dam	80mm.		8.00	16.00	

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PAM 6.7.0 Report

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
9/01/2009	2	Main Dam	57.143mm.		5.71	11.43	
19/01/2009	2	Main Dam	60mm.		6.00	12.00	
3/02/2009	2	Main Dam	60mm.		6.00	12.00	
26/02/2009	2	Main Dam	60mm.		6.00	12.00	
Irrigation		Totals :			$41.71	$83.43	
Machinery Operation							
Machinery Operations							
1/07/2008	2	4450 Tractor					
1/07/2008	2	Pioneer 8M Rake			5.00	10.00	
3/07/2008	2	4450 Tractor					
3/07/2008	2	Pioneer 8M Rake			5.00	10.00	
14/08/2008	2	8300 Tractor					
14/08/2008	2	Agroplow 4M			10.00	20.00	
2/09/2008	2	8410 Tractor					
2/09/2008	2	Rotary Hoe			15.00	30.00	
27/09/2008	2	8300 Tractor					
27/09/2008	2	Lillistons			5.00	10.00	
29/09/2008	2	7420 Tractor					
29/09/2008	2	Rollers Light			5.00	10.00	
20/10/2008	2	8410 Tractor					
20/10/2008	2	Max E Planter			5.00	10.00	
21/10/2008	2	7420 Tractor					
21/10/2008	2	18M Spray Rig			5.00	10.00	
13/11/2008	2	18M Spray Rig			5.00	10.00	
13/11/2008	2	4440 Tractor					
19/12/2008	2	7420 Tractor					
19/12/2008	2	18M Spray Rig			5.00	10.00	
24/12/2008	2	Aircraft(Spray)			16.20	32.40	
7/01/2009	2	7420 Tractor			5.00	10.00	
7/01/2009	2	8M Spray Bar					
19/01/2009	2	Aircraft(Spray)			19.95	39.90	
24/01/2009	2	Aircraft(Spray)			18.80	37.60	
19/02/2009	2	Aircraft(Spray)			17.80	35.60	
24/03/2009	2	Aircraft(Spray)			17.80	35.60	
Machinery Operations		Totals :			$160.55	$321.10	
Cotton : S80RRF (A 2 Ha)		Totals :		$0.00		$1,460.10	$0.00

Water Use Efficiency and Potential Yield details

Available Water : 701.14mm.
$ / Ha / mm : -$1.04 / Ha / mm
Total Yield (Modules) : 0.00 Kg (Lint :
Total Yield / Ha : 0.00 Kg (Lint :
Breakeven Yield / Ha : 0.00 Kg (0.00
Potential Yield : 21.03 Bls / Ha
% of Potential Yield : 0.0%
Water Use Efficiency : 0.00 Bales/Ha/ML

	Costs	Income
Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$1,460.10	$0.00
Net Income or Loss:		-$1,460.10

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$730.05	-$730.05
Costs and Net $ per Kilograms :	$0.00	$0.00
Costs and Net $ per Lint Bale :	$0.00	$0.00

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PAM 6.7.0 Report

Paddock : 05 WD

Cotton : S75 (A 63.6 Ha) Total Area: 63.6 Ha.

Crop Details

Seeding and Planting

16/10/2008	63.6	Main Crop	11Kg		5.95	65.45	4162.62
Seeding and Planting		Totals :				$65.45	$4,162.62
Crop Details		Totals :				$65.45	$4,162.62

Chemical Application

Chemicals

18/08/2008	63.6	Cobber 475	1L		10.00	10.00	636.00
18/08/2008	63.6	Roundup Ready Dry	0.8Kg		11.61	9.29	590.72
4/10/2008	63.6	Roundup CT	2L		10.00	20.00	1272.00
4/10/2008	63.6	Starane	0.5L		18.50	9.25	588.30
16/10/2008	63.6	Convoy(Cotogard)	4L	B%: 40 C%: 100	12.10	19.36	1231.30
16/10/2008	63.6	Temik	3.5Kg		14.25	49.88	3172.05
21/10/2008	63.6	Sprayseed 250	1.5L		12.00	18.00	1144.80
4/12/2008	63.6	Envoke	15g	B%: 50 C%: 100	3.78	28.35	1803.06
4/12/2008	63.6	BS1000	200mL	B%: 50 C%: 100	6.70	0.67	42.61
4/12/2008	63.6	Staple	36g	B%: 50 C%: 100	1.05	18.90	1202.04
5/12/2008	63.6	Thiodan	2.1L	B%: 50 C%: 100	8.95	9.40	597.68
17/12/2008	63.6	Decis Options	0.786L	B%: 60 C%: 100	14.00	6.60	420.00
23/12/2008	63.6	Thiodan	1.965L		8.95	17.59	1118.75
30/12/2008	63.6	Steward	0.65L		56.85	36.95	2350.18
3/01/2009	63.6	BS1000	60mL		6.70	0.40	25.57
3/01/2009	63.6	Altacor	150g		320.20	48.03	3054.71
8/01/2009	63.6	DC Trate	1.5L		4.50	6.75	429.30
8/01/2009	63.6	Diuron Flowable	1.5L		7.25	10.88	691.65
8/01/2009	63.6	Gesagard 500	1.5L		12.50	18.75	1192.50
13/01/2009	63.6	Affirm	0.55L		84.70	46.59	2962.81
13/01/2009	63.6	BS1000	40mL		6.70	0.27	17.04
13/01/2009	63.6	Ovasyn	2L		9.75	19.50	1240.20
20/01/2009	63.6	BS1000	60mL		6.70	0.40	25.57
20/01/2009	63.6	Altacor	150g		320.20	48.03	3054.71
30/01/2009	63.6	Pix	0.3L		7.20	2.16	137.38
3/02/2009	63.6	Steward	0.85L		63.70	54.14	3443.62
16/02/2009	63.6	Curacron Flexi	4L		1.00	4.00	254.40
16/02/2009	63.6	Pix	0.5L		7.20	3.60	228.96
24/03/2009	63.6	Intruder	50mL		240.00	12.00	763.20
24/03/2009	63.6	Pulse	0.06L		34.25	2.06	130.70
7/04/2009	63.6	Dropp Liquid	130mL		88.00	11.44	727.58
7/04/2009	63.6	Prep	1L		9.00	9.00	572.40
7/04/2009	63.6	Canopy	0.5L		5.00	2.50	159.00
15/04/2009	63.6	Prep	2.5L		9.00	22.50	1431.00
15/04/2009	63.6	Dropp Liquid	150mL		88.00	13.20	839.52
15/04/2009	63.6	Canopy	0.5L		5.00	2.50	159.00
1/09/2009	63.6	Tilt Extra	0.25L		44.00	11.00	699.60
Chemicals		Totals :				$603.93	$38,409.90

Fertiliser Application

Fertilisers

11/07/2008	63.6	Feedlot Manure	8.9T	14.00	124.60	7924.56
5/12/2008	63.6	Zinphos	1L	4.70	4.70	298.92
17/12/2008	63.6	Agri Potash	0.472L			
18/12/2008	23.6	FIZ	1L	4.50	4.50*	106.20

* Indicates that Costs/Ha is based on less than the cropped area

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
30/01/2009	63.6	Focus Hi K	7L	1.50	10.50	667.80	
Fertilisers		Totals :			$141.47	$8,997.48	
Irrigation							
Irrigation							
24/12/2008	63.6	Main Dam	80mm.		8.00	508.80	
9/01/2009	63.6	Main Dam	57.143mm.		5.71	363.43	
19/01/2009	63.6	Main Dam	60mm.		6.00	381.60	
3/02/2009	63.6	Main Dam	60mm.		6.00	381.60	
26/02/2009	63.6	Main Dam	60mm.		6.00	381.60	
Irrigation		Totals :			$31.71	$2,017.03	
Machinery Operation							
Machinery Operations							
11/07/2008	63.6	WallabySpreader			5.00	318.00	
11/07/2008	63.6	8300 Tractor					
18/08/2008	63.6	7420 Tractor			5.00	318.00	
18/08/2008	63.6	16M Spray Rig					
4/10/2008	63.6	7420 Tractor					
4/10/2008	63.6	16M Spray Rig			5.00	318.00	
16/10/2008	63.6	Max E Planter			5.00	318.00	
16/10/2008	63.6	8410 Tractor					
21/10/2008	63.6	7420 Tractor					
21/10/2008	63.6	16M Spray Rig			5.00	318.00	
4/12/2008	63.6	7420 Tractor					
4/12/2008	63.6	8M Spray Bar			5.00	318.00	
5/12/2008	40	8300 Tractor			0.00*		
5/12/2008	40	Lillistons			5.00*	200.00	
5/12/2008	63.6	16M Spray Rig			5.00	318.00	
17/12/2008	63.6	16M Spray Rig			5.00	318.00	
18/12/2008	23.6	Lillistons			5.00*	118.00	
18/12/2008	23.6	8300 Tractor			0.00*		
19/12/2008	43.6	Lillistons			5.00*	218.00	
19/12/2008	43.6	8300 Tractor			0.00*		
23/12/2008	63.6	4450 Tractor					
23/12/2008	63.6	16M Spray Rig			5.00	318.00	
30/12/2008	63.6	Aircraft(Spray)			18.80	1195.68	
3/01/2009	63.6	Aircraft(Spray)			18.80	1195.68	
8/01/2009	63.6	Lillistons			5.00	318.00	
8/01/2009	63.6	7420 Tractor					
13/01/2009	63.6	Aircraft(Spray)			14.95	950.82	
20/01/2009	63.6	Aircraft(Spray)			17.95	1141.62	
30/01/2009	63.6	Aircraft(Spray)			17.30	1100.28	
3/02/2009	63.6	Aircraft(Spray)			17.80	1132.08	
16/02/2009	63.6	Aircraft(Spray)			17.80	1132.08	
24/03/2009	63.6	Aircraft(Spray)			17.80	1132.08	
7/04/2009	63.6	Aircraft(Spray)			17.80	1132.08	
15/04/2009	63.6	Aircraft(Spray)			17.80	1132.08	
27/04/2009	63.6	Peterson Picker			350.00	22260.00	
1/09/2009	63.6	24M Boom Spray			5.00	318.00	
1/09/2009	63.6	7420 Tractor					
Machinery Operations		Totals :			$590.23	$37,538.48	
Manual Task							
Manual Tasks							

* Indicates that Costs/Ha is based on less than the cropped area

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
3/12/2008	63.6	Crop Scouting			25.00	1590.00	
22/12/2008	63.6	Chipping			42.00	2671.20	
30/04/2009	63.6	Crop Scouting			25.00	1590.00	
Manual Tasks		Totals :			$92.00	$5,851.20	
Harvest Information							
Harvest							
30/06/2009	63.6	052009	164066Kg	2.20			360945.20
Harvest		Totals :	164066.00				$360,945.20
Cotton : S75 (A 63.6 Ha)		Totals :		$0.00		$96,976.70	$360,945.20

Water Use Efficiency and Potential Yield details

Available Water : 601.14mm.
$ / Ha / mm : $6.90 / Ha / mm
Total Yield (Modules) : 164066.00 Kg
Total Yield / Ha : 2579.65 Kg (Lint :
Breakeven Yield / Ha : 693.09 Kg (3.05
Potential Yield : 18.03 Bls / Ha
% of Potential Yield : 63.0%
Water Use Efficiency : 1.89 Bales/Ha/ML

	Costs	Net
Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$96,976.70	$360,945.20
Net Income or Loss:		$263,968.50

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$1,524.79	$4,150.45
Costs and Net $ per Kilograms :	$0.59	$1.61
Costs and Net $ per Lint Bale :	$0.00	$0.00

Crop Average Harvest Monitoring details

Fibre Length :	0.00
Fibre Strength :	0.00
Gin Turnout % :	0.00
Micronaire :	0.00

Paddock : 07B WD

Cotton : Sicot 80BRF (A 4.4 Ha) Total Area: 4.4 Ha.

Crop Details

Seeding and Planting

21/10/2008	4.4	Main Crop	13Kg	7.00	91.00	400.40
Seeding and Planting		Totals :			$91.00	$400.40
Crop Details		Totals :			$91.00	$400.40

Chemical Application

Chemicals

20/10/2008	4.4	Roundup CT	4L	10.00	40.00	176.00
21/10/2008	4.4	Temik	3.5Kg	14.25	49.87	219.45
12/11/2008	4.4	Roundup Ready Dry	1.4Kg	23.00	32.20	141.68
19/12/2008	4.4	Roundup Ready Dry	1.5Kg	23.50	35.25	155.10
24/12/2008	4.4	Dimethoate	0.5L	8.95	4.47	19.69
30/12/2008	4.4	Bollgard Licence Fee	1L	315.00	315.00	1386.00
30/12/2008	4.4	RRFlex Licence Fee	1L	75.00	75.00	330.00
7/01/2009	4.4	DC Trate	1.5L	4.50	6.75	29.70
7/01/2009	4.4	Diuron Flowable	1.5L	7.25	10.88	47.85
7/01/2009	4.4	Roundup CT	1.5L	7.89	11.83	52.07
7/01/2009	4.4	Gesagard 500	1.5L	12.50	18.75	82.50
24/01/2009	4.4	Pulse	0.042L	34.25	1.44	6.35
24/01/2009	4.4	Shield	250mL	82.20	20.55	90.42
19/02/2009	4.4	Bulldock Dual	0.8L	22.96	18.37	80.82
18/03/2009	4.4	Canopy	0.5L	5.00	2.50	11.00
18/03/2009	4.4	Dropp Liquid	100mL	88.00	8.80	38.72
18/03/2009	4.4	Prep	0.5L	9.00	4.50	19.80
18/03/2009	4.4	Dimethoate	0.5L	9.15	4.57	20.13
24/03/2009	4.4	Prep	2L	9.00	18.00	79.20
24/03/2009	4.4	Dropp Liquid	100mL	88.00	8.80	38.72
24/03/2009	4.4	Canopy	0.5L	5.00	2.50	11.00
12/08/2009	4.4	Roundup CT	1.5L	7.89	11.83	52.07
12/08/2009	4.4	Trooper 75 D	0.5L			
Chemicals		Totals :			$701.88	$3,088.27

Fertiliser Application

Fertilisers

2/09/2008	4.4	Urea	300Kg	630.00	189.00	831.60
Fertilisers		Totals :			$189.00	$831.60

Irrigation

Irrigation

24/10/2008	4.4	Cliffies	50mm.		5.00	22.00
25/10/2008	4.4	Cliffies	75mm.		7.50	33.00
22/12/2008	4.4	Cliffies	60mm.		6.00	26.40
8/01/2009	4.4	Cliffies	80mm.		8.00	35.20
14/01/2009	4.4	Cliffies	60mm.		6.00	26.40
19/01/2009	4.4	Cliffies	50mm.		5.00	22.00
6/02/2009	4.4	Cliffies	60mm.		6.00	26.40
Irrigation		Totals :			$43.50	$191.40

Machinery Operation

Machinery Operations

18/08/2008	4.4	8300 Tractor		
18/08/2008	4.4	Agroplow 4M	10.00	44.00
2/09/2008	4.4	Rotary Hoe	15.00	66.00
2/09/2008	4.4	8410 Tractor		

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
27/09/2008	4.4	Lillistons			5.00	22.00	
27/09/2008	4.4	8300 Tractor					
29/09/2008	4.4	7420 Tractor					
29/09/2008	4.4	Rollers Light			5.00	22.00	
20/10/2008	4.4	16M Spray Rig			5.00	22.00	
21/10/2008	4.4	Max E Planter			5.00	22.00	
21/10/2008	4.4	8410 Tractor					
12/11/2008	4.4	4450 Tractor					
12/11/2008	4.4	16M Spray Rig			5.00	22.00	
19/12/2008	4.4	7420 Tractor					
19/12/2008	4.4	16M Spray Rig			5.00	22.00	
24/12/2008	4.4	Aircraft(Spray)			16.20	71.28	
7/01/2009	4.4	7420 Tractor			5.00	22.00	
7/01/2009	4.4	8M Spray Bar					
24/01/2009	4.4	Aircraft(Spray)			18.80	82.72	
19/02/2009	4.4	Aircraft(Spray)			17.80	78.32	
18/03/2009	4.4	Aircraft(Spray)			17.80	78.32	
24/03/2009	4.4	Aircraft(Spray)			17.80	78.32	
31/03/2009	4.4	Our Pickers			200.00	880.00	
1/04/2009	4.4	Our Pickers			200.00	880.00	
12/08/2009	4.4	24M Boom Spray			5.00	22.00	
12/08/2009	4.4	7420 Tractor					
Machinery Operations		Totals :			$553.40	$2,434.96	
Manual Task							
Manual Tasks							
3/12/2008	4.4	Crop Scouting			25.00	110.00	
30/04/2009	4.4	Crop Scouting			25.00	110.00	
Manual Tasks		Totals :			$50.00	$220.00	
Harvest Information							
Harvest							
30/06/2009	4.4	7b2009	7404 Kg	2.20			16288.80
Harvest		Totals :	7404.00				$16,288.80
Cotton : Sicot 80BRF (A 4.4 Ha)		Totals :		$0.00		$7,166.63	$16,288.80

Water Use Efficiency and Potential Yield details

Available Water : 435.00mm.
$ / Ha / mm : $4.77 / Ha / mm
Total Yield (Modules) : 7404.00 Kg (Lint :
Total Yield / Ha : 1682.73 Kg (Lint :
Breakeven Yield / Ha : 740.35 Kg (3.26
Potential Yield : 13.05 Bls / Ha
% of Potential Yield : 56.8%
Water Use Efficiency : 1.70 Bales/Ha/ML

Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$7,166.63	$16,288.80
Net Income or Loss:		$9,122.17

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$1,628.78	$2,073.22
Costs and Net $ per Kilograms :	$0.97	$1.23
Costs and Net $ per Lint Bale :	$0.00	$0.00

Crop Average Harvest Monitoring details

Fibre Length :	0.00
Fibre Strength :	0.00
Gin Turnout % :	0.00
Micronaire :	0.00

* Indicates that Costs/Ha is based on less than the cropped area

Farm : *The Meadows* *Season : 2009*

Paddock : 01 JK

Cotton : S80RRF (A 6.4 Ha) **Total Area: 6.4 Ha.**

Crop Details							
Seeding and Planting							
22/10/2008	6.4	Main Crop	13Kg		6.54	85.02	544.13
Seeding and Planting		Totals :				$85.02	$544.13
Crop Details		Totals :				$85.02	$544.13
Chemical Application							
Chemicals							
16/09/2008	6.4	Roundup Ready Dry	1Kg		11.61	11.61	74.30
16/09/2008	6.4	Cobber 475	0.452L		10.00	4.52	28.93
22/10/2008	6.4	Temik	2.5Kg		14.25	35.63	228.00
24/10/2008	6.4	Sprayseed 250	1.813L		12.00	21.75	139.22
15/11/2008	6.4	Roundup Ready Dry	1.5Kg		23.50	35.25	225.60
6/12/2008	6.4	Thiodan	2.1L	B%: 50 C%: 100	8.95	9.40	60.14
11/12/2008	6.4	Roundup Ready Dry	1.4Kg	B%: 10 C%: 100	23.50	3.29	21.06
17/12/2008	6.4	Decis Options	0.7L		14.00	9.80	62.72
17/12/2008	6.4	DC Tron	3L		3.50	10.50	67.20
27/12/2008	6.4	Steward	0.65L		56.85	36.95	236.50
30/12/2008	6.4	RRFlex Licence Fee	1L		75.00	75.00	480.00
5/01/2009	6.4	BS1000	45mL		6.70	0.30	1.93
5/01/2009	6.4	Altacor	150g		320.20	48.03	307.39
13/01/2009	6.4	Roundup Ready Dry	1.5Kg		23.50	35.25	225.60
13/01/2009	6.4	Gesagard 500	1.5L		12.50	18.75	120.00
13/01/2009	6.4	DC Trate	1.5L		4.50	6.75	43.20
13/01/2009	6.4	Diuron Flowable	1.5L		7.25	10.87	69.60
13/01/2009	6.4	BS1000	40mL		6.70	0.27	1.72
13/01/2009	6.4	Ovasyn	2L		9.75	19.50	124.80
13/01/2009	6.4	Affirm	0.55L		84.70	46.59	298.14
20/01/2009	6.4	BS1000	60mL		6.70	0.40	2.57
20/01/2009	6.4	Altacor	150g		320.20	48.03	307.39
30/01/2009	6.4	Pix	0.3L		7.20	2.16	13.82
3/02/2009	6.4	Steward	0.85L		63.70	54.15	346.53
19/02/2009	6.4	Pix	0.5L		7.20	3.60	23.04
19/02/2009	6.4	Curacron Flexi	4L		1.00	4.00	25.60
24/03/2009	6.4	Pulse	0.06L		34.25	2.05	13.15
24/03/2009	6.4	Intruder	50mL		240.00	12.00	76.80
31/03/2009	6.4	Prep	0.5L		9.00	4.50	28.80
31/03/2009	6.4	Canopy	0.5L		5.00	2.50	16.00
31/03/2009	6.4	Dropp Liquid	120mL		88.00	10.56	67.58
7/04/2009	6.4	Dropp Liquid	120mL		88.00	10.56	67.58
7/04/2009	6.4	Prep	2L		9.00	18.00	115.20
7/04/2009	6.4	Canopy	0.5L		5.00	2.50	16.00
Chemicals		Totals :				$615.02	$3,936.12
Fertiliser Application							
Fertilisers							
7/10/2008	6.4	Feedlot Manure	10T		18.00	180.00	1152.00
6/12/2008	6.4	Zinphos	1L		4.70	4.70	30.08
30/01/2009	6.4	Focus Hi K	7L		1.50	10.50	67.20
21/08/2009	6.4	Urea	400Kg		488.00	195.20	1249.28
Fertilisers		Totals :				$390.40	$2,498.56
Irrigation							

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
Irrigation							
25/10/2008	6.4	J K Dam	50mm.		5.00	32.00	
27/12/2008	6.4	J K Dam	100mm.		10.00	64.00	
14/01/2009	6.4	J K Dam	100mm.		10.00	64.00	
3/02/2009	6.4	J K Dam	100mm.		10.00	64.00	
Irrigation		Totals :			$35.00	$224.00	
Machinery Operation							
Machinery Operations							
16/09/2008	6.4	16M Spray Rig					
16/09/2008	6.4	7420 Tractor			5.00	32.00	
7/10/2008	6.4	7420 Tractor			5.00	32.00	
7/10/2008	6.4	WallabySpreader					
22/10/2008	6.4	8410 Tractor					
22/10/2008	6.4	Max E Planter			5.00	32.00	
24/10/2008	6.4	16M Spray Rig			5.00	32.00	
24/10/2008	6.4	7420 Tractor					
15/11/2008	6.4	7420 Tractor					
15/11/2008	6.4	16M Spray Rig			5.00	32.00	
6/12/2008	6.4	16M Spray Rig			5.00	32.00	
6/12/2008	6.4	7420 Tractor					
11/12/2008	6.4	16M Spray Rig			5.00	32.00	
11/12/2008	6.4	7420 Tractor					
16/12/2008	6.4	8300 Tractor					
16/12/2008	6.4	Lillistons			5.00	32.00	
17/12/2008	6.4	Aircraft(Spray)			12.51	80.06	
27/12/2008	6.4	Aircraft(Spray)			17.95	114.88	
5/01/2009	6.4	Aircraft(Spray)			17.95	114.88	
13/01/2009	6.4	Shielded Spray			5.00	32.00	
13/01/2009	6.4	7420 Tractor			5.00	32.00	
13/01/2009	6.4	Shielded Spray			5.00	32.00	
13/01/2009	6.4	7420 Tractor					
13/01/2009	6.4	Aircraft(Spray)			14.95	95.68	
20/01/2009	6.4	Aircraft(Spray)			17.95	114.88	
30/01/2009	6.4	Aircraft(Spray)			17.30	110.72	
3/02/2009	6.4	Aircraft(Spray)			17.80	113.92	
19/02/2009	6.4	Aircraft(Spray)			17.80	113.92	
24/03/2009	6.4	Aircraft(Spray)			17.80	113.92	
31/03/2009	6.4	Aircraft(Spray)			17.80	113.92	
7/04/2009	6.4	Aircraft(Spray)			17.80	113.92	
20/04/2009	6.4	Our Pickers			200.00	1280.00	
4/08/2009	6.4	Pioneer 8M Rake			5.00	32.00	
4/08/2009	6.4	4450 Tractor					
21/08/2009	6.4	8410 Tractor					
21/08/2009	6.4	GreenChisel Bar			5.00	32.00	
Machinery Operations		Totals :			$452.61	$2,896.70	
Manual Task							
Manual Tasks							
3/12/2008	6.4	Crop Scouting			25.00	160.00	
30/04/2009	6.4	Crop Scouting			25.00	160.00	
Manual Tasks		Totals :			$50.00	$320.00	
Harvest Information							
Harvest							

25/02/2010 10:22:32 AM * Indicates that Costs/Ha is based on less than the cropped area

PAM 6.7.0 Report

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
30/06/2009	6.4	012009	14457 Kg	2.03			29347.71
Harvest		Totals :	14457.00				$29,347.71
Cotton : S80RRF (A 6.4 Ha)		Totals :			$0.00	$10,419.51	$29,347.71

Water Use Efficiency and Potential Yield details

Available Water : 1109.50mm.
$ / Ha / mm : $2.67 / Ha / mm
Total Yield (Modules) : 14457.00 Kg (Lint
Total Yield / Ha : 2258.91 Kg (Lint :
Breakeven Yield / Ha : 801.99 Kg (3.53
Potential Yield : 33.28 Bls / Ha
% of Potential Yield : 29.9%
Water Use Efficiency : 0.90 Bales/Ha/ML

	Total Costs	Total Income
Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$10,419.51	$29,347.71
Net Income or Loss:		$18,928.20

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$1,628.05	$2,957.53
Costs and Net $ per Kilograms :	$0.72	$1.31
Costs and Net $ per Lint Bale :	$0.00	$0.00

Crop Average Harvest Monitoring details

Fibre Length :	0.00
Fibre Strength :	0.00
Gin Turnout % :	0.00
Micronaire :	0.00

Paddock : 02 JK

Cotton : S80RRF (A 66.2 Ha) Total Area: 66.2 Ha.

Crop Details

Seeding and Planting

23/10/2008	66.2	Main Crop	13Kg	6.54	85.02	5628.32
Seeding and Planting		Totals :			$85.02	$5,628.32
Crop Details		Totals :			$85.02	$5,628.32

Chemical Application

Chemicals

20/03/2008	66.2	Cobber 475	0.2L		10.00	2.00	132.40
20/03/2008	66.2	Roundup Ready Dry	1Kg		11.61	11.61	768.58
16/09/2008	66.2	Roundup Ready Dry	1Kg		11.61	11.61	768.58
16/09/2008	66.2	Cobber 475	0.452L		10.00	4.52	299.26
23/10/2008	66.2	Temik	2Kg		14.25	28.50	1886.70
24/10/2008	66.2	Sprayseed 250	1.813L		12.00	21.75	1440.00
15/11/2008	66.2	Roundup Ready Dry	1.5Kg		23.50	35.25	2333.55
6/12/2008	66.2	Thiodan	2.1L	B%: 50 C%: 100	8.95	9.40	622.12
11/12/2008	66.2	Roundup Ready Dry	1.4Kg	B%: 10 C%: 100	23.50	3.29	217.80
17/12/2008	66.2	Decis Options	0.7L		14.00	9.80	648.76
17/12/2008	66.2	DC Tron	3L		3.50	10.50	695.10
27/12/2008	66.2	Steward	0.65L		56.85	36.95	2446.26
30/12/2008	66.2	RRFlex Licence Fee	1L		75.00	75.00	4965.00
5/01/2009	66.2	Altacor	150g		320.20	48.03	3179.59
5/01/2009	66.2	BS1000	45mL		6.70	0.30	19.96
13/01/2009	66.2	DC Trate	1.5L		4.50	6.75	446.85
13/01/2009	66.2	Gesagard 500	1.5L		12.50	18.75	1241.25
13/01/2009	66.2	Diuron Flowable	1.5L		7.25	10.87	719.92
13/01/2009	66.2	Affirm	0.55L		84.70	46.59	3083.93
13/01/2009	66.2	BS1000	40mL		6.70	0.27	17.74
13/01/2009	66.2	Ovasyn	2L		9.75	19.50	1290.90
20/01/2009	66.2	Altacor	150g		320.20	48.03	3179.59
20/01/2009	66.2	BS1000	60mL		6.70	0.40	26.61
30/01/2009	66.2	Fix	0.3L		7.20	2.16	142.99
3/02/2009	66.2	Steward	0.85L		63.70	54.14	3584.40
19/02/2009	66.2	Fix	0.5L		7.20	3.60	238.32
19/02/2009	66.2	Curacron Flexi	4L		1.00	4.00	264.80
24/03/2009	66.2	Pulse	0.06L		34.25	2.05	136.04
24/03/2009	66.2	Intruder	50mL		240.00	12.00	794.40
7/04/2009	66.2	Dropp Liquid	130mL		88.00	11.44	757.33
7/04/2009	66.2	Prep	1L		9.00	9.00	595.80
7/04/2009	66.2	Canopy	0.5L		5.00	2.50	165.50
15/04/2009	66.2	Canopy	0.5L		5.00	2.50	165.50
15/04/2009	66.2	Dropp Liquid	150mL		88.00	13.20	873.84
15/04/2009	66.2	Prep	2.5L		9.00	22.50	1489.50
Chemicals		Totals :				$598.77	$39,638.86

Fertiliser Application

Fertilisers

8/10/2008	40	Feedlot Manure	10T	20.00	200.00*	8000.00
6/12/2008	66.2	Zinphos	1L	4.70	4.70	311.14
16/01/2009	66.2	Easy N	10L	1.30	13.00	860.60
30/01/2009	66.2	Focus Hi K	7L	1.50	10.50	695.10
Fertilisers		Totals :			$149.05	$9,866.84

Irrigation

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
Irrigation							
26/10/2008	66.2	J K Dam	50mm.		5.00	331.00	
30/12/2008	66.2	J K Dam	100mm.		10.00	662.00	
15/01/2009	66.2	J K Dam	100mm.		10.00	662.00	
3/02/2009	66.2	J K Dam	100mm.		10.00	662.00	
9/03/2009	66.2	J K Dam	100mm.		10.00	662.00	
Irrigation		Totals :			$45.00	$2,979.00	
Machinery Operation							
Machinery Operations							
20/03/2008	66.2	16M Spray Rig			5.00	331.00	
14/04/2008	66.2	8300 Tractor					
14/04/2008	66.2	EliminatorJanke			10.00	662.00	
3/07/2008	66.2	8410 Tractor					
3/07/2008	66.2	Howard Rotary Hoe			30.00	1986.00	
16/09/2008	66.2	16M Spray Rig					
16/09/2008	66.2	7420 Tractor			5.00	331.00	
8/10/2008	40	WallabySpreader			0.00*		
8/10/2008	40	7420 Tractor			5.00*	200.00	
8/10/2008	40	8300 Tractor			0.00*		
8/10/2008	40	Lillistons			5.00*	200.00	
8/10/2008	40	Rollers Heavy			5.00*	200.00	
8/10/2008	40	4960 Tractor			0.00*		
14/10/2008	26.5	7420 Tractor			5.00*	132.50	
14/10/2008	26.5	WallabySpreader			0.00*		
14/10/2008	26.5	8300 Tractor			0.00*		
14/10/2008	26.5	Lillistons			5.00*	132.50	
14/10/2008	26.5	4960 Tractor			0.00*		
14/10/2008	26.5	Rollers Heavy			5.00*	132.50	
23/10/2008	66.2	Max E Planter			5.00	331.00	
23/10/2008	66.2	8410 Tractor					
24/10/2008	66.2	7420 Tractor					
24/10/2008	66.2	16M Spray Rig			5.00	331.00	
15/11/2008	66.2	16M Spray Rig			5.00	331.00	
15/11/2008	66.2	7420 Tractor					
6/12/2008	66.2	7420 Tractor					
6/12/2008	66.2	16M Spray Rig			5.00	331.00	
11/12/2008	66.2	16M Spray Rig			5.00	331.00	
11/12/2008	66.2	7420 Tractor					
16/12/2008	66.2	8300 Tractor					
16/12/2008	66.2	Lillistons			5.00	331.00	
17/12/2008	66.2	Aircraft(Spray)			12.51	828.16	
27/12/2008	66.2	Aircraft(Spray)			17.95	1188.29	
5/01/2009	66.2	Aircraft(Spray)			17.95	1188.29	
13/01/2009	66.2	Shielded Spray			5.00	331.00	
13/01/2009	66.2	7420 Tractor					
13/01/2009	66.2	Aircraft(Spray)			14.95	989.69	
16/01/2009	66.2	Aircraft(Spray)			18.80	1244.56	
20/01/2009	66.2	Aircraft(Spray)			17.95	1188.29	
30/01/2009	66.2	Aircraft(Spray)			17.30	1145.26	
3/02/2009	66.2	Aircraft(Spray)			17.80	1178.36	
19/02/2009	66.2	Aircraft(Spray)			17.80	1178.36	
24/03/2009	66.2	Aircraft(Spray)			17.80	1178.36	

25/02/2010 10:22:33 AM * Indicates that Costs/Ha is based on less than the cropped area

PAM 6.7.0 Report

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
7/04/2009	66.2	Aircraft(Spray)			17.80	1178.36	
15/04/2009	66.2	Aircraft(Spray)			17.80	1178.36	
28/04/2009	66.2	Our Pickers			200.00	13240.00	
Machinery Operations		Totals :			$506.48	$33,528.84	
Manual Task							
Manual Tasks							
3/12/2008	66.2	Crop Scouting			25.00	1655.00	
30/04/2009	66.2	Crop Scouting			25.00	1655.00	
Manual Tasks		Totals :			$50.00	$3,310.00	
Harvest Information							
Harvest							
30/06/2009	66.2	022009	163414Kg	2.03			331730.42
Harvest		Totals :	163414.00				$331,730.42
Cotton : S80RRF (A 66.2 Ha)		Totals :			$0.00	$94,951.86	$331,730.42

Water Use Efficiency and Potential Yield details

Available Water : 1209.50mm.
$ / Ha / mm : $2.96 / Ha / mm
Total Yield (Modules) : 163414.00 Kg
Total Yield / Ha : 2468.49 Kg (Lint :
Breakeven Yield / Ha : 706.56 Kg (3.11
Potential Yield : 36.28 Bls / Ha
% of Potential Yield : 30.0%
Water Use Efficiency : 0.90 Bales/Ha/ML

Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$94,951.86	$331,730.42
Net Income or Loss:		$236,778.56

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$1,434.32	$3,576.72
Costs and Net $ per Kilograms :	$0.58	$1.45
Costs and Net $ per Lint Bale :	$0.00	$0.00

Crop Average Harvest Monitoring details

Fibre Length :	0.00
Fibre Strength :	0.00
Gin Turnout % :	0.00
Micronaire :	0.00

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PAM 6.7.0 Report

Paddock : 03 JK

Cotton : Sicot 80L (A 60.4 Ha) Total Area: 60.4 Ha.

Crop Details							
Seeding and Planting							
24/10/2008	60.4	Main Crop	13.46Kg		6.55	88.16	5325.05
14/11/2008	26	Cotton / Sicot 80L	13.46Kg		6.70	90.18*	2344.73
Seeding and Planting		Totals :				$126.98	$7,669.78
Crop Details		Totals :				$126.98	$7,669.78
Chemical Application							
Chemicals							
24/10/2008	60.4	Temik	3.5Kg		14.25	49.88	3012.45
24/10/2008	60.4	Roundup CT	2L		10.00	20.00	1208.00
27/10/2008	60.4	Sprayseed 250	1.5L		12.00	18.00	1087.20
24/11/2008	60.4	Liberty	3.75L		11.60	43.50	2627.40
17/12/2008	60.4	Decis Options	0.7L		14.00	9.80	591.92
17/12/2008	60.4	DC Tron	3L		3.50	10.50	634.20
21/12/2008	60.4	Liberty	3.75L	B%: 50 C%: 100	11.60	21.75	1313.70
27/12/2008	60.4	Steward	0.65L		56.85	36.95	2231.93
5/01/2009	60.4	Altacor	150g		320.20	48.03	2901.01
5/01/2009	60.4	BS1000	45mL		6.70	0.30	18.21
13/01/2009	60.4	Ovasyn	2L		9.75	19.50	1177.80
13/01/2009	60.4	Affirm	0.55L		84.70	46.58	2813.73
13/01/2009	60.4	BS1000	40mL		6.70	0.27	16.19
17/01/2009	60.4	Liberty	3.75L		11.60	43.50	2627.40
19/01/2009	60.4	DC Trate	1.5L		4.50	6.75	407.70
19/01/2009	60.4	Diuron Flowable	1.5L		7.25	10.88	656.85
19/01/2009	60.4	Gesagard 500	1.5L		12.50	18.75	1132.50
20/01/2009	60.4	Altacor	150g		320.20	48.03	2901.01
20/01/2009	60.4	BS1000	60mL		6.70	0.40	24.28
30/01/2009	60.4	Pix	0.3L		7.20	2.16	130.46
1/02/2009	60.4	Liberty Link Licence	1L		50.00	50.00	3020.00
3/02/2009	60.4	Steward	0.85L		63.70	54.15	3270.36
19/02/2009	60.4	Pix	0.5L		7.20	3.60	217.44
19/02/2009	60.4	Curacron Flexi	4L		1.00	4.00	241.60
24/03/2009	60.4	Pulse	0.06L		34.25	2.05	124.12
24/03/2009	60.4	Intruder	50mL		240.00	12.00	724.80
17/04/2009	60.4	Dropp Ultra Max	130mL		220.00	28.60	1727.44
17/04/2009	60.4	Prep	1L		9.00	9.00	543.60
17/04/2009	60.4	Canopy	0.5L		5.00	2.50	151.00
25/04/2009	60.4	Dropp Ultra Max	120mL		220.00	26.40	1594.56
25/04/2009	60.4	Prep	3L		9.00	27.00	1630.80
25/04/2009	60.4	Canopy	0.5L		5.00	2.50	151.00
Chemicals		Totals :				$677.33	$40,910.66
Fertiliser Application							
Fertilisers							
26/08/2008	60.4	Feedlot Manure	9T		20.00	180.00	10872.00
29/09/2008	60.4	Urea	400Kg		630.00	252.00	15220.80
30/01/2009	60.4	Focus Hi K	7L		1.50	10.50	634.20
30/01/2009	60.4	Easy N	10L		1.30	13.00	785.20
Fertilisers		Totals :				$455.50	$27,512.20
Irrigation							
Irrigation							
29/10/2008	60.4	J K Dam	100mm.			10.08	609.00

* Indicates that Costs/Ha is based on less than the cropped area

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
3/01/2009	60.4	J K Dam	100mm.		10.08	609.00	
22/01/2009	10	J K Dam	100mm.		10.00*	100.00	
28/01/2009	43.9	J K Dam	100mm.		10.00*	439.00	
12/02/2009	7	J K Dam	100mm.		10.00*	70.00	
2/03/2009	60.4	J K Dam	100mm.		10.08	609.00	
Irrigation		Totals :			$40.33	$2,436.00	
Machinery Operation							
Machinery Operations							
25/08/2008	60.4	Agroplow 4M			10.00	604.00	
25/08/2008	60.4	8300 Tractor					
26/08/2008	60.4	WallabySpreader					
26/08/2008	60.4	7420 Tractor			5.00	302.00	
29/09/2008	60.4	Rotary Hoe			15.00	906.00	
29/09/2008	60.4	8410 Tractor					
2/10/2008	60.4	7420 Tractor					
2/10/2008	60.4	Rollers Heavy			5.00	302.00	
24/10/2008	60.4	8410 Tractor					
24/10/2008	60.4	Max E Planter			5.00	302.00	
24/10/2008	60.4	18M Spray Rig			5.00	302.00	
24/10/2008	60.4	7420 Tractor					
27/10/2008	60.4	7420 Tractor					
27/10/2008	60.4	18M Spray Rig			5.00	302.00	
14/11/2008	26	8410 Tractor			0.00*		
14/11/2008	26	Max E Planter			0.00*		
24/11/2008	60.4	18M Spray Rig			5.00	302.00	
24/11/2008	60.4	7420 Tractor					
17/12/2008	60.4	Aircraft(Spray)			12.51	755.60	
21/12/2008	60.4	7420 Tractor			5.00	302.00	
21/12/2008	60.4	8M Spray Bar					
27/12/2008	60.4	Aircraft(Spray)			17.95	1084.18	
1/01/2009	60.4	Lillistons			5.00	302.00	
1/01/2009	60.4	8300 Tractor					
5/01/2009	60.4	Aircraft(Spray)			17.95	1084.18	
13/01/2009	60.4	Aircraft(Spray)			14.95	902.98	
17/01/2009	60.4	7420 Tractor					
17/01/2009	60.4	Shielded Spray			5.00	302.00	
19/01/2009	60.4	Directed Spraye			5.00	302.00	
19/01/2009	60.4	7420 Tractor					
20/01/2009	60.4	Aircraft(Spray)			17.95	1084.18	
30/01/2009	60.4	Aircraft(Spray)			18.80	1135.52	
3/02/2009	60.4	Aircraft(Spray)			17.80	1075.12	
19/02/2009	60.4	Aircraft(Spray)			17.80	1075.12	
24/03/2009	60.4	Aircraft(Spray)			17.80	1075.12	
17/04/2009	60.4	Aircraft(Spray)			17.80	1075.12	
25/04/2009	60.4	Aircraft(Spray)			17.80	1075.12	
7/05/2009	53	Our Pickers			200.00*	10600.00	
11/05/2009	7.9	Our Pickers			200.00*	1580.00	
Machinery Operations		Totals :			$465.77	$28,132.24	
Manual Task							
Manual Tasks							
3/12/2008	60.4	Crop Scouting			25.00	1510.00	
30/04/2009	60.4	Crop Scouting			25.00	1510.00	

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PAM 6.7.0 Report

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
Manual Tasks		Totals :			$50.00	$3,020.00	
Harvest Information							
Harvest							
30/06/2009	60.4	032009	144365Kg	2.20			317603.00
Harvest		Totals :	144365.00				$317,603.00
Cotton : Sicot 80L (A 60.4 Ha)		Totals :		$0.00		$109,680.88	$317,603.00

Water Use Efficiency and Potential Yield details

Available Water : 1359.50mm.
$ / Ha / mm : $2.53 / Ha / mm
Total Yield (Modules) : 144365.00 Kg
Total Yield / Ha : 2390.15 Kg (Lint :
Breakeven Yield / Ha : 825.41 Kg (3.64
Potential Yield : 40.78 Bls / Ha
% of Potential Yield : 25.8%
Water Use Efficiency : 0.77 Bales/Ha/ML

	Costs	Income
Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$109,680.88	$317,603.00
Net Income or Loss:		$207,922.12

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$1,815.91	$3,442.42
Costs and Net $ per Kilograms :	$0.76	$1.44
Costs and Net $ per Lint Bale :	$0.00	$0.00

Crop Average Harvest Monitoring details

Fibre Length :	0.00
Fibre Strength :	0.00
Gin Turnout % :	0.00
Micronaire :	0.00

* Indicates that Costs/Ha is based on less than the cropped area

Paddock : 08 TM

Cotton : S45B (A 42 Ha) **Total Area: 42 Ha.**

Crop Details							
Seeding and Planting							
28/10/2008	42	Main Crop	13Kg		7.00	91.00	3822.00
Seeding and Planting		Totals :				$91.00	$3,822.00
Crop Details		Totals :				$91.00	$3,822.00
Chemical Application							
Chemicals							
28/10/2008	42	Convoy(Cotogard)	4L	B%: 40 C%: 100	12.10	19.36	813.12
28/10/2008	42	Stomp	4L	B%: 40 C%: 100	8.15	13.04	547.68
28/10/2008	42	Temik	3.5Kg		14.25	49.88	2094.75
28/10/2008	42	Sprayseed 250	1.5L		12.00	18.00	756.00
15/12/2008	42	Envoke	15g	B%: 50 C%: 100	3.78	28.35	1190.70
15/12/2008	42	Staple	36g	B%: 50 C%: 100	1.05	18.90	793.80
15/12/2008	42	BS1000	100mL	B%: 50 C%: 100	6.70	0.34	14.07
30/12/2008	42	Bollgard Licence Fee	1L		315.00	315.00	13230.00
2/01/2009	42	BS1000	50mL		6.70	0.34	14.07
2/01/2009	42	Dimethoate	0.5L		9.15	4.58	192.15
15/01/2009	42	Gesagard 500	1.5L		12.50	18.75	787.50
15/01/2009	42	DC Trate	1.5L		4.50	6.75	283.50
15/01/2009	42	Diuron Flowable	1.5L		7.25	10.88	456.75
24/01/2009	42	Regent	60mL		390.20	23.41	983.30
19/02/2009	42	Pix	0.5L		7.20	3.60	151.20
19/02/2009	42	Bulldock Dual	0.8L		22.96	18.37	771.46
24/03/2009	42	Dimethoate	0.5L		8.95	4.47	187.95
7/04/2009	42	Dropp Liquid	130mL		88.00	11.44	480.48
7/04/2009	42	Prep	1L		9.00	9.00	378.00
7/04/2009	42	Canopy	0.5L		5.00	2.50	105.00
15/04/2009	42	Canopy	0.5L		5.00	2.50	105.00
15/04/2009	42	Dropp Liquid	150mL		88.00	13.20	554.40
15/04/2009	42	Prep	2.5L		9.00	22.50	945.00
1/09/2009	42	Tilt Extra	0.25L		44.00	11.00	462.00
Chemicals		Totals :				$626.14	$26,297.88
Fertiliser Application							
Fertilisers							
2/10/2008	42	Urea	450Kg		630.00	283.50	11907.00
Fertilisers		Totals :				$283.50	$11,907.00
Irrigation							
Irrigation							
30/10/2008	42	TM Dam	100mm.			10.00	420.00
2/01/2009	42	TM Dam	100mm.			10.00	420.00
23/01/2009	10	TM Dam	100mm.			10.00*	100.00
27/01/2009	32	TM Dam	100mm.			10.00*	320.00
11/02/2009	10	TM Dam	100mm.			10.00*	100.00
26/02/2009	32	TM Dam	100mm.			10.00*	320.00
Irrigation		Totals :				$40.00	$1,680.00
Machinery Operation							
Machinery Operations							
19/08/2008	42	8300 Tractor					
19/08/2008	42	Agroplow 4M				10.00	420.00
28/08/2008	14	8410 Tractor				0.00*	
28/08/2008	14	Rotary Hoe				15.00*	210.00

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PAM 6.7.0 Report

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
2/10/2008	42	Rotary Hoe			15.00	630.00	
2/10/2008	42	8410 Tractor					
6/10/2008	42	Rollers Heavy			5.00	210.00	
6/10/2008	42	7420 Tractor					
28/10/2008	42	8410 Tractor					
28/10/2008	42	Max E Planter			5.00	210.00	
28/10/2008	42	7420 Tractor					
28/10/2008	42	16M Spray Rig			5.00	210.00	
15/12/2008	42	8M Spray Bar					
15/12/2008	42	7420 Tractor			5.00	210.00	
31/12/2008	42	8300 Tractor					
31/12/2008	42	Lillistons			5.00	210.00	
2/01/2009	42	Aircraft(Spray)			14.20	596.40	
15/01/2009	42	Lillistons					
15/01/2009	42	7420 Tractor			5.00	210.00	
24/01/2009	42	Aircraft(Spray)			18.80	789.60	
19/02/2009	42	Aircraft(Spray)			17.80	747.60	
24/03/2009	42	Aircraft(Spray)			17.80	747.60	
7/04/2009	42	Aircraft(Spray)			17.80	747.60	
15/04/2009	42	Aircraft(Spray)			17.80	747.60	
24/04/2009	23	Our Pickers			200.00*	4600.00	
1/09/2009	42	7420 Tractor					
1/09/2009	42	24M Boom Spray			5.00	210.00	
Machinery Operations		Totals :			$278.72	$11,706.40	
Manual Task							
Manual Tasks							
3/12/2008	42	Crop Scouting			25.00	1050.00	
8/01/2009	42	Chipping			42.00	1764.00	
30/04/2009	42	Crop Scouting			25.00	1050.00	
Manual Tasks		Totals :			$92.00	$3,864.00	
Harvest Information							
Harvest							
30/06/2009	42	082009	94357 Kg	2.20			207585.40
Harvest		Totals :	94357.00				$207,585.40
Cotton : S45B (A 42 Ha)		Totals :			$0.00	$59,277.28	$207,585.40

Water Use Efficiency and Potential Yield details

Available Water : 759.50mm.
$ / Ha / mm : $4.65 / Ha / mm
Total Yield (Modules) : 94357.00 Kg (Lint
Total Yield / Ha : 2246.60 Kg (Lint :
Breakeven Yield / Ha : 641.53 Kg (2.83
Potential Yield : 22.79 Bls / Ha
% of Potential Yield : 43.4%
Water Use Efficiency : 1.30 Bales/Ha/ML

	Costs	Income
Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$59,277.28	$207,585.40
Net Income or Loss:		$148,308.12

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$1,411.36	$3,531.15
Costs and Net $ per Kilograms :	$0.63	$1.57
Costs and Net $ per Lint Bale :	$0.00	$0.00

Crop Average Harvest Monitoring details

Fibre Length :	0.00
Fibre Strength :	0.00
Gin Turnout % :	0.00
Micronaire :	0.00

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* Indicates that Costs/Ha is based on less than the cropped area

PAM 6.7.0 Report

Paddock : 09 TM

Cotton : DP412B (A 32.1 Ha) Total Area: 32.1 Ha.

Crop Details							
Seeding and Planting							
25/10/2008	32.1	Main Crop	13Kg		5.54	72.02	2311.84
Seeding and Planting		Totals :				$72.02	$2,311.84
Crop Details		Totals :				$72.02	$2,311.84
Chemical Application							
Chemicals							
20/08/2008	32.1	Roundup Ready Dry	1Kg		11.61	11.61	372.68
20/08/2008	32.1	Cobber 475	1L		10.00	10.00	321.00
25/10/2008	32.1	Convoy(Cotogard)	4L	B%: 40 C%: 100	12.10	19.36	621.46
25/10/2008	32.1	Stomp	4L	B%: 40 C%: 100	8.15	13.04	418.58
25/10/2008	32.1	Temik	3Kg		14.25	42.75	1372.28
27/10/2008	32.1	Roundup CT	2L		4.70	9.40	301.74
15/12/2008	32.1	Envoke	15g	B%: 50 C%: 100	3.78	28.35	910.03
15/12/2008	32.1	Staple	36g	B%: 50 C%: 100	1.05	18.90	606.69
15/12/2008	32.1	BS1000	100mL	B%: 50 C%: 100	6.70	0.34	10.75
30/12/2008	32.1	Bollgard Licence Fee	1L		315.00	315.00	10111.50
2/01/2009	32.1	Dimethoate	0.5L		9.15	4.57	146.86
2/01/2009	32.1	BS1000	50mL		6.70	0.34	10.75
24/01/2009	32.1	Regent	60mL		390.20	23.41	751.53
19/02/2009	32.1	Bulldock Dual	0.8L		22.96	18.37	589.61
19/02/2009	32.1	Pix	0.5L		7.20	3.60	115.56
24/03/2009	32.1	Dimethoate	0.5L		8.95	4.47	143.65
17/04/2009	32.1	Dropp Ultra Max	130mL		220.00	28.60	918.06
17/04/2009	32.1	Prep	1L		9.00	9.00	288.90
17/04/2009	32.1	Canopy	0.5L		5.00	2.50	80.25
25/04/2009	32.1	Canopy	0.5L		5.00	2.50	80.25
25/04/2009	32.1	Dropp Ultra Max	120mL		220.00	26.40	847.44
25/04/2009	32.1	Prep	3L		9.00	27.00	866.70
Chemicals		Totals :				$619.51	$19,886.27
Fertiliser Application							
Fertilisers							
28/05/2008	32.1	Urea	150Kg		630.00	94.50	3033.45
Fertilisers		Totals :				$94.50	$3,033.45
Irrigation							
Irrigation							
31/12/2008	32.1	TM Dam	100mm.			10.00	321.00
17/01/2009	32.1	TM Dam	100mm.			10.00	321.00
3/02/2009	32.1	TM Dam	100mm.			10.00	321.00
2/03/2009	32.1	Main Dam	100mm.			10.00	321.00
Irrigation		Totals :				$40.00	$1,284.00
Machinery Operation							
Machinery Operations							
28/05/2008	32.1	Single Disc				5.00	160.50
28/05/2008	32.1	8410 Tractor					
20/08/2008	32.1	7420 Tractor				5.00	160.50
20/08/2008	32.1	16M Spray Rig					
3/10/2008	32.1	8300 Tractor					
3/10/2008	32.1	Lillistons				5.00	160.50
6/10/2008	32.1	Rollers Heavy				5.00	160.50
6/10/2008	32.1	7420 Tractor					

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
25/10/2008	32.1	Max E Planter			5.00	160.50	
25/10/2008	32.1	8410 Tractor					
27/10/2008	32.1	7420 Tractor					
27/10/2008	32.1	16M Spray Rig			5.00	160.50	
15/12/2008	32.1	7420 Tractor			5.00	160.50	
15/12/2008	32.1	8M Spray Bar					
27/12/2008	32.1	8300 Tractor					
27/12/2008	32.1	Lillistons			5.00	160.50	
2/01/2009	32.1	Aircraft(Spray)			14.20	455.82	
24/01/2009	32.1	Aircraft(Spray)			18.80	603.48	
19/02/2009	32.1	Aircraft(Spray)			17.80	571.38	
24/03/2009	32.1	Aircraft(Spray)			17.80	571.38	
17/04/2009	32.1	Aircraft(Spray)			17.80	571.38	
25/04/2009	32.1	Aircraft(Spray)			17.80	571.38	
12/05/2009	32.1	Our Pickers			200.00	6420.00	
Machinery Operations		Totals :			$344.20	$11,048.82	
Manual Task							
Manual Tasks							
3/12/2008	32.1	Crop Scouting			25.00	802.50	
8/01/2009	32.1	Chipping			42.00	1348.20	
30/04/2009	32.1	Crop Scouting			25.00	802.50	
Manual Tasks		Totals :			$92.00	$2,953.20	
Harvest Information							
Harvest							
30/06/2009	32.1	092009	87428Kg	2.27			198461.56
Harvest		Totals :	87428.00				$198,461.56
Cotton : DP412B (A 32.1 Ha)		Totals :			$0.00	$40,517.58	$198,461.56

Water Use Efficiency and Potential Yield details

Available Water : 400.00mm.
$ / Ha / mm : $12.30 / Ha / mm
Total Yield (Modules) : 87428.00 Kg (Lint
Total Yield / Ha : 2723.61 Kg (Lint :
Breakeven Yield / Ha : 556.05 Kg (2.45
Potential Yield : 12.00 Bls / Ha
% of Potential Yield : 100.0%
Water Use Efficiency : 3.00 Bales/Ha/ML

	Costs	Income
Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$40,517.58	$198,461.56
Net Income or Loss:		$157,943.98

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$1,262.23	$4,920.37
Costs and Net $ per Kilograms :	$0.46	$1.81
Costs and Net $ per Lint Bale :	$0.00	$0.00

Crop Average Harvest Monitoring details

Fibre Length :	0.00
Fibre Strength :	0.00
Gin Turnout % :	0.00
Micronaire :	0.00

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PAM 6.7.0 Report

Paddock : 13A

Cotton : S70BRF (A 23.4 Ha) **Total Area: 23.4 Ha.**

Crop Details

Seeding and Planting

14/10/2008	23.4	Main Crop	13Kg	6.54	85.02	1989.47
Seeding and Planting		Totals :			$85.02	$1,989.47
Crop Details		Totals :			$85.02	$1,989.47

Chemical Application

Chemicals

20/08/2008	23.4	Cobber 475	1L	10.00	10.00	234.00
20/08/2008	23.4	Roundup Ready Dry	1Kg	11.61	11.61	271.67
3/10/2008	23.4	Roundup CT	2L	10.00	20.00	468.00
14/10/2008	23.4	Temik	3.5Kg	14.25	49.88	1167.08
3/11/2008	23.4	Roundup Ready Dry	1.494Kg	23.75	35.48	830.17
25/11/2008	23.4	Roundup Ready Dry	0.747Kg	23.50	17.55	410.71
27/12/2008	23.4	Roundup Ready Dry	1.5Kg	23.50	35.25	824.85
30/12/2008	23.4	Bollgard Licence Fee	1L	315.00	315.00	7371.00
30/12/2008	23.4	RRFlex Licence Fee	1L	75.00	75.00	1755.00
2/01/2009	23.4	Dimethoate	0.5L	9.15	4.58	107.06
2/01/2009	23.4	BS1000	50mL	6.70	0.34	7.84
5/01/2009	23.4	DC Trate	1.5L	4.50	6.75	157.95
5/01/2009	23.4	Diuron Flowable	1.5L	7.25	10.88	254.47
5/01/2009	23.4	Roundup Ready Dry	0.996Kg	23.50	23.40	547.62
5/01/2009	23.4	Gesagard 500	1.5L	12.50	18.75	438.75
24/01/2009	23.4	Regent	60mL	390.20	23.41	547.84
19/02/2009	23.4	Bulldock Dual	0.8L	22.96	18.37	429.81
24/03/2009	23.4	Dimethoate	0.5L	8.95	4.48	104.72
31/03/2009	23.4	Dropp Liquid	120mL	88.00	10.56	247.10
31/03/2009	23.4	Prep	0.5L	9.00	4.50	105.30
31/03/2009	23.4	Canopy	0.5L	5.00	2.50	58.50
7/04/2009	23.4	Canopy	0.5L	5.00	2.50	58.50
7/04/2009	23.4	Dropp Liquid	120mL	88.00	10.56	247.10
7/04/2009	23.4	Prep	2L	9.00	18.00	421.20
Chemicals		Totals :			$729.33	$17,066.24

Fertiliser Application

Fertilisers

7/08/2008	23.4	Urea	250Kg	630.00	157.50	3685.50
29/01/2009	23.4	Focus Hi K	7L	1.50	10.50	245.70
Fertilisers		Totals :			$168.00	$3,931.20

Irrigation

Irrigation

21/10/2008	23.4	TM Dam To Lateral	10mm.	3.85	90.00
10/12/2008	23.4	TM Dam To Lateral	40mm.	17.31	405.00
20/12/2008	23.4	TM Dam To Lateral	20mm.	9.62	225.00
31/12/2008	23.4	TM Dam To Lateral	50mm.	23.08	540.00
9/01/2009	23.4	TM Dam To Lateral	50mm.	23.08	540.00
16/01/2009	23.4	TM Dam To Lateral	50mm.	23.08	540.00
16/01/2009	23.4	TM Dam To Lateral	50mm.	23.08	540.00
28/01/2009	23.4	TM Dam To Lateral	30mm.	13.46	315.00
3/02/2009	23.4	TM Dam To Lateral	30mm.	13.46	315.00
14/02/2009	23.4	TM Dam To Lateral	40mm.	18.00	421.20
5/03/2009	23.4	TM Dam To Lateral	35mm.	15.38	360.00
Irrigation		Totals :		$183.38	$4,291.20

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
Machinery Operation							
Machinery Operations							
7/08/2008	23.4	8410 Tractor					
7/08/2008	23.4	Single Disc			5.00	117.00	
20/08/2008	23.4	7420 Tractor			5.00	117.00	
20/08/2008	23.4	16M Spray Rig					
3/10/2008	23.4	16M Spray Rig			5.00	117.00	
3/10/2008	23.4	7420 Tractor					
14/10/2008	23.4	Max E Planter			5.00	117.00	
14/10/2008	23.4	8410 Tractor					
3/11/2008	23.4	7420 Tractor					
3/11/2008	23.4	16M Spray Rig			5.00	117.00	
25/11/2008	23.4	16M Spray Rig			5.00	117.00	
3/12/2008	23.4	8300 Tractor					
3/12/2008	23.4	Lillistons			5.00	117.00	
27/12/2008	23.4	7420 Tractor					
27/12/2008	23.4	16M Spray Rig			5.00	117.00	
2/01/2009	23.4	Aircraft(Spray)			14.20	332.28	
5/01/2009	23.4	8M Spray Bar					
5/01/2009	23.4	7420 Tractor			5.00	117.00	
24/01/2009	23.4	Aircraft(Spray)			18.80	439.92	
29/01/2009	23.4	Aircraft(Spray)			17.95	420.03	
19/02/2009	23.4	Aircraft(Spray)			17.80	416.52	
24/03/2009	23.4	Aircraft(Spray)			17.80	416.52	
31/03/2009	23.4	Aircraft(Spray)			17.80	416.52	
7/04/2009	23.4	Aircraft(Spray)			17.80	416.52	
21/04/2009	23.4	Our Pickers			200.00	4680.00	
Machinery Operations		Totals :			$367.15	$8,591.31	
Manual Task							
Manual Tasks							
3/12/2008	23.4	Crop Scouting			25.00	585.00	
30/04/2009	23.4	Crop Scouting			25.00	585.00	
Manual Tasks		Totals :			$50.00	$1,170.00	
Harvest Information							
Harvest							
30/06/2009	23.4	13a2009	60050Kg	2.03			121901.50
Harvest		Totals :	60050.00				$121,901.50

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PAM 6.7.0 Report

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
Cotton : S70BRF (A 23.4 Ha)		Totals :			$0.00	$37,039.42	$121,901.50

Water Use Efficiency and Potential Yield details

Available Water : 405.00mm.
$ / Ha / mm : $8.95 / Ha / mm
Total Yield (Modules) : 60050.00 Kg (Lint
Total Yield / Ha : 2566.24 Kg (Lint :
Breakeven Yield / Ha : 779.74 Kg (3.43
Potential Yield : 12.15 Bls / Ha
% of Potential Yield : 93.0%
Water Use Efficiency : 2.79 Bales/Ha/ML

Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$37,039.42	$121,901.50
Net Income or Loss:		$84,862.08

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$1,582.88	$3,626.58
Costs and Net $ per Kilograms :	$0.62	$1.41
Costs and Net $ per Lint Bale :	$0.00	$0.00

Crop Average Harvest Monitoring details

Fibre Length :	0.00
Fibre Strength :	0.00
Gin Turnout % :	0.00
Micronaire :	0.00

Paddock : 13B

Cotton : S71BRF (A 24.8 Ha) Total Area: 24.8 Ha.

Crop Details

Seeding and Planting

14/10/2008	24.8	Main Crop	13Kg	6.54	85.02	2108.50
Seeding and Planting		Totals :			$85.02	$2,108.50
Crop Details		Totals :			$85.02	$2,108.50

Chemical Application

Chemicals

20/08/2008	24.8	Cobber 475	1L	10.00	10.00	248.00
20/08/2008	24.8	Roundup Ready Dry	1Kg	11.61	11.61	287.93
3/10/2008	24.8	Roundup CT	2L	10.00	20.00	496.00
14/10/2008	24.8	Temik	3.5Kg	14.25	49.88	1236.90
3/11/2008	24.8	Roundup Ready Dry	1.494Kg	23.75	35.48	879.83
25/11/2008	24.8	Roundup Ready Dry	0.747Kg	23.50	17.55	435.29
27/12/2008	24.8	Roundup Ready Dry	1.5Kg	23.50	35.25	874.20
30/12/2008	24.8	Bollgard Licence Fee	1L	315.00	315.00	7812.00
30/12/2008	24.8	RRFlex Licence Fee	1L	75.00	75.00	1860.00
2/01/2009	24.8	Dimethoate	0.5L	9.15	4.57	113.46
2/01/2009	24.8	BS1000	50mL	6.70	0.33	8.31
5/01/2009	24.8	DC Trate	1.5L	4.50	6.75	167.40
5/01/2009	24.8	Diuron Flowable	1.5L	7.25	10.88	269.70
5/01/2009	24.8	Roundup Ready Dry	0.996Kg	23.50	23.40	580.38
5/01/2009	24.8	Gesagard 500	1.5L	12.50	18.75	465.00
24/01/2009	24.8	Regent	60mL	390.20	23.41	580.62
19/02/2009	24.8	Bulldock Dual	0.8L	22.96	18.37	455.53
24/03/2009	24.8	Dimethoate	0.5L	8.95	4.47	110.98
31/03/2009	24.8	Dropp Liquid	120mL	88.00	10.56	261.89
31/03/2009	24.8	Prep	0.5L	9.00	4.50	111.60
31/03/2009	24.8	Canopy	0.5L	5.00	2.50	62.00
7/04/2009	24.8	Canopy	0.5L	5.00	2.50	62.00
7/04/2009	24.8	Dropp Liquid	120mL	88.00	10.56	261.89
7/04/2009	24.8	Prep	2L	9.00	18.00	446.40
Chemicals		Totals :			$729.33	$18,087.30

Fertiliser Application

Fertilisers

7/08/2008	24.8	Urea	250Kg	630.00	157.50	3906.00
29/01/2009	24.8	Focus Hi K	7L	1.50	10.50	260.40
Fertilisers		Totals :			$168.00	$4,166.40

Irrigation

Irrigation

21/10/2008	24.8	TM Dam To Lateral	10mm.	3.63	90.00
10/12/2008	24.8	TM Dam To Lateral	40mm.	18.15	450.00
20/12/2008	24.8	TM Dam To Lateral	20mm.	9.07	225.00
31/12/2008	24.8	TM Dam To Lateral	50mm.	21.77	540.00
9/01/2009	24.8	TM Dam To Lateral	50mm.	21.77	540.00
16/01/2009	24.8	TM Dam To Lateral	50mm.	21.77	540.00
16/01/2009	24.8	TM Dam To Lateral	50mm.	21.77	540.00
28/01/2009	24.8	TM Dam To Lateral	30mm.	12.70	315.00
3/02/2009	24.8	TM Dam To Lateral	30mm.	12.70	315.00
14/02/2009	24.8	TM Dam To Lateral	40mm.	18.00	446.40
5/03/2009	24.8	TM Dam To Lateral	35mm.	16.33	405.00
Irrigation		Totals :		$177.68	$4,406.40

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
Machinery Operation							
Machinery Operations							
7/08/2008	24.8	8410 Tractor					
7/08/2008	24.8	Single Disc			5.00	124.00	
20/08/2008	24.8	16M Spray Rig					
20/08/2008	24.8	7420 Tractor			5.00	124.00	
3/10/2008	24.8	16M Spray Rig			5.00	124.00	
3/10/2008	24.8	7420 Tractor					
14/10/2008	24.8	Max E Planter			5.00	124.00	
14/10/2008	24.8	8410 Tractor					
3/11/2008	24.8	7420 Tractor					
3/11/2008	24.8	16M Spray Rig			5.00	124.00	
25/11/2008	24.8	16M Spray Rig			5.00	124.00	
3/12/2008	24.8	8300 Tractor					
3/12/2008	24.8	Lillistons			5.00	124.00	
27/12/2008	24.8	16M Spray Rig			5.00	124.00	
27/12/2008	24.8	7420 Tractor					
2/01/2009	24.8	Aircraft(Spray)			14.20	352.16	
5/01/2009	24.8	8M Spray Bar					
5/01/2009	24.8	7420 Tractor			5.00	124.00	
24/01/2009	24.8	Aircraft(Spray)			18.80	466.24	
29/01/2009	24.8	Aircraft(Spray)			17.95	445.16	
19/02/2009	24.8	Aircraft(Spray)			17.80	441.44	
24/03/2009	24.8	Aircraft(Spray)			17.80	441.44	
31/03/2009	24.8	Aircraft(Spray)			17.80	441.44	
7/04/2009	24.8	Aircraft(Spray)			17.80	441.44	
22/04/2009	24.8	Our Pickers			200.00	4960.00	
Machinery Operations		Totals :			$367.15	$9,105.32	
Manual Task							
Manual Tasks							
3/12/2008	24.8	Crop Scouting			25.00	620.00	
30/04/2009	24.8	Crop Scouting			25.00	620.00	
Manual Tasks		Totals :			$50.00	$1,240.00	
Harvest Information							
Harvest							
30/06/2009	24.8	13b	68340Kg	2.03			138730.20
Harvest		Totals :	68340.00				$138,730.20

25/02/2010 10:22:38 AM * Indicates that Costs/Ha is based on less than the cropped area

PAM 6.7.0 Report

Date	Area	Item	Rate or Yield	Unit Cost or Price	Cost/Ha	Total Costs	Total Income
Cotton : S71BRF (A 24.8 Ha)		Totals :			$0.00	$39,113.92	$138,730.20

Water Use Efficiency and Potential Yield details

Available Water : 405.00mm.
$ / Ha / mm : $9.92 / Ha / mm
Total Yield (Modules) : 68340.00 Kg (Lint
Total Yield / Ha : 2755.65 Kg (Lint :
Breakeven Yield / Ha : 776.93 Kg (3.42
Potential Yield : 12.15 Bls / Ha
% of Potential Yield : 99.9%
Water Use Efficiency : 3.00 Bales/Ha/ML

	Total Costs	Total Income
Other Costs and Income:	$0.00	$0.00
Insurance charge:	$0.00	
Carried Costs from Prior Seasons:	$0.00	
Total Costs and Income:	$39,113.92	$138,730.20
Net Income or Loss:		$99,616.28

Breakdown by Areas: (Incl. Carried Costs)	Costs	Net
Costs and Net income per Ha (Cropped Area):	$1,577.17	$4,016.79
Costs and Net $ per Kilograms :	$0.57	$1.46
Costs and Net $ per Lint Bale :	$0.00	$0.00

Crop Average Harvest Monitoring details

Fibre Length :	0.00
Fibre Strength :	0.00
Gin Turnout % :	0.00
Micronaire :	0.00

* Indicates that Costs/Ha is based on less than the cropped area

Appendix 6

Fuel consumptions and machinery list for case studies 2 - 12

Case study 2 Fuel Consumption

On Farm Operation	Fuel Consumption	Repeating Times	Total fuel usage per Ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	6 times	11.1 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Case study 2 machinery list

Machinery Description		Average Mass
Pioneer 8m Rake		2000 kg
Agroplow 4m		2000 kg
Rotary Hoe		2500 kg
Lillistons		4500 kg
Light Roller		2000 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
8m Spray Bar		1000 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	John Deere 4450	5831 kg
	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg
	John Deere 4440	6350 kg

Case study 3 Fuel Consumption

On Farm Operation	Fuel Consumption	Repeating Times	Total fuel usage per Ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	4 times	7.4 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Case study 3 machinery list

Machinery Description		Average Mass
Pioneer 8m Rake		2000 kg
Agroplow 4m		2000 kg
Rotary Hoe		2500 kg
Lillistons		4500 kg
Light Roller		2000 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
8m Spray Bar		1000 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	John Deere 4450	5831 kg
	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg
	John Deere 4440	6350 kg

Case study 4 Fuel Consumption

On Farm Operation	Fuel Consumption	Repeating Times	Total fuel usage per Ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	10 times	18.5 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Case study 4 machinery list

Machinery Description		Average Mass
Lillistons		4500 kg
24m Boom Sprayer		1200 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
8m Spray Bar		1000 kg
Peterson Pickers		#2 each 15000 kg=30000 kg
Tractors	John Deere 4450	5831 kg
	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg

Case study 5 Fuel Consumption

On Farm Operation	Fuel Consumption	Repeating Times	Total fuel usage per Ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	5 times	9.25 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Case study 5 machinery list

Machinery Description		Average Mass
Agroplow 4m		2000 kg
Rotary Hoe		2500 kg
Lillistons		4500 kg
Light Roller		2000 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
8m Spray Bar		1000 kg
24m Boom Sprayer		1200 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	John Deere 4450	5831 kg
	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg

Case study 6 Fuel Consumption

On Farm Operation	Fuel Consumption	Repeating Times	Total fuel usage per Ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	11 times	20.35 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Case study 6 machinery list

Machinery Description		Average Mass
Pioneer 8m Rake		2000 kg
Wallaby Spreader		3000 kg
Agroplow 4m		2000 kg
Lillistons		4500 kg
Light Roller		2000 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
8m Spray Bar		1000 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	John Deere 4450	5831 kg
	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg

Case study 7 Fuel Consumption

On Farm Operation	Fuel Consumption	Repeating Times	Total fuel usage per Ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	12 times	22.2 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Case study 7 machinery list

Machinery Description		Average Mass
Rotary Hoe		2500 kg
Wallaby Spreader		3000 kg
Mulcher		1000 kg
Lillistons		4500 kg
Heavy Roller		2000 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
Shielded Spray		1000 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	John Deere 4960	9888 kg
	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg

Case study 8 Fuel Consumption

On Farm Operation	Fuel Consumption	Repeating Times	Total fuel usage per Ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	11 times	20.35 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Case study 8 machinery list

Machinery Description		Average Mass
Rotary Hoe		2500 kg
Wallaby Spreader		3000 kg
Lillistons		4500 kg
Heavy Roller		2000 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
Shielded Spray		1000 kg
Agroplow 4m		2000 kg
8m Spray Bar		1000 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg

Case study 9 Fuel Consumption

On Farm Operation	Fuel Consumption	Repeating Times	Total fuel usage per Ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	6 times	11.1 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Case study 9 machinery list

Machinery Description		Average Mass
Rotary Hoe		2500 kg
Lillistons		4500 kg
Heavy Roller		2000 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
Boom Spray		1000 kg
Agroplow 4m		2000 kg
8m Spray Bar		1000 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg

Case study 10 Fuel Consumption

On Farm Operation	Fuel Consumption	Repeating Times	Total fuel usage per Ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	6 times	11.1 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Case study 10 machinery list

Machinery Description		Average Mass
Lillistons		4500 kg
Heavy Roller		2000 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
Agroplow 4m		2000 kg
8m Spray Bar		1000 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg

Case study 11 Fuel Consumption

On Farm Operation	Fuel Consumption	Repeating Times	Total fuel usage per Ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	7 times	12.95 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Case study 11 machinery list

Machinery Description		Average Mass
Lillistons		4500 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
Agroplow 4m		2000 kg
8m Spray Bar		1000 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg

Case study 12 Fuel Consumption

On Farm Operation	Fuel Consumption	Repeating Times	Total fuel usage per Ha
Hilling	20 L/ha	1	20 L/ha
Cultivation	10 L/ha	3 times	30 L/ha
Rolling	5 L/ha	1	5 L/ha
Aerial spraying	1.85 L/ha	7 times	12.95 L/ha
Single disc	5 L/ha	1	5 L/ha
Fertilising	5 L/ha	1	5 L/ha
In crop operations fertilising	5 L/ha	1	5 L/ha
Planting	5 L/ha	1	5 L/ha
In crop operations spraying	5 L/ha	1	5 L/ha
Harvesting	45 L/ha	1	45 L/ha
Post harvest light operations	4 L/ha	1	4 L/ha
Mulching	20 L/ha	1	20 L/ha
Off setting	20 L/ha	1	20 L/ha

Case study 12 machinery list

Machinery Description		Average Mass
Lillistons		4500 kg
Max E Planter		2500 kg
16m Spray Rig		1200 kg
Agroplow 4m		2000 kg
8m Spray Bar		1000 kg
Pickers		#2 each 15000 kg=30000 kg
Tractors	John Deere8300	8809 kg
	John Deere 8410	9271 kg
	John Deere 7420	6463 kg

Appendix 7

Kim Bremner Questionnaire (filled)

Questionnaire 400 ha of 50% GM and 50% non GM

On farm direct operations 2009-2010
Farm survey on 25.02.2010
How much diesel is used during the on farm operations listed below?

1. Tillage

	GM COTTON	NON GM COTTON
Hilling	20 L/ha	20 L/ha
Cultivator	10 L/ha	10 L/ha
Rolling	5 L/ha	5 L/ha

2. Harrowing

Field Preparation		
Planting		

3. Weeding

Field Preparation		
Planting		
In Crop operations		

4. Fertilising

Single disk	5 L/ha	5 L/ha
Planting	5 L/ha	5 L/ha
In Crop operations	5 L/ha	5 L/ha

5. Planting

Planting	5 L/ha	5 L/ha

6. Spraying

In Crop operations	5 L/ha	5 L/ha
Cultivation	2-3 times	2-3 times
Insecticide application by air plane	2-4 times	5-8 times

7. Harvesting

Harvesting	45 L/ha	45 L/ha

8. Infield operations

Harvesting		

9. Crop Destruction

Post Harvest light operation	4-5 L/ha	4-5 L/ha
Mulching	20 L/ha	20 L/ha
Off setting	20 L/ha	20 L/ha

10. Irrigation

	Type of irrigation i.e. Furrow	Energy source i.e. electricity, Diesel	Water usage i.e. (l/ha)	Energy unit used i.e. KWh, l
GM Cotton	Furrow + Lateral	Diesel	4 ML/ha	25 L/ML or 100L /ha
Non GM Cotton	Furrow	Diesel	4 ML/ha	25 L/ML or 100L /ha

On farm indirect operations

What quantity is used from the units listed below on each farming method?

	GM COTTON	NON GM COTTON
Herbicides (L)		
Insecticides (kg)		
Fungicides (L)		
Plant Growth Regulator (kg)		
Oil (L)		
Nitrogen (kg)		
Ammonia		
Urea (kg)		
Diammonium Phosphate (kg)		
Potassium		
Sulphur (kg)		
Lime		
Seeds (kg)	14 kg	12 kg

Please choose the machinery used during your farming sections from the list below and fill the relevant data.

	Please tick if used	**Average mass (kg)**	**Machinery type if applicable** i.e. John Deere 3050
Planter (kg)	*	2500	JD max emerge Planter
Mower (kg)	***mulcher**	1000	Janke eliminator
Harvester (kg)	***cotton picker#2**	15000	John Deere 9960
Silage Feed Wagon (kg)			
Bale Feeder (kg)			
Front End Loader (kg)	*	8000	JCB tele handler
Fertiliser Spreader (kg)	*	3000	Wallaby
Sprayer (kg)	***24 m Boom**	1200	Hand made

Hay Rake (kg)			
Hay Baler (kg)			
Tractors (kg)	*#2	10000	8410 , 8300 JD
Farm Implements (kg)			
Plough (kg)	***off setts**	4500	Rubin
Discs (kg)			
Hilling (kg)	*	2000	Hand made
Single disk spreader (kg)	*	3000	Grays
Cultivator (kg) Rolling	*	2500	Gessener
Harrows (kg)			
Roller (kg) Heavy duty	*	2000	Hand made
Drill (kg)			
Trailer (kg)			
Post Rammer (kg)			
Grader Blade (kg)			

Have you seen a change in the numbers of machinery you need for GM cotton and Non GM cotton farming?

( ) Yes (*) No

What major changes you found while comparing input used i.e. fertiliser, Diesel, between GM Cotton and Non GM cotton farming systems?

Farmer though the both used generally same energy and the outcome is same as well on 10 Bales/ha. The only difference id GM cotton needs 10 ML/ha and non GM needs 4 ML/ha. Another reason that farmer believes on same benefit out of both farming system was Dalby farm lands have better soils comparing northern NSW which leads to less evaporation and higher water keeping capacity.

Is there any other information that you may note during comparison of GM and Non GM cotton Farming Systems?

If more reliable water available they will plant more GM cotton.
Cost Biotech cotton higher
Conventional cotton lower
*Risk management: people are planting on their available water

Thanks for your time.

Appendix 8

Keytah study full data

Zero tillage case study

Process	Practice	No. Passes	Operation	Fuel Use per pass (L/Ha)	Total Fuel (L)	Energy (GJ)	Emission (kg CO2)	Cost (A$)	% Energy	
Preparation	Spraying (Herbicide) - Raptor	6	Spraying	3	93600	3613	271440	88920	6%	
	Spread Fertiliser	1	Fertiliser	3	15600	602	45240	14820	1%	7%
Planting	Plant Cotton (MaxEmerge)	1	Planter	5	26000	1004	75400	24700	2%	
	Boom Spray (Herbicide – Roundup)	1	Spraying	3	15600	602	45240	14820	1%	2%
In Season	Inter-row Cultivation (clean furrows)	1	Tillage	5	26000	1004	75400	24700	2%	
	Boom Spray (Herbicide – Roundup)	2	Spraying	3	31200	1204	90480	29640	2%	
	Boom Spray (Insecticide)	3	Spraying	3	46800	1806	135720	44460	3%	
	Aerial Spray (Insecticide)	9	Spraying	0.035	1638	63	4750.2	1556	0%	
	Aerial Spray (Defoliation)	2	Spraying	0.035	364	14	1055.6	346	0%	6%
Irrigation	Irrigation (7 ML / Ha)	2.5	Irrigation	77	1001000	38639	2902900	950950	60%	60%
Harvest	Cotton Picker	1	Harvesting	45	234000	9032	678600	222300	14%	
	Module Builder	1	Harvesting	5	26000	1004	75400	24700	2%	16%
Post Harvest	Root Cut	1	Crop Dest.	7	36400	1405	105560	34580	2%	
	Mulcher	1	Crop Dest	7	36400	1405	105560	34580	2%	
	Ripper (Pupae Bust)	1	Tillage	16.5	85800	3312	248820	81510	5%	9%
					1676402	64709	4861565.8	1592581.9	100%	

Minimum tillage case study

Process	Practice	No. Passes	Operation	Fuel Use per pass (L/Ha)	Total Fuel (L)	Energy (GJ)	Emission (kg CO2)	Cost (A$)	% Energy	
Preparation	Deep Ripping	1	Tillage	18	93600	3612.96	271440	88920	5%	
	Lister – Bed Forming (apply N)	1	Fert	20	104000	4014.40	301600	98800	5%	
	Ripper (apply MAP)	1	Fert	7	36400	1405.04	105560	34580	2%	
	Spraying (Herbicide) - Raptor	7	Spraying	3	109200	4215.12	316680	103740	6%	
	Cultipacker	1	Tillage	4	20800	802.88	60320	19760	1%	19%
Planting	Plant Cotton (MaxEmerge)	1	Planter	5	26000	1003.60	75400	24700	1%	
	Boom Spray (Herbicide – Roundup)	1	Spraying	3	15600	602.16	45240	14820	1%	2%
In Season	Inter-row Cultivation (clean furrows)	1	Tillage	5	26000	1003.60	75400	24700	1%	
	Boom Spray (Herbicide – Roundup)	2	Spraying	3	31200	1204.32	90480	29640	2%	
	Boom Spray (Insecticide)	3	Spraying	3	46800	1806.48	135720	44460	2%	
	Aerial Spray (Insecticide)	8	Spraying	0.035	1456	56.20	4222.4	1383	0%	
	Aerial Spray (Defoliation)	2	Spraying	0.035	364	14.05	1055.6	346	0%	5%
Irrigation	Irrigation (7 ML / Ha)	2.5	Irrigation	77	1001000	38638.60	2902900	950950	52%	52%
Harvest	Cotton Picker	1	Harvesting	45	234000	9032.40	678600	222300	12%	
	Module Builder	1		5	26000	1003.60	75400	24700	1%	13%
Post Harvest	Root Cut	1	Crop Dest.	7	36400	1405.04	105560	34580	2%	
	Mulcher	1	Crop Dest	7	36400	1405.04	105560	34580	2%	
	Ripper (Pupae Bust)	1	Tillage	16.5	85800	3311.88	248820	81510	4%	8%
					1931020	74537.372	5599958	1834469	100%	

Conventional tillage case study

Process	Practice	No. Passes	Operation	Fuel Use per pass (L/Ha)	Total Fuel (L)	Energy (GJ)	Emission (kg CO2)	Cost (A$)	% Energy	
Preparation	Discing	3	Tillage	12	187200	7226	542880	177840	9%	
	Regrade (60 L/Ha / 5)	1	Tillage	30	156000	6022	452400	148200	7%	
	Deep Ripping	1	Tillage	18	93600	3613	271440	88920	4%	
	Lister – Bed Forming (apply N)	1	Fert	20	104000	4014	301600	98800	5%	
	Ripper (apply MAP)	2	Fert	7	72800	2810	211120	69160	3%	
	Cultipacker	1	Tillage	4	20800	803	60320	19760	1%	
	Spraying (Herbicide) - Raptor	7	Spraying	3	109200	4215	316680	103740	5%	34%
Planting	Plant Cotton (MaxEmerge)	1	Planter	5	26000	1004	75400	24700	1%	
	Aerial Spray (Herbicide)	1	Spraying	0.035	182		527.8	173	0%	
	Chains	1	Tillage	4	20800	803	60320	19760	1%	2%
In Season	Inter-row Cultivation (clean furrows)	2	Tillage	6	62400	2409	180960	59280	3%	
	Shielded Spray (Herbicide)	1	Spraying	3	15600	602	45240	14820	1%	
	Boom Spray (Insecticide)	2	Spraying	3	31200	1204	90480	29640	1%	
	Aerial Spray (Insecticide)	9	Spraying	0.035	1638	63	4750.2	1556	0%	
	Aerial Spray (Defoliation)	2	Spraying	0.035	364	14	1055.6	346	0%	5%
Irrigation	Irrigation (7 ML / Ha)	2.5	Irrigation	77	1001000	38639	2902900	950950	46%	46%
Harvest	Cotton Picker	1	Harvesting	45	234000	9032	678600	222300	11%	
	Module Builder	1	Harvesting	5	26000	1004	75400	24700	1%	12%
Post Harvest	Mulcher	1	Crop Dest	7	36400	1405	105560	34580	2%	2%
					2199184	84881	6377634	2089225	100%	

Machinery list for Keytah case studies

No.	Tractors	Engine Power (KW)	Engine Power (H.P)	Fuel Use (l/hr)
4	Case IH MX 305	223.49	299.7	64.44
2	CASE IH MX 275	200.33	268.64	57.71
2	CASE IH MX 210	147.73	198.11	41.74
1	Caterpillar MT 765	222.79	298.77	61.03
1	Caterpillar MT 855	337.28	452.31	88.04
1	Caterpillar MT 865B	405.49	543.77	108.59

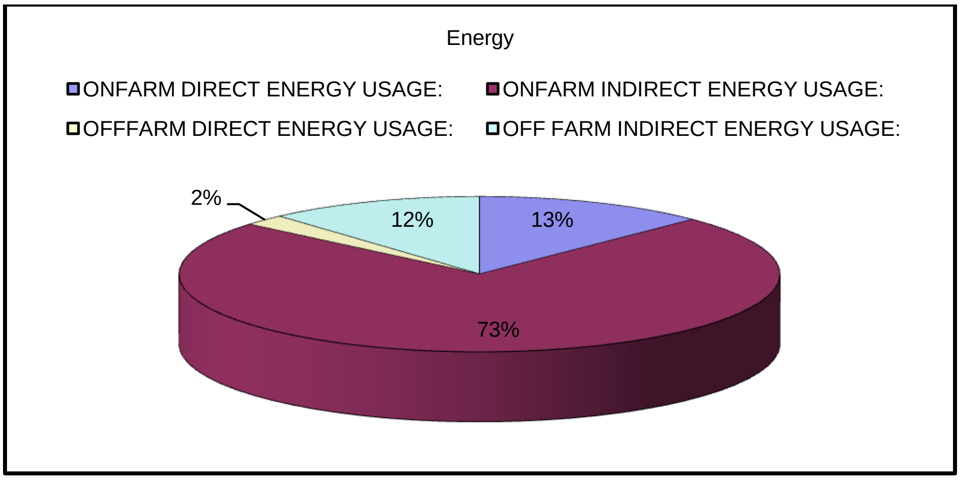
Appendix 9

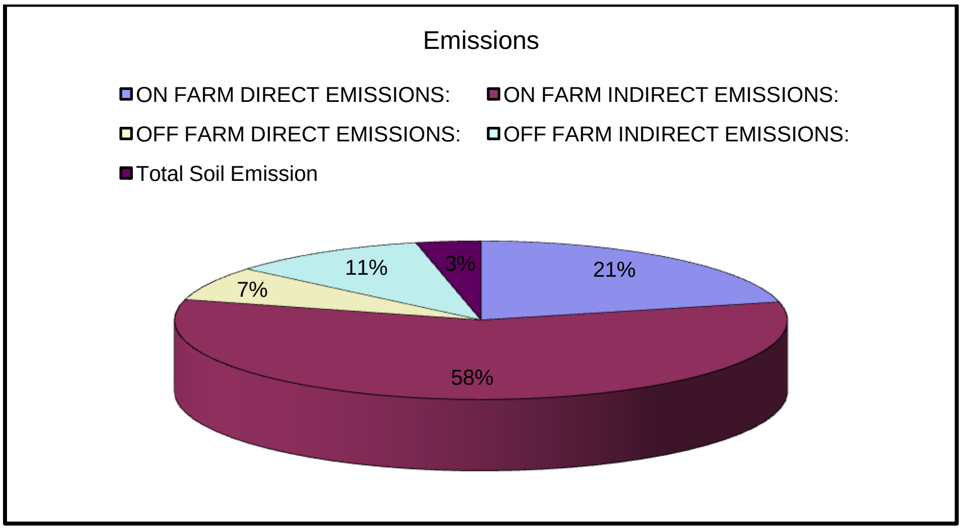
Results of case studies 2 – 12

Case Study 2

By applying the values for case study 2 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

ON-FARM DIRECT ENERGY CONSUMPTION:	11599.48	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	67949.49	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	2106.755	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	79548.97	MJ
Total off-farm Energy Consumption:	12835.18	MJ
Total Energy Used in Cotton Production Per Year:	92384.16	MJ
ON-FARM DIRECT EMISSIONS:	1876.01	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	5081.637	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	614.7395	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.2744	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	6957.647	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1532.014	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year:	8789.661	Kg CO_2e



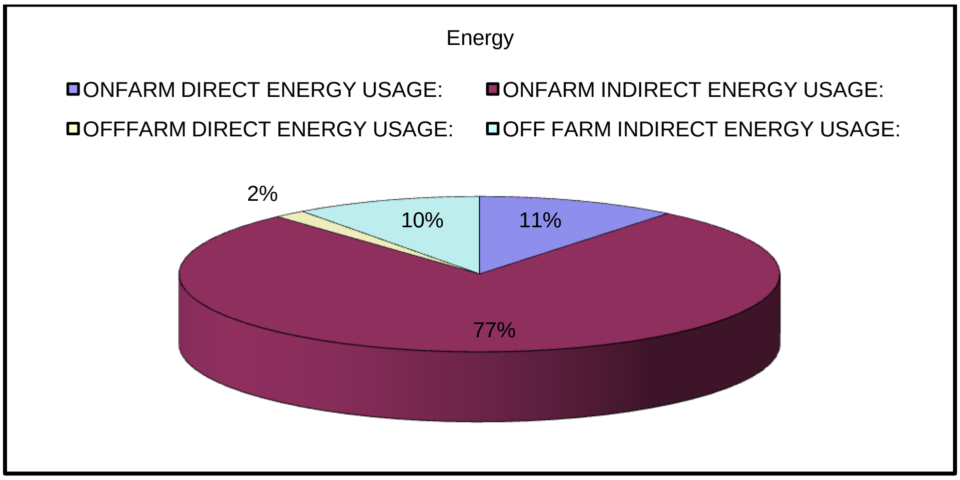


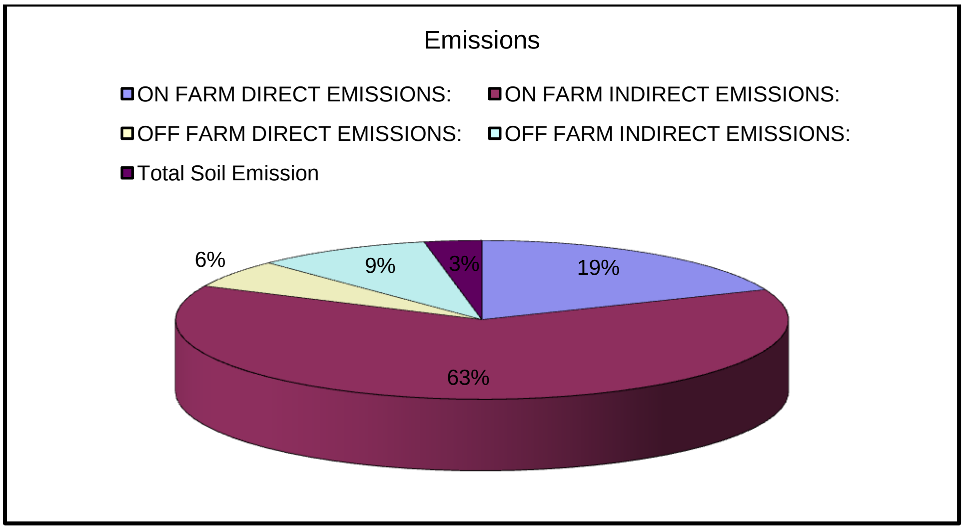
The main reason for the reduction in the indirect on-farm energy usage and emissions share is in case study 2 they did not use the feedlot manure for fertiliser purposes. The farmer referred to the reason for this as the history of this paddock for not using the manure.

Case Study 3

By applying the values for case study 3 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

ON-FARM DIRECT ENERGY CONSUMPTION:	11502.32	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	82603.42	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	1815.66	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	94105.74	MJ
Total off-farm Energy Consumption:	12544.09	MJ
Total Energy Used in Cotton Production Per Year:	106649.8	MJ
ON-FARM DIRECT EMISSIONS:	1864.1	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	6257.046	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	567.966	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.2744	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	8121.146	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1485.24	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year:	9906.386	Kg CO_2e

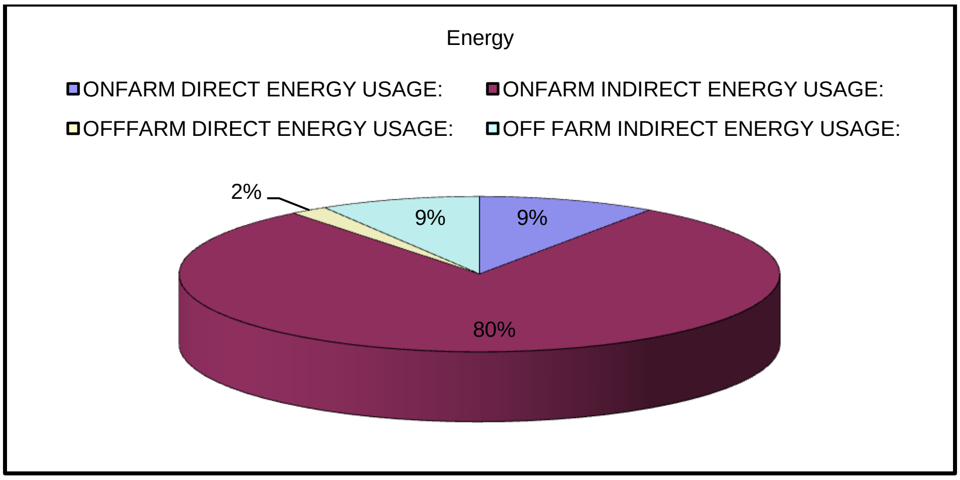


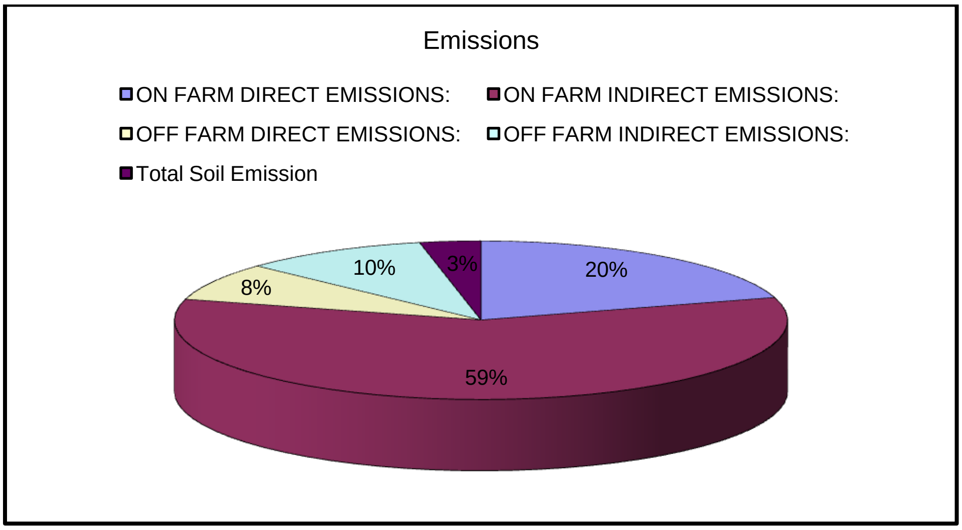


Case Study 4

By applying the values for case study 4 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

ON-FARM DIRECT ENERGY CONSUMPTION:	11874	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	98925.22	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	2474.289	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	110799.2	MJ
Total off-farm Energy Consumption:	13202.72	MJ
Total Energy Used in Cotton Production Per Year:	124001.9	MJ
ON-FARM DIRECT EMISSIONS:	1904.5	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	5487.286	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	721.9649	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.2744	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	7391.786	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1639.239	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year:	9331.025	Kg CO_2e

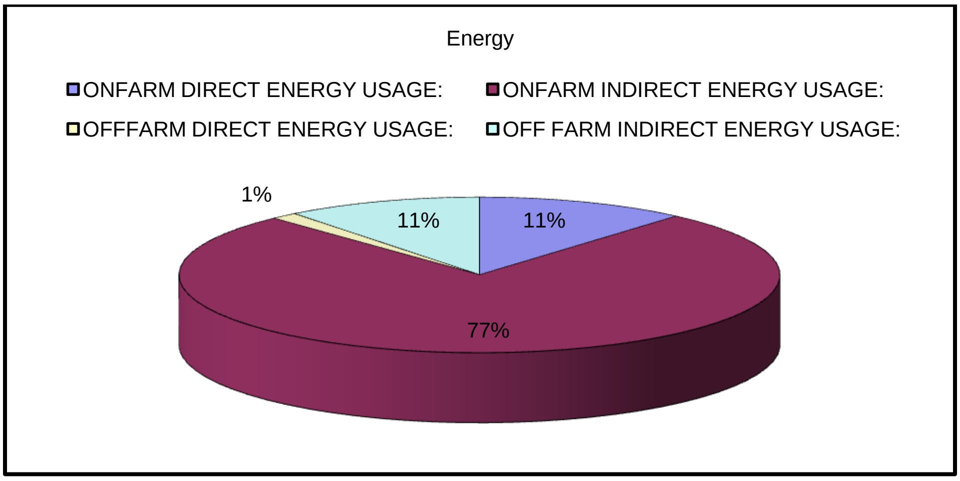


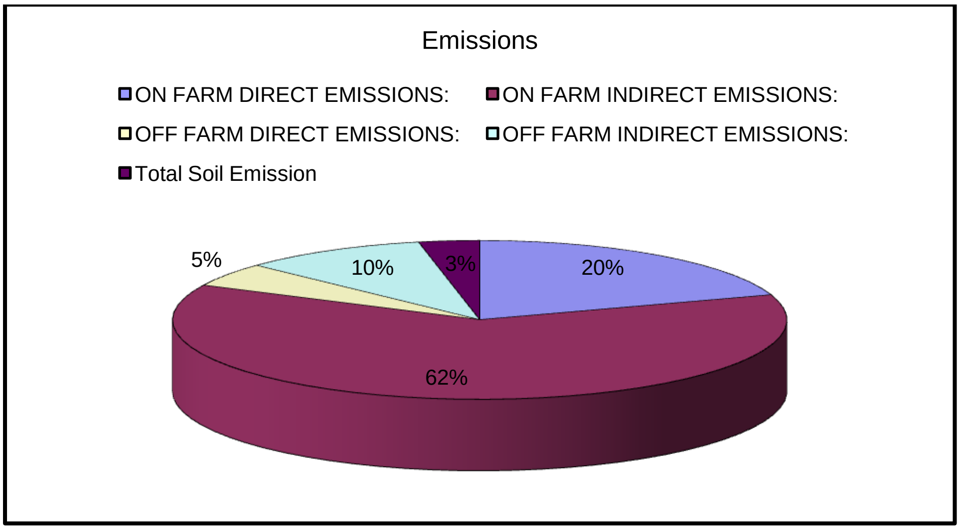


Case Study 5

By applying the values for case study 5 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

ON-FARM DIRECT ENERGY CONSUMPTION:	11531.4	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	77708.28	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	1454.876	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	89239.68	MJ
Total off-farm Energy Consumption:	12183.31	MJ
Total Energy Used in Cotton Production Per Year:	101423	MJ
ON-FARM DIRECT EMISSIONS:	1868.61	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	5842.788	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	455.1099	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.2744	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	7711.398	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1372.384	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year:	9383.782	Kg CO_2e

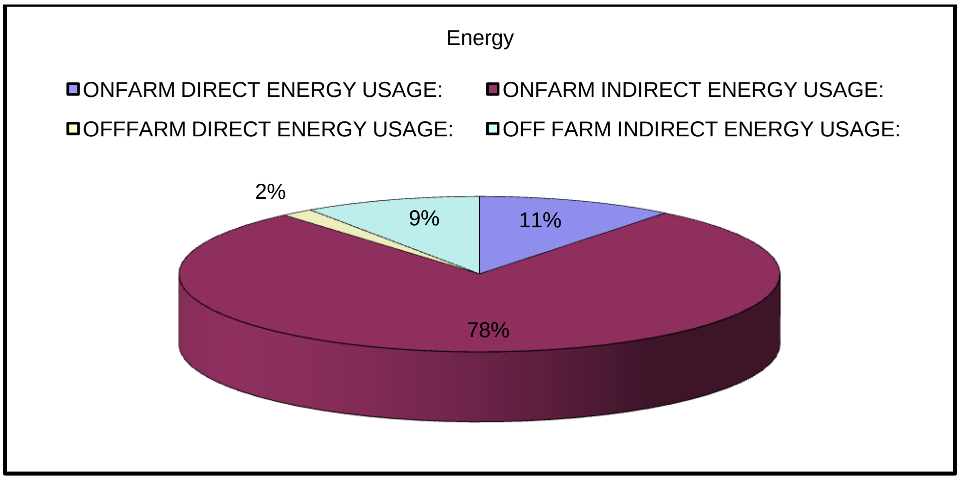


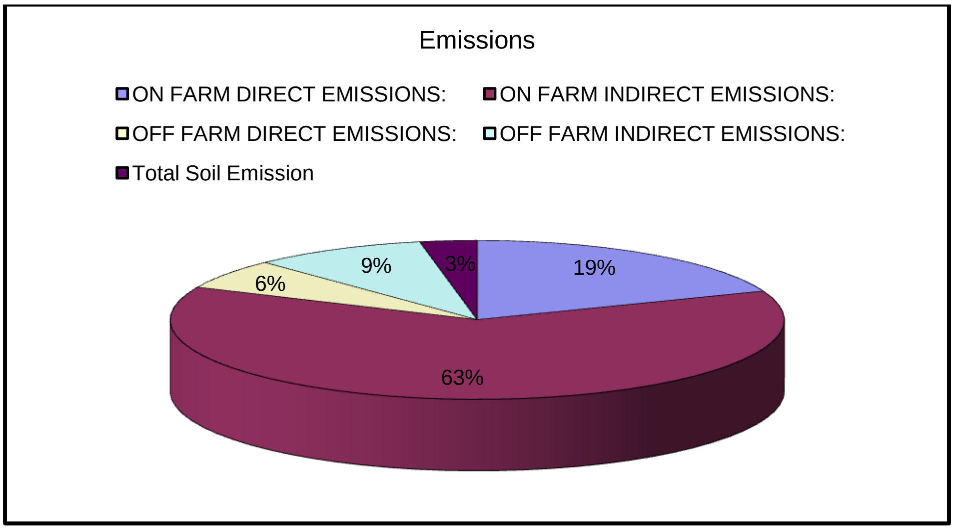


Case Study 6

By applying the values for case study 6 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

ON-FARM DIRECT ENERGY CONSUMPTION:	11939.88	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	87793.14	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	1953.054	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	99733.02	MJ
Total off-farm Energy Consumption:	12681.48	MJ
Total Energy Used in Cotton Production Per Year:	112414.5	MJ
ON-FARM DIRECT EMISSIONS:	1913.01	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	6255.332	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	610.9448	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.2744	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	8168.342	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1528.219	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year:	9996.561	Kg CO_2e

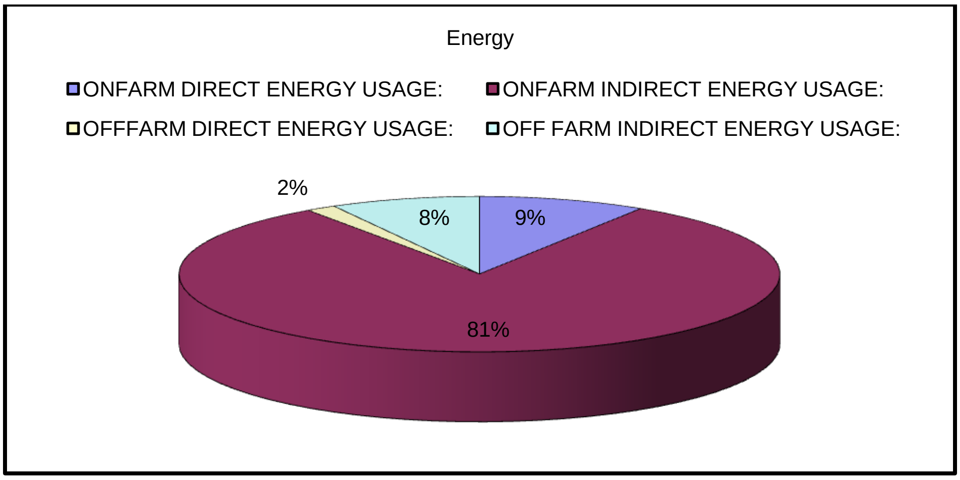


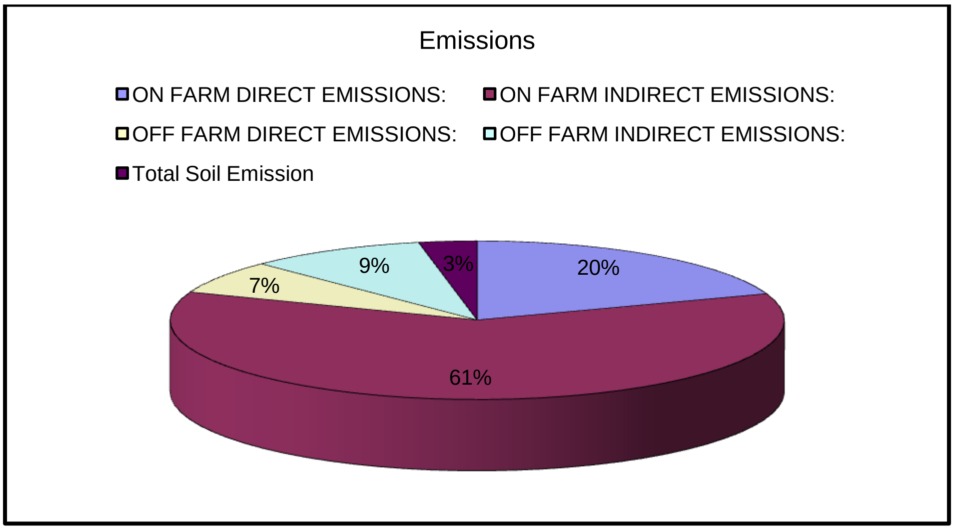


Case Study 7

By applying the values for case study 7 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

ON-FARM DIRECT ENERGY CONSUMPTION:	12007.96	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	108100.5	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	2133.833	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	120108.4	MJ
Total off-farm Energy Consumption:	12862.26	MJ
Total Energy Used in Cotton Production Per Year:	132970.7	MJ
ON FARM DIRECT EMISSIONS:	1920.41	Kg CO_2e
ON FARM INDIRECT EMISSIONS:	5981.958	Kg CO_2e
		Kg CO_2e
OFF FARM DIRECT EMISSIONS:	667.4953	Kg CO_2e
OFF FARM INDIRECT EMISSIONS:	917.2744	Kg CO_2e
TOTAL ON FARM EMISSIONS:	7902.368	Kg CO_2e
TOTAL OFF FARM EMISSIONS:	1584.77	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year:	9787.138	Kg CO_2e

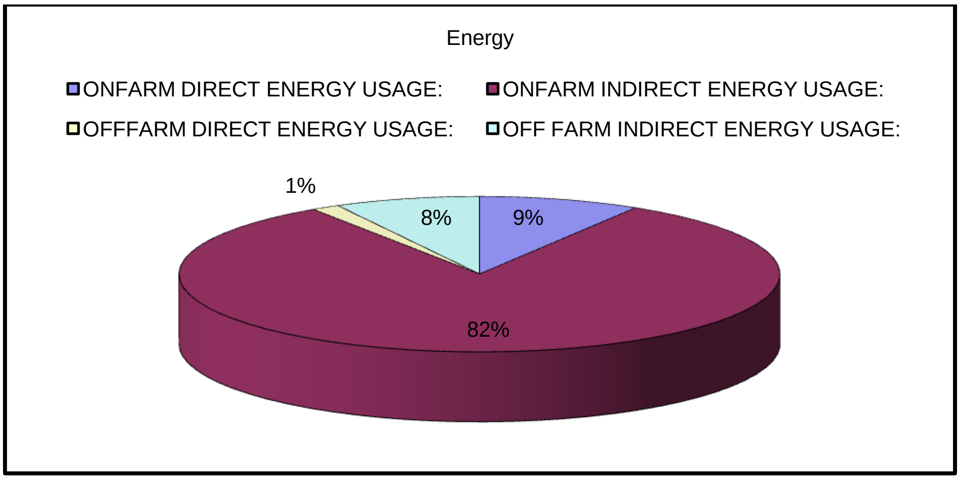


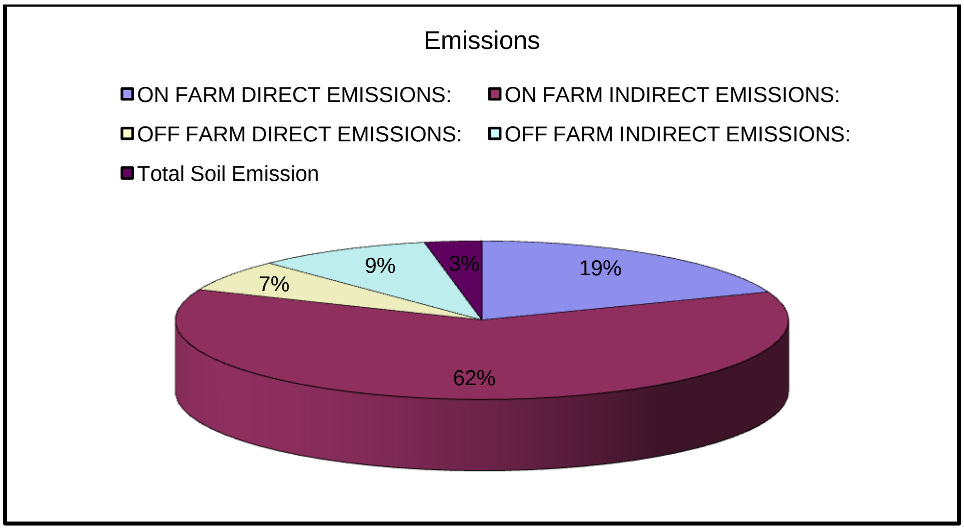


Case Study 8

By applying the values for case study 8 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

ON-FARM DIRECT ENERGY CONSUMPTION:	11939.88	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	112272.1	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	2066.394	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	124212	MJ
Total off-farm Energy Consumption:	12794.82	MJ
Total Energy Used in Cotton Production Per Year:	137006.8	MJ
ON-FARM DIRECT EMISSIONS:	1913.01	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	6170.13	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	646.3994	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.2744	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	8083.14	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1563.674	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year:	9946.814	Kg CO_2e

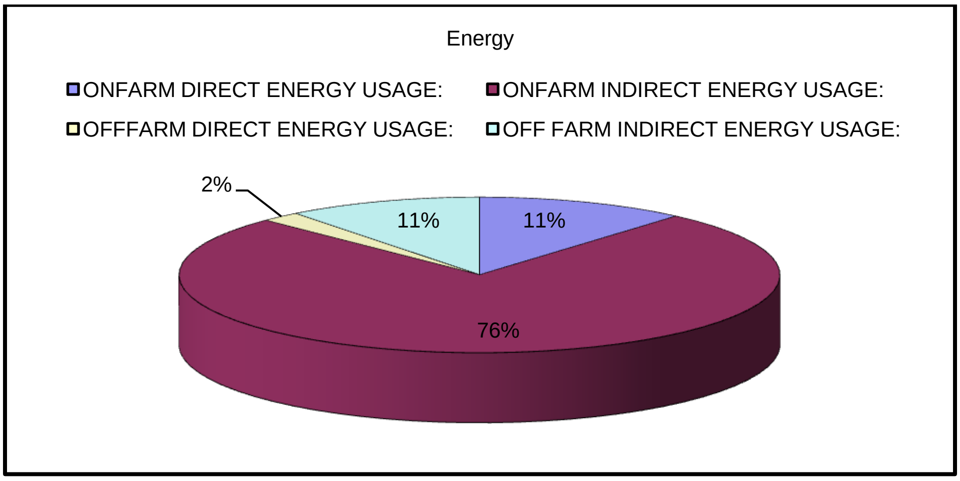


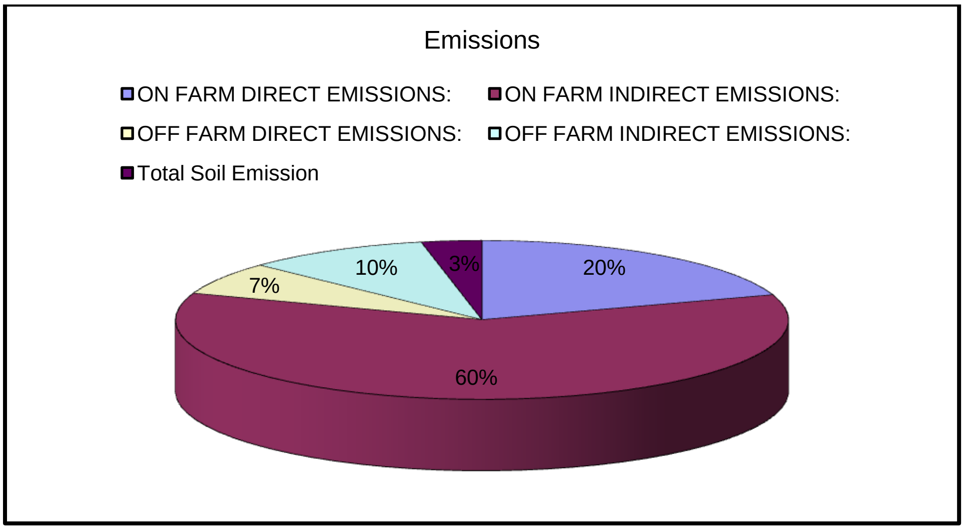


Case Study 9

By applying the values for case study 9 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

ON-FARM DIRECT ENERGY CONSUMPTION:	11599.48	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	77624.38	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	2144.964	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	89223.86	MJ
Total off-farm Energy Consumption:	12873.39	MJ
Total Energy Used in Cotton Production Per Year:	102097.3	MJ
ON-FARM DIRECT EMISSIONS:	1876.01	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	5698.505	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	627.8708	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.2744	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	7574.515	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1545.145	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year:	9419.66	Kg CO_2e

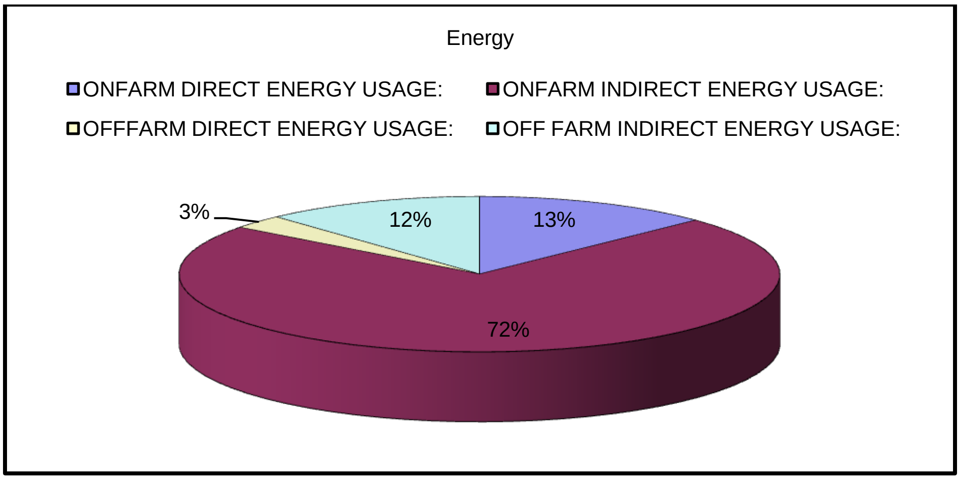


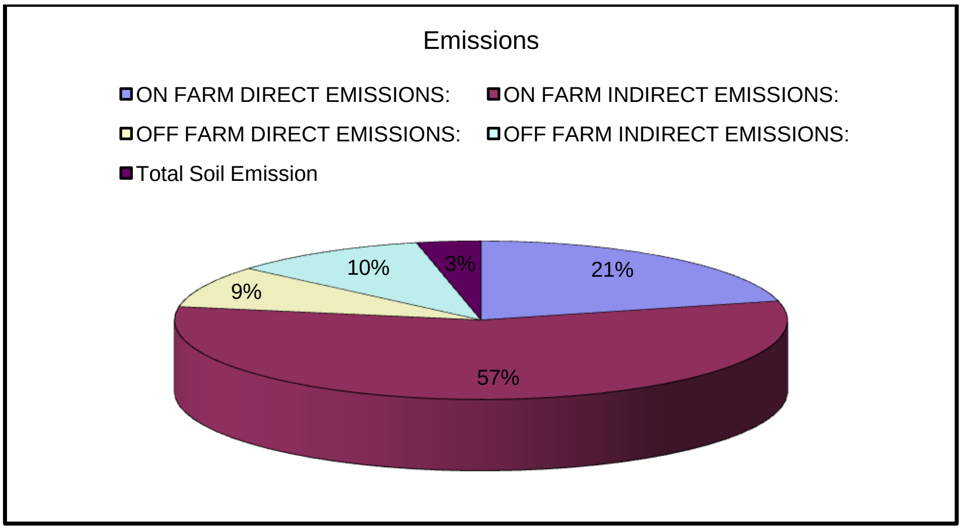


Case Study 10

By applying the values for case study 10 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

ON-FARM DIRECT ENERGY CONSUMPTION:	11599.48	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	65744.03	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	2612.862	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	77343.51	MJ
Total off-farm Energy Consumption:	13341.29	MJ
Total Energy Used in Cotton Production Per Year:	90684.8	MJ
ON-FARM DIRECT EMISSIONS:	1876.01	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	5017.983	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	762.4304	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.2744	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	6893.993	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1679.705	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year:	8873.698	Kg CO_2e

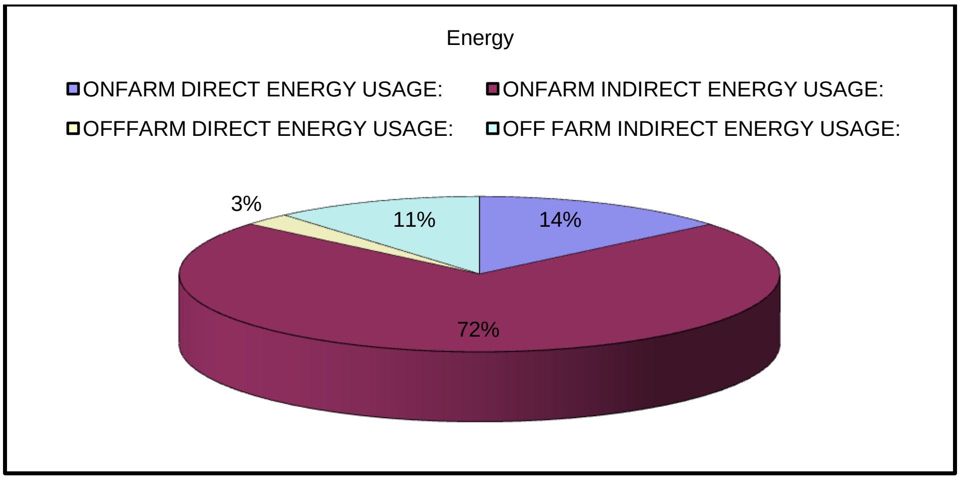


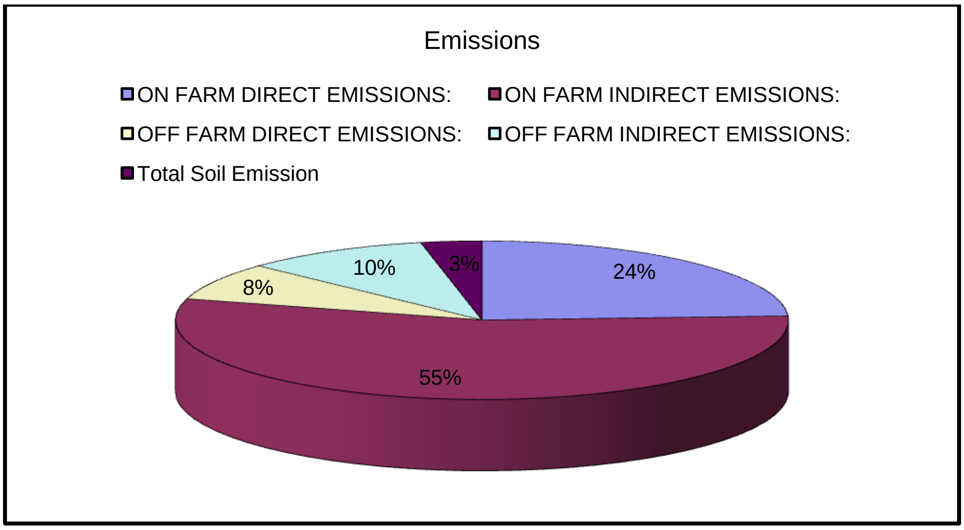


Case Study 11

By applying the values for case study 11 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

ON-FARM DIRECT ENERGY CONSUMPTION:	13267.56	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	68752.37	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	2461.944	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	82019.93	MJ
Total off-farm Energy Consumption:	13190.37	MJ
Total Energy Used in Cotton Production Per Year:	95210.3	MJ
ON-FARM DIRECT EMISSIONS:	2263.81	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	5156.088	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	718.3826	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.2744	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	7419.898	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1635.657	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year:	9355.555	Kg CO_2e

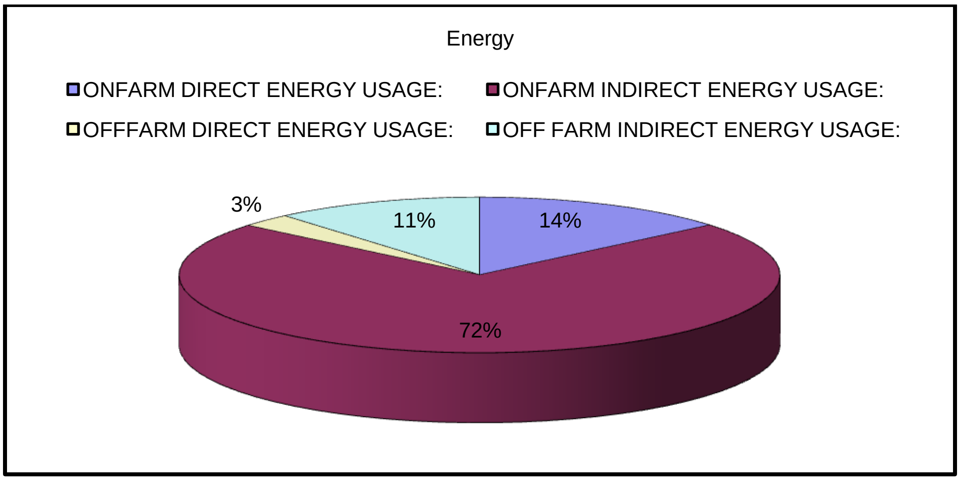


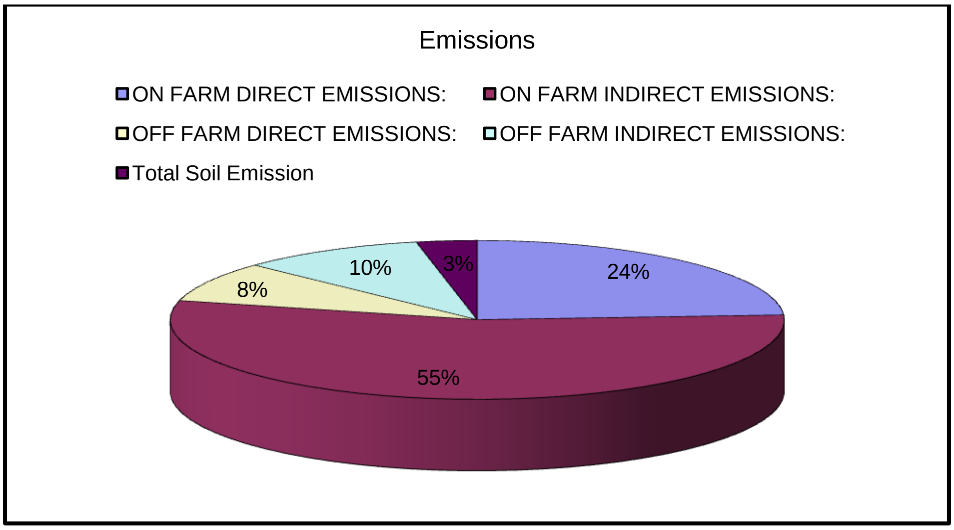


Case Study 12

By applying the values for case study 12 from Chapter 5 in the developed model, the energy consumption and emissions for various stages and in total are calculated per hectare of cotton farming as shown below.

ON-FARM DIRECT ENERGY CONSUMPTION:	13267.56	MJ
ON-FARM INDIRECT ENERGY CONSUMPTION:	68783.38	MJ
OFF-FARM DIRECT ENERGY CONSUMPTION:	2643.66	MJ
OFF-FARM INDIRECT ENERGY CONSUMPTION:	10728.43	MJ
Total On-farm Energy Consumption:	82050.94	MJ
Total off-farm Energy Consumption:	13372.09	MJ
Total Energy Used in Cotton Production Per Year:	95423.03	MJ
ON-FARM DIRECT EMISSIONS:	2263.81	Kg CO_2e
ON-FARM INDIRECT EMISSIONS:	5157.949	Kg CO_2e
		Kg CO_2e
OFF-FARM DIRECT EMISSIONS:	771.4056	Kg CO_2e
OFF-FARM INDIRECT EMISSIONS:	917.2744	Kg CO_2e
TOTAL ON-FARM EMISSIONS:	7421.759	Kg CO_2e
TOTAL OFF-FARM EMISSIONS:	1688.68	Kg CO_2e
Total Soil Emission	300	Kg CO_2e
Total Emissions From Cotton Production Per Year:	9410.439	Kg CO_2e




Emissions
ON FARM DIRECT EMISSIONS:
ON FARM INDIRECT EMISSIONS:
OFF FARM DIRECT EMISSIONS:
OFF FARM INDIRECT EMISSIONS:
Total Soil Emission
10%
3%
24%
8%
55%