From seed to harvest: A comparative life cycle assessment of conventional vs. organic cotton agriculture

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FROM SEED TO HARVEST: A COMPARATIVE LIFE CYCLE ASSESSMENT OF CONVENTIONAL VS. ORGANIC COTTON AGRICULTURE

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FROM SEED TO HARVEST: A COMPARATIVE LIFE CYCLE ASSESSMENT OF CONVENTIONAL VS. ORGANIC COTTON AGRICULTURE

A dissertation presented in part fulfillment of the requirements for the Degree of Master of Science in Sustainable Environmental Resource Management/ Master of Science in Integrated Science & Technology

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October 2010

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ABSTRACT

REBECCA HOEHN

FROM SEED TO HARVEST: A COMPARATIVE LIFE CYCLE ASSESSMENT OF CONVENTIONAL VS. ORGANIC COTTON AGRICULTURE

CONVENTIONAL AND ORGANIC COTTON FARMING PRACTICES BOTH HAVE BENEFITS AND DETRIMENTS TO EACH TYPE. COTTON AGRICULTURE IS RESPONSIBLE FOR THE USE OF A THIRD OF THE AGRICULTURE INDUSTRIES’ PESTICIDE USE. IN ORDER TO HELP ALLEVIATE THE USE OF PESTICIDE DEPENDENCY THE FOLLOWING STUDY REVIEWS THE USE OF PESTICIDES AS WELL AS OTHER STRESSORS OF BOTH SYSTEMS AND HOPES TO DECIDE HOW SUSTAINABLE AGRICULTURE IN THE COTTON INDUSTRY CAN BE ATTAINED. EVALUATIONS OF BOTH SYSTEMS HAVE BEEN COMPARED IN ORDER TO REACH THE DECISIONS OF SUSTAINABILITY.

DR. STEVEN P. FRYSINGER
DR. WAYNE TEEL
DR. EVERALDO ATTARD

KEYWORDS: AGRICULTURE, ORGANIC, COTTON, COMPARISON

MSc. SERM / MS ISAT
OCTOBER 2010
The following work is original research done by Rebecca Hoehn and is authenticated as my own personal writings.
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THESIS STATEMENT

The goal of this dissertation is to use Life Cycle Assessment (LCA) to compare agricultural practices of conventional and organic cotton farming. This LCA will be streamlined to focus specifically on cotton production only from seed to harvest. The objective of this dissertation is to analyze fiber production methods and investigate their environmental and social impacts, aiming towards a more sustainable textile market.
CHAPTER 1 - INTRODUCTION

BACKGROUND AND SIGNIFICANCE OF COTTON

Cotton is grown in tropical or sub-tropical regions with moderate rainfall and is very sensitive to frost. The areas of cotton cultivation, however, are expanding due to the implementation of irrigation systems. The best quality cotton has a longer and finer staple/lint. Long staple lengths can only be grown in the most ideal conditions with regards to quality of soil, water, temperature and light.

Farmers usually plant cotton in the spring, although in certain climates some areas can plant as early as February or as late as June. About two months after planting flower buds appear on cotton plants and open about three weeks later. When the petals wither and die the cotton bolls are exposed. The fiber is inside this boll and will burst out of the boll when it is fully ripened.

There are currently four different types of cotton species that are domesticated and used commercially. They are all in the genus *Gossypium*, with the following species: *hirsutum*, *bardadense*, *arboreum*, and *herbaceum* (Matlock, Thoma, Nutter, & Costello, 2008). According to the National Cotton Council of America the largest producers of conventional and organic cotton are China, India and the United States while the largest exporters are Africa and the United States (National Cotton Council of America, 2010). An average yield in the U.S. is 1 1/3 bales per acre and 1,078 pounds of seed. A U.S. bale currently weighs about 500 pounds and due to improvements in cotton farming yields have doubled since 1950 (National Cotton Council).

Globally cotton is used more for textiles than any other fiber (National Cotton Council) and is the most important non-food agriculture commodity. About 99% of the world’s cotton farmers live in developing nations and because of their poverty are only able to cultivate small portions of land consisting of less than one acre (EJF, 2007). While its main purpose is for textiles, cotton can also provide a food source. Pressed cottonseeds are used in vegetable oil and for animal feed (Matlock, Thoma, Nutter, & Costello, 2008). The short fuzz on the cottonseed provides cellulose that can be made into plastics (National Cotton Council).

Cotton production has increased dramatically over the past few decades. This is directly due to the yield increases that cotton cultivation has undergone. We can attribute the yield increases to the advances and increased use of pesticides (Banuri, 1998).

The conventional production methods of cotton have significant and avoidable environmental and health related costs. There are some sustainable alternatives such as organic cultivation,
integrated pest management (IPM) or integrated crop management (ICM) and even genetically engineered cotton. A more thorough comparison of these will be seen in Chapter 2.

**IMPACTS OF COTTON FARMING**

Cotton farming generally can have significant impacts on the environment and on human health. Impacts can occur from irrigation systems, pesticide use including herbicides and insecticides, synthetic fertilizers and clearing of forest areas to be used for agriculture systems. The implementation of irrigation systems and salinization of the soils go hand in hand. Since cotton requires a significant amount of water, areas suffering from irregular precipitation patterns are forced to rely on irrigation. In order to set up irrigation systems rivers are diverted, groundwater is pumped or dams are built (Kooistra, Termorshuizen, & Pyburn, 2006). Irrigated cotton fields generally have higher yields but at a cost. Areas such as the Aral Sea have undergone complete climate change due to over extraction of water & water shortages from the large diversion of the freshwater rivers. When there is a large drop in water levels there is a drop in biodiversity and an increase in concentration of chemicals. It is estimated that 1-6% of all freshwater withdrawal worldwide is used for cotton farming. (Kooistra, Termorshuizen, & Pyburn, 2006).

Pesticides are a huge environmental threat within the cotton farming industry. Insecticides are meant to manage insect damages and, control soil borne pathogens. Herbicides are used for maintaining weeds and defoliation purposes. Globally, cotton production utilizes 2.5% of cultivated land but it is responsible for 16% of the global insecticide and 6.8% of herbicide use, which is more than any other single crop (EJF, 2007).

The pesticides used on conventional cotton are usually the most toxic types. They are organochlorides that have a persistence of residing in soil for long periods of time and organophosphates which are much more toxic but not as persistent as the organochlorides. Common insecticides of this nature used are Malathion, Aldicarb, Parathion, Acephate and Methamidophos. There is also use of herbicides; such as Methylarsonic acid and Pendimethalin and use of fungicide, Etridiazole. All of these chemicals are listed on the World Health Organization (WHO) in categories from slightly hazardous to extremely hazardous both orally and dermally (EJF, 2007; Banuri, 1998). Most of these products have the potential to do severe harm to environmental and human health. River systems are affected by runoff of these pesticides, which significantly reduces the biodiversity of the related ecosystems. Not only are the flora and fauna in the rivers affected but other species who feed off the river system, such as birds, are also highly affected (Pesticide Action Network North America, 2008).
Pesticides also put human health at great risk because of the lack of regulations on pesticides in many developing nations. Aldicard, parathion and methamidopho are three of the most hazardous insecticides known to affect human health according to the World Health Organization. Aldicard can kill a person with just one drop being absorbed into the skin and unfortunately it is still used in 25 countries globally (Organic Trade Association, 2009). Farmers essentially poison themselves with the use of pesticides in the developing nations because of poor spraying materials and environmental practices. In Tanzania a survey conducted in 2002 found that farmers were storing lethal pesticides in their bedrooms and even near food (EJF, 2007).

The use of artificial fertilizers also creates environmental hardships. Fertilizers contain combinations of Nitrogen, Phosphorus and Potassium. Phosphates and Potassium are often over mined and supplies are left depleted. Problems also occur when extensive amounts of fertilizers are used because there is often runoff into surface waters or leaching into groundwater. Phosphorus and Nitrogen can cause accelerated eutrophication of lakes, streams and other aquatic systems (U.S. Geological Survey, 2010).

Agriculture will always affect natural habitats because they will need to be cleared to be cultivated. Fortunately, there is not a lot of land that is directly cleared for the cultivation of cotton alone; as corn, wheat and beans are also harvested in the same areas as cotton.

**Growing Interest in Organic Products**

Globally only 0.76% of all cotton agriculture was produced organically in 2009 (Marquardt, 2010), which is an increase in growth from 2006 which represented only 0.15%. Today’s increasing environmental concerns puts pressure on producers to limit environmental degradation. It is essential to provide education to producers about cost benefits and organic agricultural management practices.

Organic cotton will reduce the exposure of toxic chemicals to the land, air, water and food supply. The movement toward organic agriculture is being facilitated by action towards better human health and environmental management. Farmers could avoid health risks, debt from pesticide loans and the possibility of receiving subsidies for going organic (EJF, 2007). They would also be celebrated by organic cotton consumers who have been steadily growing since 2001. A survey conducted in 2007 showed that 50% of women want more organic products sold in markets (Organic Exchange, 2007). In 2009 organic products reached $4.3 billion in sales in the U.S. this is a 35% increase over just one year, these organic products have a high demand
from U.S. because they say that environmental concerns help shape how and where they shop (Grady, 2010).

**Organization of Dissertation**

Would this work better in paragraph form with slightly more description?

- **Overview on Cotton Farming: Types, benefits & limitations? Locations?**
- **Methodology:** Discusses LCA methodology in general
- **Goal Definition and Scope:** Discuss the study purpose and scope
- **Life-Cycle Inventory:** Describes process and provides LCI results for each individual system
- **Life Cycle Impact:** Discuss the Impact assessment for each system.
- **Life-Cycle Interpretation/Improvement:** Conclusions and discussion about LCI and LCIA results
- **Recommendations:** Recommendations and possibilities for future research
CHAPTER 2 - OVERVIEW OF COTTON FARMING

Cultivation of cotton is done in many different ways. There is a small push to move to more sustainable methods in certain areas of the globe. The original practices of pest control are labor intensive including handpicking of pests; inter-cropping, where two or more crops are grown very close to each other; crop rotations, farmers will grow a series of different crops in the same area during different seasons; and burning of residues from the soil. These techniques can distract pests and also not allow pests to linger in the same area for long periods of time.

Farming has evolved because of the introduction of pesticides. Pesticides have enabled these tedious practices to be phased out. With the increase in pesticide use there is also an increase in water use because the pesticides reduce soil quality therefore not allowing the plants to properly and efficiently absorb water. The large quantity of water used in areas has led to water scarcity and a higher salinity in these areas. The high salinity is due to over extraction of groundwater so that ocean waters can penetrate the water table. If the water table has suffered from mixing with saline waters, irrigation water can be brackish and not healthy for proper growth. The salinity of the water can also transfer into the soil and reducing the quality of soil as well (EJF, 2007).

The problems of pesticide use are overshadowed by their immediate benefit to the farmers. Use of pesticides has increased levels of cotton yields significantly on an immediate level. The effects of environmental degradation are not seen until later when the soil and water quality, the local biodiversity and ecological balance have all be seriously harmed and in some cases it is too late to reverse the impacts.

Pesticide management needs to be enforced but for the cotton crop it may never be eradicated. Globally 15% of cotton yields are lost to insect damage. This can be a large and expensive loss to farmers. The most prominent pests are Pectinophora gossypiella (pink bollworm), Anthonomus grandis (boll weevil), Earias insulana (Egyptian bollworm), Diparopsis castanea (red bollworm) and Bemisia gossypiella (white fly) (Kooistra, Termorshuizen, & Pyburn, 2006).

TYPES OF COTTON FARMING

CONVENTIONAL FARMING

Conventional farming accounts for 80% of the global cotton produced with the majority of production coming from China (24%), United States (19%) and India (16%) (Kooistra, Termorshuizen, & Pyburn, 2006). Within conventional cotton farming practices can vary
tremendously, this is because of the significant differences in farm sizes, types of chemical inputs allowed, and climates in each area.

Developing countries, like China, India, Pakistan and parts of West Africa, tend to have less regulation and cultivate on small mixed cropped farms. These farms integrate different crops throughout the year but lean more towards cultivation of cotton as long as possible because of its high value. Regulations on pesticides in these areas are limited and many types of poisonous chemicals are frequently misused.

In developed countries such as United States and Australia farms are usually over 20 hectares and have no crop rotation. The goal of these large farms is maximizing profit. The large farms size requires mechanization and chemical defoliants in order to harvest the cotton because hand picking would be time consuming and more expensive (Kooistra, Termorshuizen, & Pyburn, 2006).

**Benefits & Limitations**

Since conventional farming depends a lot on pesticide use there is usually a higher yield associated with these farms. Conventional farms have also been around for many years and have the additional benefit of the farmers knowing their land and what works best for them.

Farmers are restricted by the amount of capital they have available to cultivate these farms and are therefore susceptible to purchasing inexpensive pesticides.

Unfortunately irresponsible use of pesticides can lead to a vicious cycle due to resistance. As pesticide use goes up cost to the farmer is increased, as are environmental costs because insects can become resistant. Eventually the chemical inputs in addition to degradation from tillage soils can undergo complete chemical changes and become unfit for cotton cultivation entirely leaving the farmer with no choice but to abandon the land. Another factor that could lead to soil degradation is the possible overuse and misuse of irrigation.

**Organic Farming**

Organic cotton is cultivated in such a way that it is certified for production without the use of synthetic chemicals (Guerena & Sullivan, 2003). In some cases an organic crop cannot have been sourced from a genetically modified organism. Organic crops not only reduce pollution of water and land but also promote biodiversity in agriculture. As of 2009 organic cotton accounts for only 0.76% of cotton cultivated globally (Marquardt, 2010). Farms also range from large to small sizes. The majority of demand for organic cotton comes from Europe (58%) and United States (33%).
Turkey is the number one producer of organic cotton, supplying 29% of the organic fiber (Kooistra, Termorshuizen, & Pyburn, 2006). The main reason for this is because of the country’s climate and culture. Since the 1980s Turkey has been adopting organic farming principles. In 1992 the Turkish Association of the Organic Agricultural Movement (ETO) was established in order to provide assistance to organic farmers in Turkey. This entity enabled many farmers access to information in order to practice organic agriculture properly and attain the certifications necessary (Eraslan, 2004).

In order for cotton to be deemed organic it must follow cultural practices involving natural fertilizers and biological controls for pests and soil management. Soil nutrients are supplied through the use of animal manures, compost and sometimes deep root cover crops that bring nutrients up from deep soil. If a third-party group investigates and confirms the farming practices with farm inspections and upon receipt of a certification fee farms can be certified organic. Although some farmers may lack the money to afford certification fees they can still learn how to farm organically. This will allow them to slowly transition and hopefully earn enough income to eventually become certified.

Some organic practices include cover crops, strip cropping and crop rotations. Cover crops are able to protect against erosion in soil and also add organic matter, suppress weeds and sometimes provide nitrogen. Rye, brassicas, clovers, hairy vetch and other small grains are perfect crops for this task (Guerena & Sullivan, 2003). The cover crops can help additionally by providing shelter to predatory insects that attack the cotton pests. The cotton pests could also utilize the cover crops as a source of food when they are in bloom. Strip crops essentially have the same benefits as cover crops but are planted in full strips between the cotton plants.

Crop rotations allow the soil to be nourished by other plants. For example, rotating cotton with legumes provides the soil with a nitrogen fixer in the winter off months. Crop rotation is also the most effective way of interrupting pests’ lifecycles.

**Benefits & Limitations**

The benefits of organic farming are that the areas are managed in a more sustainable fashion. Use of chemical fertilizers and all types of pesticides are eliminated therefore protecting biodiversity.

The main obstacle to sustainability is the lack of knowledge of the alternative. The cotton commodity chain is set up so the majority of costs for transition to organic practices are put onto the manufacturers and farmers. Farmers do however receive more money for organic cotton but the markup from retailers allows the retailers to see the majority of the profits. Farmers must
put in a lot of time and invest in studying their farms ecosystem. Initially farmers will also see a significant yield decrease which can eventually reverse itself in time as soil nutrients increase. In many cases yields may not reach as high as conventional cotton farming practices because of large numbers of natural pest populations (Banuri, 1998).

Unfortunately another hurdle for organic agriculture is that there are several standards and definitions that have been developed worldwide. The most common standards have been created by the International Federation of Organic Agricultural Movements (IFOAM) which is governing 570 active member groups within 100 countries (Banuri, 1998).

Organic cotton farming has yet to become a large market with long-term economic trends. This is because organic farming has a long turnover rate in order to make profits. Diving into this market is risky for business owners who do not do proper research or have proper support

**Integrated Pest Management Farming (IPM)/Integrated Crop Management Farming (ICM)**

Integrated Pest Management (IPM) and Integrated Crop Management (ICM) use practices that have been around for decades. There is no specific definition of IPM but it focuses on the “long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices and use of resistant varieties” (Kooistra, Termorshuizen, & Pyburn, 2006). The US Environmental Protection Agency (EPA) has a set of principles for IPM. The principles are meant to control not eliminate pests (Environmental Protection Agency, 2009). Pests are still present within these farms but they are maintained at a low enough population to not create economically damaging harm. Natural predators can be introduced into the system as well in order to help keep pest populations at a manageable level. It can also use crop rotation or inter-cropping methods (cultural control), hand picking of pests and use of pheromones to trap pests (physical control) and integration of less toxic chemicals. A total of around 38% less insecticides can be expected on IPM farms (Swezey, Goldman, Bryer, & Nieto, 2006). Since it can be a bit more labor intensive IPM manages to create additional employment but with a resulting higher yield it still manages to be economically sound.

ICM is different from IPM because it is more holistic in thinking. It incorporates fertility, soil quality and crop management as well, whereas IPM is only focused on reducing the amount of pesticides used. ICM requires more thought and skills from farmers because it is necessary to monitor the soils organic matter content and decide what crops are best grown in rotation or together.
Benefits & Limitations

Due to the loose definition of IPM and ICM they are having a hard time being recognized and replacing conventional practices because they involve more time and effort, and hiring skilled labor, which may or may not be readily available. Both methods require very complex methods in eliminating pests and enhancing the surrounding environments. Studies and information for IPM and ICM are not readily available for many third world countries. Although globally IPM is not widely known, in the US IPM could be a promising alternative and is being used on 70% of total cotton areas (Kooistra, Termorshuizen, & Pyburn, 2006). IPM farms are much more commonly found than organic cotton farms because there is no need for certification. All principles that guide these practices do not need to be followed specifically and farmers have the flexibility to pick and choose practices that suit their needs.

Genetically Modified Cotton

Genetically engineered cotton modifies plant characteristics such as the shape and size of leaves so the insects are not getting as many nutrients from them, and allowing the plant to have a quicker rate of ripening which limits the exposure to insects and combining insect repellent into the plants genes. All forms of genetically modified cotton are still in experimental stages (Aksoy & Beghin, 2005).

Benefits & Limitations

Genetically modified cotton is still being researched and could be promising. The problem with introducing genetically modified organisms (GMOs) to natural systems is that there could be effects on homeostasis. Long term studies are needed in order to ensure that crops would not harm their surrounding environments.

Locations

Almost 99% of all cotton farmers in the world are living in a developing nation. India accounts for over a third of all cotton farmers who use 54% of all pesticides while only maintaining 5% of cultivated land. Other significant farming regions are China, West Africa, and South America. These farms are small to moderate size and usually practice crop rotation, so cotton is not their only source of income.

Developed nations such as Australia and the United States produce significant amounts of cotton but mainly grow on monoculture large scale farms. As of 2005, Turkey was the leader in production of Organic cotton producing around 29% of total supply (Kooistra, Termorshuizen, & Pyburn, 2006)
Chapter 3 - Methodology

Life Cycle Assessment (LCA) is a cradle-to-grave assessment of products, services or processes (Matlock, Thoma, Nutter, & Costello, 2008). The concept of LCA is to evaluate the environmental effects associated with any given activity from the initial gathering of raw material from the earth until the point at which all residuals are returned to the earth. The goals of LCA are to improve environmental performance in surface and groundwater pollution, air emissions and waste management as well as choosing the best produce, process or service that has the least effect on human and environmental health.

Life-cycle assessments can be utilized for process analysis, material selection, evaluating or comparing products, or in forming policies. Life-cycle assessments look at processes holistically and identify opportunities in which environmental impacts can be reduced. Environmental benefits can be reached in all three of the later steps (Vigon, Tolle, Cornaby, & Latham, 1994).

Life Cycle Assessment Components

LCA is a system that uses a systematic step-by-step approach. The four components of LCA are:

- Goal and Scope – defining the system that will be analyzed
- Life Cycle Inventory – Identifying and quantifying the system components
- Impact assessment – assessing the impact potential of the system inputs
- Interpretation/Improvement Analysis – having detailed understanding and suggesting improvements for the system
Figure 1. Steps of Life Cycle Assessment, after Graedel

The figure shows that in the LCA there will be a lot of back and forth among all the steps. This means that no step is fully complete until you have finished all steps of your LCA. Upon completion of this LCA, the data collected will be used to suggest optimal conditions for cotton production in agriculture. This should help provide enough information to alleviate pressures on the industry and lead to a more sustainable process.

Analysis is done by compiling inventory of the inputs, usually raw materials and energy and the potential impacts from the inputs are evaluated. This should provide a guideline for improvement in further development of the systems eventually leading to smaller requirements of energy and raw materials (Matlock, Thoma, Nutter, & Costello, 2008).

**Goal Definition and Scope**

In order to carry out a proper LCA it is important to maintain the structure of the goal definition throughout the LCA. The goal/objective should define and describe the product, process or service and establish how it will be assessed. Environmental stressors are usually the most common attributes assessed in LCA (Graedel, 1998).
In order to determine how much time and resources will be allotted for the assessment determining the following is necessary to decide: the type of information needed, the specificity of the data and how results will be displayed. The most limited scope of analysis that will still provide an adequate interpretation of the systems should be the target. This will avoid any extra expenditure of resources.

During comparative studies, such as the study done here, the system boundaries should be defined at same level of detail in each system to prevent skewed results (Vigon, Tolle, Cornaby, & Latham, 1994). Boundaries of the system should be defined in order to define how complex the LCA will be. Boundaries can be set in many ways such as defining how much of a product’s life cycle will be evaluated, the extent of detail to be analyzed and boundaries based on spatial and temporal scales. These will limit the study in order to get a more precise analysis for the overall system.

The process of defining a scope necessarily requires assumptions, and it is critical to document these assumptions so that your audience is aware. The assumptions that are made by a researcher may not be the same overall therefore thorough documentation leads to no misunderstandings.

**Inventory Analysis**

It is very important to define your goals and objectives clearly when starting your LCA, but the other steps are not always done in a linear fashion. Information from each of these steps will complement the other and iterating between steps is expected (Vigon, Tolle, Cornaby, & Latham, 1994).

The inventory analysis will use quantitative data as well as qualitative information to determine the environmental effects of the fiber agriculture business. During the inventory analysis all inputs and outputs are accounted for. This step should be the most developed and detailed of the entire assessment. It is done so that all relevant data can be organized properly and will describe the environmental impacts that are occurring with the hope of pointing out where improvements can be made.

This step should include all pollutants released and their quantities along with defining energy requirements. The key steps as defined by the United States Environmental Protection Agency (EPA) are:

- Develop flow diagram of processes being evaluated
- Develop data collection plan
• Collect the data
• Evaluate and report the results

The flow diagram maps inputs and outputs utilizing the system boundaries defined in the goal definition and scope.

When collecting the data it is important to find a balance between time and resources against quality of data. Basic inputs to consider are raw materials used; energy resources; types of fuel are being used and how much; and water volume required.

One important output to be considered is atmospheric emissions which are usually reported by weight. Some typical emissions to consider are nitrogen and sulfur oxides, volatile organic compounds (VOCs), carbon monoxide, ammonia and lead. Waterborne wastes are another essential output that should be measured. This is usually measured by pollutants per unit of water. Some common waste measurements are biochemical oxygen demand (BOD), suspended solids, dissolved solids, oil and grease, iron, chromium, tin, and phosphates. Solid waste disposed from the system is another output that can be measured; again this is measured by weight (SAIC, 2006).

Transportation is sometimes overlooked but requires a lot of energy and generates emissions; therefore it should also be reported in the inventory analysis when relevant. This can be recorded in miles/kilometers shipped, or unit of energy required per acre or other functional unit. Then the weight of the products shipped can determine tons shipped per mile/kilometer (Vigon, Tolle, Cornaby, & Latham, 1994).

A functional unit is the amount of product, material, or service to which the LCA is applied (Graedel, 1998). This is important to define because it helps when comparing two similar yet different systems. For example, if comparing types of shopping bags: canvas and plastic, the first, canvas bags are more durable can be used multiple times while the latter is usually only used once and then disposed of. Instead of comparing bag for bag you could compare the amount of times versus the number used.

Inventory analyses also consider qualitative variables such as quality and durability of product, economic inputs and outputs and consumer values.

**Impact Analysis**

The Impact Analysis relates the inputs and outputs of a system to the impacts they have on the real world. The human and ecological effects of energy, water and material use are analyzed here. It is important to identify ‘stressors’ in the Inventory analysis and figure out how they relate
to environmental degradation. There are two ways of predicting impacts; the simple way only estimates potential impacts, but in order to predict actual impacts this will require elaborate detailed data acquisition and help from environmental scientists (Graedel, 1998). The results of the Impact Analysis should determine which system is less detrimental to the environment based on the stressors.

The following steps encompass an Impact Analysis (SAIC, 2006):

Definition of Categories - Define environmental impact categories such as global warming, eutrophication or human toxicity.

Classification - Assign each input/output from the inventory analysis is to a category. For some inventory results there is the possibility that it could fit two or more categories.

Characterization – This shows exactly what the impacts have potential to do, for example the potential to speed up eutrophication or the lethal dose to 50% of humans (LD50).

Normalization or Localization – This involves taking the potential impacts and comparing them in a fair manner. For example, comparing the relationship of the same amount of Carbon dioxide emission into two different environments, one where the environment has a higher density already than the other is more detrimental (Graedel, 1998).

Weighting/Valuation - Deciding on the most important potential impacts and ranking them. The impacts will also have to be evaluated based on how they affect the system holistically, this means looking at actions that will cause impacts at a later stage in the system.

Matrices can be used to link the stressors and impacts. It can be done simply by comparing activities versus the impacts they have or be more complicated showing cumulative impacts for comparisons (Graedel, 1998).

**IMPROVEMENT ANALYSIS/INTERPRETATION**

Finally, an improvement analysis is an interpretation of the inventory and impact to focus on overall performance of each system and to compare them. At this stage, the LCA will reveal how efficient the current design is and the areas for improvement will be uncovered. A selection of the preferred product, process or service will be done here. It is chosen based on what is most profitable while causing the least amount of environmental and human harm. This analysis might result in proposed changes, the resulting design of which would be fed back through the LCA cycle.

It can take a lot of time and effort to improve the overall system especially if there are a lot of suggested changes. It is important to prioritize these changes while considering the technical
feasibility, improvements to the environment, benefits associated with economy, whether it will add customer-perceived value and if it impacts the time it takes to produce or deliver the product or service (Guinee, et al., 2002).

During the interpretation it is also important to evaluate the sensitivity of your results to assumptions made, determine where there is any uncertainty, and evaluate whether it is appropriate to adjust assumptions in order to reduce this uncertainty. This is where a final walkthrough of the whole LCA will be conducted in order to ensure that all data is represented consistently. If gaps in the data are found then they must be reported and an estimate of the impact on the whole study must be provided (SAIC, 2006). Providing information on the inconsistencies between alternatives is also helpful in identifying the quality of the data and will help when drawing the final conclusions and recommendations.

**LCA Benefits**

LCA can provide a streamlined assessment in order to help decision makers select products, processes and services that have the least environmental impact. With this efficient and thorough assessment many areas where environmental harm used to be overlooked are now reviewed in detail. The LCA will attempt to prevent unintended consequences by looking at systems holistically and regarding their potential impacts.

**LCA Limitations**

Time and resources are extensively utilized during an LCA. It is sometimes impossible to gain all resources necessary for the project. Therefore, gathering data can be problematic. Data can also be unavailable in general or just to the public. Any data that have not been taken into consideration will impact the final results. The LCA is not based on objective science entirely; it also takes into consideration the modeler's subjective assessments.
CHAPTER 4 - GOAL DEFINITION AND SCOPE

INTRODUCTION

The goal of the following research is to identify differences in cotton production and clearly compare their range of environmental and social impacts and advantages. A literature review related to cotton’s agricultural industries has been conducted. Readings on LCA methodologies have been evaluated to understand more of the steps in depth.

Specifically, this study compares conventional cotton farming practices to organic cotton farming practices in the United States. The goal was to understand the inputs and outputs of both systems and figure out ways to make cotton farming a more environmentally stable trade while keeping it economically feasible.

PURPOSE OF STUDY

This study identified the impacts of conventional and organic cotton farming with the hope of finding ways to alleviate the stressors. By doing a comparison of different types of farming many different practices were recognized. A combination of good practices was determined in order to create a more environmentally sustainable way to grow cotton.

PREVIOUS RESEARCH

Center for Agricultural and Rural Sustainability at University of Arkansas

A study carried out by the University of Arkansas' agricultural division for Cotton Incorporated (2008) quantified the energy requirements for ten regional cotton producers around the globe. It was found that there is a high variability in cotton farming practices, even regionally, because of infrastructure, topography, climate, culture and agro-economics (Matlock, Thoma, Nutter, & Costello, 2008).

The energy inputs that were considered included direct energy from machinery, animals and humans; as well as embodied energies in fertilizers and manure. Another energy that was assessed here was the potential recoverable energy from a secondary product of cotton such as seed and oils. Energy processes that were not included were from transport, ginning and processing of the cotton. This study was strictly done to analyze energy efficiency and there was no focus on green house gases.

The conclusions here were that six of the ten regions had the potential to become net energy producing. Manure is a high embodied energy cost, even though it is a good green option for
fertilizer there is also the opportunity to use it as a fuel instead of a fertilizer. Due to low monetary access in some areas it can be considered unfortunate that manure must be used as a fertilizer because the manure could potentially be a lost source of inexpensive energy production. This leaves farmers with no choice and therefore a loss of energy (Matlock, Thoma, Nutter, & Costello, 2008).

**Life Cycle Assessment for Cotton Underwear**

Students at the University of Michigan (2006) were tasked with a small project to conduct a life cycle assessment of a certain product. These students chose cotton underwear. The project is very general but the goal was to understand the inputs and outputs necessary to produce a pair of cotton underwear and to use the results to establish what it takes to make a sustainable pair of cotton underwear.

The study broke down the entire process of producing a pair of underwear into raw material extraction, material processing, product manufacturing, product use and disposal. Each stage was rated on how severely they impacted the environment and they decided that erosion, and chemical runoff was the most important impacts (Dalton, Rankin, Fisherman, & Gonzalez, 2006).

**Life Cycle Inventory Data of Cotton**

Cotton Incorporated (2009) provided Inventory data on cotton produced in the United States. Land, water and energy use, the amount of green house gas emissions and the ecosystem services provided by cotton were evaluated for inventory data.

Cotton Incorporated, reported that the amount of land use for cotton is small and efficient due to measures taken that have improved yields tremendously over the past few decades. The amount of water used on cotton is also considered to be low using only 3% of agricultural water globally. It is believed that cotton is a net energy producer because the secondary products of cotton produce more energy than what is necessary for fiber production. Cotton has the ability for carbon sequestration in the fibers and in the soil which helps keep the plant GHG neutral. Cotton also can provide oxygen and habitat.

Although Cotton Incorporated has made an excellent case for how cotton being grown in the United States is not very harmful to the environment they still seek to make improvements. They have identified two input areas, use of fertilizers and irrigation. Fertilizer is a large portion of cotton’s energy because of the nitrogen in these products. Cotton Incorporated has begun studies that measure in real-time cotton’s Nitrogen requirement, researching a good candidate for nitrogen fixing ground cover crops that are adaptable to multiple environments and investigating cross breeds that could require less nitrogen.
Improvements in irrigation are being made because as time goes on our water resources are becoming more depleted and valuable energy is consumed by irrigation because of deep pumping. A solution to the large amount of energy necessary for these systems is investment in renewable energies that will lower carbon emissions (Cotton Incorporated, 2009).

Center for Agroecology and Sustainable Food Systems

A study carried out by the University of California (2006) compared organic, IPM and conventional cotton production practices in San Joaquin Valley, California. This study was carried out over a period of six years, from 1996 to 2001. The study wanted to address what would happen to insect populations with the reduction or elimination of insecticides, how costs and yields varied and could organic cotton be economically competitive.

The study monitored pest populations, analyzed the cotton plant development and density in the field, and recorded the lint quality and yield. The cost of production was also monitored by conducting interviews with farmers after the harvests.

The results of the study showed that there was not a significant difference in pest populations. The difference was just the types of pests that were occurring in the fields. Organic cotton had a slower development and smaller density than both IPM and conventional farms. While the color in organic cotton suffered the rest of the quality did not, fiber strength and length were very similar to IPM and conventional fibers.

A large disadvantage to the organic fields was the lower yields. This directly related to the higher cost of operations because there was not as much fiber to return profits. The overall cost of production for organic farms was 37% higher than a conventional producer. The global cotton market allows for international imports of organic cotton at a cheaper price giving US farmers no incentives for organic production (Swezey, Goldman, Bryer, & Nieto, 2006).

Intended Audience and Use of Study

Cotton Agriculture Industry

Cotton farmers around the globe are engaged in many different ways of cultivating their cotton crops. In some areas, mostly third world countries farmers are not given proper access to information about safety with regards to pesticides. This means they may not even realize that there are other options, besides the pesticides they currently use. This other options could potentially even bring benefits to their land. Even farmers in the developed nations may not realize there could be benefits from changing some of their old habits to help revitalize land that they have been cultivating for years. This study is designed to inform farmers around the world
about different ways to cultivate cotton and the benefits each type provides environmentally and economically.

**Policy Makers**

Policy makers are the people who are able to change laws, rules and regulations about common practices in their nations. They are able to determine the way things should be done and make sure that the citizens abide by the rules. This is important because a well informed policy maker will tend towards making holistic decisions that should benefit the majority. If the policy maker knows the harmful impacts of some agricultural practices along with the potential solutions, it should be simple to get them to adopt rational policies.

**Consumers**

Consumers have the right to know exactly where their products are coming from. If most consumers knew that the money they spent on a brand of cotton t-shirts was supporting damage to ecosystems and harming many people in India and Africa they probably would not be inclined to buy from that vendor. Instead they might spend a few extra dollars to know that the product they are purchasing has been sufficiently regulated without bringing social or environmental harm.

The purchasers of cotton also should be knowledgeable about other ways to farm cotton so that they can try to push the policy makers into making better decisions about regulations. If the public knows about what is right they might be able to influence farmers and policy makers into growing cotton the most efficient and sustainable way.

**System Boundaries**

The scope of this study will be to determine the inputs and outputs required to produce cotton in both systems, i.e. conventional and organic agricultural practices. The focus is strictly on cotton’s agriculture process, this means that evaluation will only be during the period from field preparations until harvesting the cotton fibers. The collection of data was limited to cotton agriculture in the United States. Relevant and comparable data for international farms were unavailable. Data was collected generally from the USDA website. It is understood that there are different climates and soil types associated with all farms and that different manual inputs are required based on this; therefore the US averages for amount of pesticides, fertilizer use, amount of water from irrigation, harvested and planted acres and yields will be used for comparisons. The results are meant to show the environmental stressors that cotton farming has on the planet and suggest opportunities where stressors can be alleviated.
Each system was broken down into three phases; field preparation and planting, field operations, and harvesting. The inputs and outputs of each phase were determined and compared in order to seek the differences. The differences were then evaluated against one another to obtain a recommended farming practice. Categories of specific interest to this study were greenhouse gas emissions, toxicity to aquatic and terrestrial life, effects on human health and natural resource depletion.

**General Assumptions**

The data collected for the comparison between conventional cotton and organic cotton is from the year 2008 because that is the latest year of data published for organic cotton on the USDA website. Although there is more recent data on conventional cotton a comparison of the same year was done to align with the same season.

In order to be deemed organic cotton there are standards that farms must obey. The information provided on the USDA website about organic cotton farms assumes that these farms have met the standards. It is assumed that the averages in the US will give credible data when making decisions for farming practices because of the diversity of climates throughout the country. The study also assumes that all conventional farms utilized the following chemical aids for production; fertilizer with nitrogen and phosphorous and pesticides prior to harvest. Generalizations about the plant density and fiber quality (color, strength and length) will be determined from previous studies and surveys.

We assume that organic cotton farms might still utilize irrigation systems and tractors for tilling, spreading natural fertilizers and harvesting. This means that greenhouse gas emissions from the energy required to run these systems can be assumed equal per volume of water pumped and acre of land treated.
CHAPTER 5 - LIFE-CYCLE INVENTORY

CONVENTIONAL COTTON

FLOW DIAGRAM

Figure 2. Inputs and Outputs of a Conventional Cotton Farming system

Conventional farms in the United States use five times as much pesticide per acre than other row crops (Thurman, Zimmerman, Scribner, & Coupe Jr., 2008). In some cases large amounts of water, sometimes from irrigation, are necessary because these chemicals do not allow the plants to absorb water efficiently. The pesticide use however allows the farmers more freedom because they do not have to consistently monitor for pests on site. Since the pesticides kill all predators the bolls are considered to be safe and farmers can count on higher yields of cotton when compared to organic farming.
A lot of conventional farms stand by a monoculture system, planting only cotton, and this also leads to soil degradation because the same nutrients are being taken from the soil and not returned at a later date. Over time this leads to higher fertilizer needs with smaller yields, consequently this can reduce a farmer’s profit margin. Synthetic fertilizers are used to replace the nutrients being taken out of the soil from the crops. Unfortunately these synthetic fertilizers come from taking natural resources from elsewhere, for example mining for phosphorus. The use of the synthetic fertilizers can also result in agricultural runoff, polluting surrounding areas with nitrogen and phosphates and the possibility of eutrophication of surrounding water bodies.

**Organic Cotton**

**Flow Diagram**

![Diagram of Organic Cotton Farming System]

Figure 3. Inputs and Outputs of an Organic Cotton Farming System

More human labor is necessary in organic systems because they have to keep an eye on weeds and insect populations because they do not use synthetic chemical treatments and the natural pesticides such as predator introduction and sulfur must be steadily monitored. Maintenance of
hand-weeding and intercropping also calls for specific skills from hand labor. This takes a lot of time and resources to sustain a healthy farm.

The soil must be kept fertile to continue with the best growth. In order to do so there is a need for compost. The organic materials act as a natural fertilizer which helps the cotton thrive. Compost can take up to a year to make with old yard and kitchen scraps, since this process takes a lot of time and effort it is not as immediately efficient as synthetic fertilizer use.

Manure can also be used as a natural fertilizer in organic cotton farms. This manure, although considered more environmentally friendly than synthetics can also lead to emissions of methane and ammonia in an anaerobic setting, fortunately this is not common.

**SUMMARY OF LIFE-CYCLE INVENTORY RESULTS**

Comparison considerations:

- Chemical Use
- Water Quantity Usage
- Genetically Modified Organisms (GMO) Seeds
- Soil Quality
- Transport
- Cost/Profits
## Considerations

<table>
<thead>
<tr>
<th>Chemical Use</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticide use is five times as high as other row crops</td>
<td>No chemicals allowed to be used from pesticides, including herbicides, fungicides or insecticides as well as any synthetic fertilizers</td>
<td></td>
</tr>
<tr>
<td>Crops receive synthetic fertilizers to obtain nutrients such as nitrogen and phosphorus</td>
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</table>

<table>
<thead>
<tr>
<th>Water Usage</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticide leads to higher water use because the soil quality degrades with excess chemicals. Excess chemicals do not allow the plants to efficiently absorb the water.</td>
<td>Water use during transitional period can be much higher (2-3 years); this is because the soil quality has not been turned around properly. After the transitional period water usage is lower or equal to conventional farms depending on the organic matter present in the soil.</td>
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<table>
<thead>
<tr>
<th>GMO Seed</th>
<th>Conventional</th>
<th>Organic</th>
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</thead>
<tbody>
<tr>
<td>GMO seeds are treated with pest resistant products that pests could potentially become immune to.</td>
<td>Study in India of 100 cotton farms showed that non-Bt cotton out produced the GMO seeds by 16% (Organic Exchange, 2007).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil Quality</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional cotton has the potential to render bad soil quality from the chemicals used in fertilizers, pesticides, insecticides and herbicides.</td>
<td>Organic cotton can help create or maintain good soil quality because of the lack of additives. Additional organic matter added to the soil through compost and manure and crop rotations allows the soil to be more fertile and pest resistant</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transport</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional cotton is grown in abundance globally and therefore sourcing conventional cotton locally is easy</td>
<td>Organic cotton farming is predominantly found in Turkey and China so exporting this cotton turns a significant global footprint. States such as Texas, California and New Mexico are pioneers in producing more and more organic cotton for the United States.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost/Profits</th>
<th>Conventional</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selling conventional cotton has a profit margin that is attainable because of the higher yields, even with the lower selling price.</td>
<td>Organic cotton needs to be sold at a higher cost because of the lower yield. This cost also will make up for extra labor and other operational costs. Organic cotton also requires a transitional period where the chemicals in the soil are slowly eliminated. This period has the smallest yields for farmers because of the new practices and the soil quality turnover.</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. A comparison of conventional and organic cotton farming considerations

### Discussion of Inventory Results

Impacts to the environment are greenhouse gas emissions and effects on quality of soil and water. From the flow charts we are able to see that the air emissions from tractors or other machinery used to tillage and harvest can be assumed to be equal for both systems. If either
category is utilizing irrigation systems we can assume that the energy use there is also similar. Emissions from transportation of organic cotton may be higher because there are not as many farms. Exports from these particular farms are high and can travel across the entire globe in cases such as Turkey.

The chief environmental difference between the organic and conventional systems is the use of chemicals. Fertilizers and pesticides used in conventional farms can cause harm to soil and water quality. The soil is affected because the plants will take extra nutrients from soil without returning them when cotton is harvested in a monoculture fashion. Soil is also not as fertile because the use of fertilizers adds all the nutrients necessary, while in organic farming systems organic matter is added back to the earth with compost from available biomass on farm or through intercropping of nitrogen fixing crops such as legumes. Synthetic fertilizers also require natural resource extraction in order to be produced; this harms the environment where the fertilizers have been sourced. Both systems have be affected by higher salt contents because of too much irrigation, although it has been seen in previous studies that after the first couple years of conversion from conventional to organic farmers will notice a smaller water requirement for their crop because of the increase in organic matter that helps the soil hold water more efficiently.

Pesticides also can affect the quality of the soil because of their harmful chemicals are retained in the soil for a period of time. The accumulation of pesticide changes the chemical properties of the soil, such as pH, permeability, and amounts of organic matter (USDA Natural Resources Conservation Service, 1998).

Water quality is affected because conventional farms produce chemical runoff into surrounding aquatic areas. If a farm is close to a water source chemicals can be found and disrupt the biodiversity of the surrounding habitats. Runoff carries off excess fertilizers, which can lead to eutrophication of aquatic systems because of excess nutrients and can also carry pesticides whose toxic chemicals also disrupt aquatic life.

Irrigation, which is used in both systems, can also affect water quality when water is used in excess. In coastal regions, the ground water below being used for irrigation could potentially be abstracted at such a high rate that the water table is unable to sustain itself and will end up with salt-water intrusion.

In conventional farming systems there is also a presence of genetically modified seeds (GMOs). With the extensive use of GMOs there is a possibility that insects will become resistant. This will lead to either excess pesticide application or another modification must be made to the seed.
A study done in India showed that without using the GMO cotton there was 16% more yield than the areas that had GMO cotton farms. Studies have not been done that prove GMO cotton is more profitable and has higher yields.

Since organic cotton requires more hands on care and official certifications there are not as many organic farms as conventional farms. This means that organic cotton is transported farther distances and is not as plentiful as conventional cotton. Due to these restraints organic cotton must be sold at a higher cost in order to make profits. This higher cost also affects customers because they will in turn pay more for organic products.
**CHAPTER 6 - LIFE-CYCLE IMPACT**

**CLASSIFICATION OF IMPACT CATEGORIES**

- Global Warming
- Aquatic Toxicity (water quality and water wildlife)
- Terrestrial Toxicity (soils, insects, other animals)
- Human Health
- Natural Resource Depletion

**CHARACTERIZATION OF IMPACT**

<table>
<thead>
<tr>
<th>Impact Category</th>
<th>Cause</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Warming</td>
<td>Emissions from energy used in tractors and irrigation systems</td>
<td>Increased temperature from greenhouse gases</td>
</tr>
<tr>
<td>Aquatic Toxicity</td>
<td>Chemical runoff from pesticides and fertilizers into surrounding water bodies</td>
<td>Eutrophication Harm to biodiversity of aquatic habitats</td>
</tr>
<tr>
<td>Terrestrial Toxicity</td>
<td>Chemical residues on plants and in soil from the pesticides and fertilizers used</td>
<td>Possible mutation or extinction of insect species Harm to birds and other predators of habitants of fields Soil degradation from nutrients not being returned into the environment</td>
</tr>
<tr>
<td>Human Health</td>
<td>Use of deadly pesticides</td>
<td>Causing injury, sickness or death in humans when exposed to certain pesticides at high levels without proper knowledge of safety</td>
</tr>
<tr>
<td>Natural Resource Depletion</td>
<td>Acquiring phosphates for synthetic fertilizers</td>
<td>Resource depletion</td>
</tr>
</tbody>
</table>

Table 2. The characterization of impact categories in conventional cotton farming
<table>
<thead>
<tr>
<th>Impact Category</th>
<th>Cause</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Warming</td>
<td>Emissions from energy used in tractors and irrigation systems</td>
<td>Increased temperature from greenhouse gases</td>
</tr>
<tr>
<td></td>
<td>Emissions of methane and ammonia from animal manure</td>
<td></td>
</tr>
<tr>
<td>Aquatic Toxicity</td>
<td>Runoff from manure into surrounding water bodies</td>
<td>Eutrophication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Harm to biodiversity of aquatic habitats</td>
</tr>
<tr>
<td>Terrestrial Toxicity</td>
<td>none known</td>
<td></td>
</tr>
<tr>
<td>Human Health</td>
<td>none known</td>
<td></td>
</tr>
<tr>
<td>Natural Resource Depletion</td>
<td>Use of animal manure</td>
<td>Resource depletion of animal manure as fertilizer instead of fuel</td>
</tr>
</tbody>
</table>

Table 3. The characterization of impact categories in organic cotton farming

**Discussion of Impact Results**

Although all the harmful effects are important impacts on the environment, the most important potential impacts here are human health and environmental toxicity. Global warming effects from machinery use and irrigation systems are considered to be about equal in each method. This means that comparatively there is not much of a difference.

Human health is a very important impact because without healthy people there will no longer be farmers or consumers. This means it is important to educate society about the harmful effects of pesticides and how to properly apply and use them. With education and awareness of the dangers of these chemicals there will be a better practice of safety meaning humans would not be exposed to these pesticides in unfit ways.

Toxicity to the terrestrial environment is important because farmers need healthy land in order to grow crops. In addition to healthy land and soil it is important to have an entire habitat healthy. When GMO products are introduced there is a possibility that adaption of insects and other species can occur to combat against the GMO product. The presence of chemicals from pesticides also pollutes the soil and does not give it a chance to become self-sustainable. When the pesticides leave residuals on the farm it can also harm birds and other predators who feed off organisms in the field.

Aquatic toxicity is also a huge impact because their environments can become chaotic and organisms will suffer. Poor water quality from too many nutrients and chemicals present can lead to losses in biodiversity and also a loss of water supply.
Natural resource depletion is a serious issue as well but can be prevented if fertilizers are sourced in a sustainable way. When mining for phosphorus materials the rate of excavation should be decreased because there is only a fixed volume of the source as phosphorus is not able to accumulate at a fast pace. If mining continues to be done so quickly in the future there will be no resources left to use for fertilizers.
CHAPTER 7 - LIFE-CYCLE INTERPRETATION/IMPROVEMENT

CONCLUSION

Conventional cotton farming and organic cotton farming both have certain advantages and disadvantages. When comparing the two farming practices, environmental quality as well as the quality of the farmer’s life; economically, socially and physically, should be considered.

Pesticides, which include the use of insecticides and herbicides, cause harm to the farmer as well as the surrounding habitats of the cotton farms. If pesticides are overused or used improperly there is health risks associated to humans. Many pesticides contain chemicals that can create illness or even worse cause fatalities to humans. Chemical build up in the soil can also harm the biodiversity of the farms. Without the presence of certain species soil quality can degrade. It is important to regulate these chemicals and provide safety education to any person who utilizes pesticides. Another way to manage this problem is to use natural pesticides such as sulfur or natural predators.

From the impact results we can see that synthetic fertilizers can also cause a variety of damage. These synthetic fertilizers cause eutrophication in aquatic environments, excessively utilize natural resources. The pollution caused in aquatic environments both ground and surface waters can create excess nutrient build up directly affecting habitats as well as the water we drink. This however can be managed if fertilizers are not overused so the plants are absorbing all the nutrients or if organic fertilizers are used.

Compost and manure seem to be better options for fertilizing lands but do require more extensive work than synthetics. Compost can sometimes take over a year to degrade properly and become useable, and manures can also be used as a fuel source.

GMO seeds can become a problem when they become ineffective because the organisms have mutated or evolved to protect themselves from the product. There have been no proper studies done that show GMO products have benefits to increase yields.

Organic farming does have a lot of hurdles in order to be attained. The regulations are very strict and can consume a lot of time of money. During the transitional period into organic farming, where no chemicals or artificial fertilizers may be used for two years, a farmer will see a lot of loss in profits as the soil quality adapts to new practices. The yields will not be as high and the farmer is unable to sell the product at the organic prices. After the transitional period the yields may still not be as high depending on the location of the farm. This is a gamble that farmers must take when they decide to convert. Some farmers will find that organic practices
end up saving them money in the long run though because they are not incurring the cost of the synthetic fertilizers or the chemical pesticides.

Conventional farming has been around for more years and although it causes harm to the environment, cotton is always needed at high quantities so farmers continue to mass produce. The farmers know their soil and the quantities of resources needed in order to gain maximum yields because they have been doing these practices for so long. These habits are hard to break especially if the farmer sees a profit in their systems every year.

Providing information on the harmful effects of synthetic fertilizers and chemical pesticides to farmers may convince them to change. If information is conveyed to policy makers they might make regulations about these practices so they farmers are forced to change. More importantly there needs to be incentives and support provided to the farmers in order to see change. Since conventional farming will not disappear overnight it would be helpful for to offer instruction to farmers on different techniques that can alleviate the stressors of conventional farming. Practices like Integrated Pest Management (IPM) and Integrated Crop Management (ICM) would be practical because they do not require certifications, enrollment fees or strict regulations. These practices could ease farmers into a more sustainable way of agriculture.

**Future Research**

If given a longer period of time with more resources research should be extended over years of actual data collected from farms globally. These farms should be located in a variety of areas with differing climates and sizes. It would be important to survey farms worldwide because of the different regulations each country has on agriculture. There is also a need to examine cotton farming in developing nations because chemical risks are the highest here due to the lack of education and safety awareness.

Some important considerations for collecting the data besides the yields and profits would be the air, soil and water pollution being caused by the specific farms. Quality of the surrounding habitats should be evaluated based on these pollutants. The major pollutants to consider are nitrogen and phosphates released from the fertilizers compared to the emissions from composting and methane emissions from animal manure. Although these considerations were evaluated generally in this study a more detailed manner with exact amounts of pollutant per farm area.

More research should also be done on the advantages of converting to an Integrated Pest Management or Integrated Crop Management farm. These farms can have many benefits to the environment and are seemingly easier to convert to than organic farming. These practices
also have less stringent rules and regulations, which may seem more appealing to farmers. Research should be done on the benefits of IPM/ICM farming to both the environment and the economic status of the farmer.

Data should also be gathered on social and economic factors in order to properly evaluate profits from each type of farming. Prices of fertilizers and pesticides compared to time and money resources to make compost or maintain the intercropping would be useful in understanding the management of resources. While farmers may want to create a better more sustainable farm in the end they want to turn a good profit so they can feed themselves and their families.

There are success stories of organic cotton farms all over the world. It is time to use those farms as role models in creating a more sustainable agriculture in the textile market.
WORKS CITED


