Revival of Industrial Hemp:
A systematic analysis of the current global industry to determine limitations and identify future potentials within the concept of sustainability

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ABSTRACT

Industrial hemp or *Cannabis sativa* L. is a quick growing, annual herb with a multitude of uses covering a range of products derived from fiber or oilseed that have been known throughout history. Cultivation in industrialized countries more or less halted in the early 20th century when hemp became intrinsically linked with marijuana, the species other phenotype, which contains larger quantities of the psychoactive compound, THC. Recently, a renewed interest in hemp for industrial purposes has occurred due to environmental concerns, the over production of food crops coupled with a need for new sources of fiber. The aim of this research is to present a comprehensive foundation in order to evaluate the hemp industry and its contribution to sustainable agriculture. This includes determining the variables limiting growth at this stage. Hemp scores high in environmental and social aspects but the economics were not as convincing. If the industry is to receive a substantial share in any particular market, industry limitations caused by educational, technical, and political obstacles need to be addressed. Further investigation into the future potential of hemp markets revealed that only niche markets are viable in the near future. More market opportunities exist for the mid and long term future of the industry, especially for value added products. Recommendations include addressing the social stigma, and research efforts aimed at improving farm gate profitability through breeding and technological improvements. If the recommendations are applied and effectively used to reduce the industry's obstacles, the economic outlook for the industry will substantially improve, especially if bioregional economics is employed. This study has shown that industrial hemp can play an important role in sustainable agriculture - environmentally, socially and ultimately economically.

Key words: industrial hemp, Cannabis sativa L., hemp seed, sustainable agriculture, system analysis

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Abbreviations and Acronyms

AAFC – Agriculture and Agri-Foods Canada
ANZFA – Australia New Zealand Food Authority
CBD – Cannabinidol
CBN – Cannabinol
CIS – Commonwealth of Independent States (formerly the Former Soviet Union)
CLD – Casual Loop Diagram
CSA – Controlled Substance Act
DEA – Drug Enforcement Administration (of the USA)
DoJ – Department of Justice (of Canada)
DPR – Democratic People's Republic (of Korea)
DWI – Drug Watch International
E(E)C – European (Economic) Community
EF – Ecological Footprint
EFA – Essential Fatty Acids
FAO – Food and Agriculture Organization (of the UN)
GAP – Good Agricultural Practice
LCA – Life Cycle Assessment/Analysis
NAFTA – North American Free Trade Agreement
NGO – Non-Governmental Organization
ONDCP – Office of National Drug Control Policy (of the USA)
PUFA – Polyunsaturated Fatty Acids
THC – Δ^9-Tetrahydrocannabinol
USD – American dollars ($)
VRI – Vavilov Research Institute
WEA – World Energy Assessment

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1.0 Introduction

Industrial hemp is an interesting and unique crop with a vivid history spanning centuries. However, the hemp plant has been faced with controversy in the last 70 years. The industry is experiencing restrictions that are thought to be imposed by the current social, economic and political atmosphere surrounding key stakeholders, rather than any technical inferiority. Education regarding this subject seems inadequate and appears restricted to those who actively research the topic themselves. As a fiber and oilseed crop, hemp offers agricultural potential as well as the ability to be manufactured into valuable end uses. Possibilities exist for expanded growth in hemp markets and a closer look should be taken to reexamine the current situation and highlight the future of the industry.

Industrial hemp has been identified as a renewable resource and the following accumulation of events have made more careful consideration necessary. Firstly, unsustainable agriculture, associated with high input-high impact crops is a global problem (van der Werf, 2004). Secondly, the use of non-renewable resources has been linked with global climate change and a reduction in both water and air quality (WEA 2000; Harris, 2002). Furthermore, growing populations and ever increasing resource demand makes the depletion of non-renewable resources inevitable considering our current dependence (Harris, 2002). Thirdly, there exists a need and demand for industrial non-food crops, especially fiber crops, due to an overproduction of food in the developed world (Roulac, 1997; Harris, 2002; Wötzel *et al*., 1999; Ranalli & Venturi, 2004). Fourthly, natural health foods and products, although currently a small industry, are receiving more attention and gaining popularity (Lachenmeier & Walch, 2005).

As a renewable resource, industrial hemp, seems to address these demands, and is believed to be a crop that can contribute to sustainability (Roulac, 1997; Alden *et al*., 1998, Ranalli & Venturi, 2004). Critics claim that hemp is nothing but a means to legitimize narcotic use and refute its contribution to sustainability (DWI, 2002). Sustainability is based on three main aspects, namely environmental, social and economic considerations. In relation to sustainable development, hemp contributes most significantly to sustainable agriculture which will be expanded upon in the following chapter on theoretical framework.

Following the framework, materials and methodology are presented in Chapter 3. Chapter 4 includes essential background information on hemp and the derived products. This background section is unconventionally long but nevertheless justified based on the fact that the author has perceived a general lack of knowledge on the issue, both prior to and during the research phase. In addition, little of the literature provided a comprehensive background. If the reader is familiar with industrial hemp these sections may be skipped in order to proceed to the main body of the report. Chapter 5 comprises of information from hemp growing countries around the world. A global outlook was taken as the hemp industry is in varying stages of growth, geographically. Chapter 6 evaluates hemp's contribution to sustainable agriculture and is the heart of the report including three major sections of sustainability, current industry restrictions and synthesis. The synthesis is perhaps the most important section in this chapter including systems thinking, time perspective, market projections, consideration of developing countries role and finally recommendations. Chapter 7 summarizes with conclusions.

1.1 Limitations and Scope

Limitations and boundaries of scope should also be mentioned. First of all, although referred to in terms of politics and education, marijuana[1] is not the subject of this study and issues surrounding its legalization in any way, even for medicinal purposes will not be addressed. This issue is beyond the scope of this paper and the confusion between the two is one of the motivational reasons for the selection of this topic. Secondly, despite hemp's Asian roots and current production in many developing countries, the majority of the modern hemp research and markets lie within developed countries. Therefore, another limitation of this study lies in the fact that most of the literature is built upon research conducted in developed countries. Thirdly, this study focuses on hemp's contribution to sustainable agriculture although sustainable processing, manufacturing and retailing efforts must also be considered in relation to sustainable development; these topics are only briefly mentioned and not investigated further. Lastly, the 'hemp industry' will be focused on the bioproduct sector[2] as well as the natural food and product industry.

1.2 Research Objectives

The aim of this research is to present a comprehensive foundation in order to critically and holistically evaluate the hemp industry and its contribution to sustainable agriculture. Specific research questions to be answered include:

1.) Does industrial hemp align with sustainable agriculture systems? If so, how?
2.) What are the variables limiting industry growth? What are their interactions?
3.) What are the future market potentials of the hemp industry?
4.) What recommendations can be made that will ensure future market growth?

2.0 Theoretical Framework

The debate over whether hemp is a viable alternative crop or not is often fueled by controversy and strong pro- and anti-hemp beliefs. Those for an expansion of the hemp industry claim its ability to measure up to sustainable agricultural requirements. While those against typically dismiss the idea on the grounds of a connection with marijuana and therefore a drug-culture. The framework that will be used herein is that of sustainable agriculture.

Harris (2002) has defined sustainable agriculture as follows, "systems of agricultural production that do not deplete the productivity of the land or environmental quality, including such techniques as integrated pest management, organic techniques and multiple cropping" (p.454). It should be added that sustainable agriculture includes more than only the environmental aspects, but also the up- and downstream economic aspects of farming communities and the social aspects of farmer's livelihoods and other stakeholders involved in the processing, manufacturing, distribution and retailing of hemp derived products.

3.0 Materials and Methodology

The methodology used throughout this study is twofold; first a literature review will be used to gather background information and material on the industry and second, system analysis theory will be applied to the industry and the important interactions presented. The combination of these methodologies is used to answer the research questions. The methodology is justified based on the fact that the hemp industry is immature and therefore

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[1] Throughout this paper the term marijuana (or marihuana) will refer to the psychoactive variety (containing high levels of THC) of *Cannabis sativa* L.

[2] A bioproduct can include cereals, farmed fish and paper; however, in this context modern industrial bioproducts are refer to innovative uses of new or waste biomass for renewable product manufacture.

has few resources, yet its globally distribution and variety of sectoral interests prove to complicate matters.

During the literature review it became apparent that peer reviewed scientific and academic work in this area is limited due to a number of reasons, but generally because of the current small scale of the hemp industry. Much of the literature focused on specific products, markets or properties and did not provide enough of the background information that is necessary for a thorough understanding of the issues. Therefore, the materials utilized combined peer reviewed scientific literature, government resources, non-governmental organization (NGO) authored research, and media sources. The language barrier also poised problem when looking at the industry from a global perspective.

Overall, there was a lack in quantity of interdisciplinary peer reviewed academic information on the hemp industry, readily available in English. According to Walker (1994) "most of the contemporary research on the subject of hemp cultivation is reported in Romanian, Bulgarian, and Russian" (p.83). It was also discovered that a good deal of literature is available in German, Dutch and French but unfortunately has not been translated. The vast majority of publicly available hemp information does not come from the scientific community and unfortunately, for the hemp industry, may be in part based on unsubstantiated claims or facts taken out of context regarding the abilities of the crop. This is an issue which seems to have permeated the industry and affected some key stakeholders. In addition, it was noticed that some facts used to base arguments upon were in disagreement between different sources. This can partially be attributed to the climate and gene-dependant nature of agricultural crops. In these cases data was verified from as many references as possible, and returning to the original source, when available, to extract the intended meaning within the context given. In addition, it appears as though University libraries (based on the author's own experience) do not carry much scientific literature on this topic; however, this may be location dependant (i.e. not much hemp cultivation in Scandinavia). That said it should also be noted that most modern hemp research is ongoing with University collaboration, specific to regions where hemp has or is being cultivated. Due to more recent government and agricultural interests, the volume of hemp research is rapidly growing.

System thinking is an interdisciplinary approach that is used by numerous industries, academia, NGOs and government institutions to improve problem understanding and solving. System thinking consists of system analysis and system dynamics (Haraldsson, 2004). System analysis is qualitative in nature and uses systematic and holistic thinking to organize complex relationships between factors in any given situation or problem to present a mental model (Haraldsson, 2004). System dynamics, on the other hand, is a qualitative approach that uses mathematical relationships to assign value or equations to the variables within a system (Haraldsson, 2004). In system dynamics, software models are typically used to make changes to one variable and observe the subsequent reaction in other variables.

Qualitative data on the hemp industry is highly variable and dependent strongly on agronomic conditions, as well as political, social and economic climates in any one location, therefore system dynamics is not a suitable concept for this study, which provides a global perspective. Therefore, the current study will use system analysis to establish the interrelations between the actors and factors in the hemp industry. The mental model of the industry will be presented through the use of a transparent casual loop diagram (CLD) which is a method or tool used to explain the builder's logic to the reader (Haraldsson, 2004). Applying system analysis methodology to industrial hemp will aid in determining the most important stakeholders and variables contributing to the limitation or expansion of the industry.

4.0 Background

The following five sections provide background information on the hemp industry vital for understanding this plant and giving information necessary to determine whether hemp can fit into sustainable agricultural systems. Sections on hemp history, taxonomy and botany, agronomy, potential product lines as well as competing products are included in this chapter.

4.1 Hemp History

Hemp is known throughout the world and has been cultivated for thousands of years. There are many pseudonyms for hemp, throughout history and in different languages. Hemp is a term that has also been used casually to describe other fiber plants such as Manila hemp (abaca) and Sunn hemp; however they are not true hemp. This can and has lead to confusion both within and outside the academic community. This section will outline the historical relationship that humans have had with hemp otherwise known by its Latin name, *Cannabis sativa* L.

Throughout history *Homo sapiens* depended on plant resources for the manufacturing of many useful products. Hemp is a prime example as Clarke (1999a) states, “[p]rior to 1000 B.C. until the late 1800’s, *Cannabis* was used to produce myriad necessities such as cordage, cloth, food, lighting oil, and medicine and was one of the most widely cultivated plants” (p.7-8). *Cannabis sativa* L. cultivation for ropes and fishnets is believed to have originated in China as early as 4000 B.C., according to Clarke and Lu (1995). Hemp was cultivated for centuries in China before its agricultural use was spread outside its borders in the 3rd century B.C. (Roulac, 1997). Figure 1 shows the Chinese character for hemp or ‘*ma*’, which depicts the male and female plants in a shed used for drying purposes (Roulac, 1997).

Figure 1. Chinese Character for Hemp (Roulac, 1997)

The art of paper making originated in China and one of the main raw materials was recycled hemp fiber (Roulac, 1997). In addition, the ancient Chinese considered hemp seeds to be one of the five major grains (Iverson, 2000). Hemp became important in many East and South East Asian religions where it was considered a symbol of purity and fertility (Roulac, 1997). This religious association can be further illustrated by the legend of Buddha, which claims that Siddhartha ate only hemp seeds for 6 years before announcing his truths and becoming Buddha in 5th century B.C. (Herer, 2000; Iverson, 2000).

As with other Asian commodities like spices, hemp came to Europe along traditional trade routes (Roulac, 1997). One of the oldest examples of hemp textiles in Europe was found around 400 B.C. in Germany (Roulac, 1997). At this time hemp was cultivated in central Europe and was spreading. The Spanish Moors introduced Europe to the art of hemp papermaking by building the first European paper mill in 1150 B.C. (Roulac, 1997). The next 500 years in Europe were a period where paper making was perfected and utilized hemp as the main source of raw material. Renaissance paintings were painted on hemp cannabis (hence the term canvas) and hemp oil based paints were often used (Roulac, 1997).

The 16th to 18th centuries saw hemp and flax dominate fiber crops in Asia, Europe, and North America. At this point in time, hemp was used, almost universally, for ship sails and ropes. It was a highly valuable and necessary material for the shipping/trading industry, colonizing the new world, as well as for military purposes (Roulac, 1997). By the 20th century advances in technology, such as the steam and petroleum fueled engines, made the largest demand for hemp, in shipping, decline. Hemp remained a labour intensive crop, due in large part to the dew retting procedure and lack of a mechanized method for harvesting (Roulac, 1997). Hemp became unable to compete economically with cotton, due to the invention of the cotton gin (Roulac, 1997) until which point in time, hemp had been the most common textile fiber (Clarke, 1997).

With a decline of hemp farming in North America in the beginning of the 20th century, manufacturing and textile importers became dependent on cheap Russian hemp. Imports from Russia were no longer possible during World War I and the American demand for supplies required domestic hemp cultivation to double every year from 1914 to 1917. In the post war period, the demand for supplies declined and therefore the importation of cheap hemp resumed its course. (Roulac, 1997)

In 1916, a hemp decorticator (for fiber separating) was invented, making long and short fiber separation much faster than by hand alone (Roulac, 1997). Even so, wood pulp was becoming increasingly favoured. Various conspiracy theories about this time in hemp's history have recently surfaced (e.g. Herer, 2000), although none of which has been verified. The 1930's saw a reappearance of the hemp industry in the USA with more farmers using decortication machines. The concept of chemurgy also became popular at this time and was supported by Henry Ford and Thomas Edison (Roulac, 1997). Chemurgy combined chemistry and agriculture and was based on the idea that any product "that can be made from a hydrocarbon can be made from a carbohydrate" (Roulac, 1997, p.41). Henry Ford was determined that agriculture could support modern industries and in 1941 he attempted to prove this by constructing a biocomposite automobile including hemp fibers (Roulac, 1997).

In 1937, the American government passed the Marihuana Tax Act which outlawed and criminalized marijuana, the variety of *Cannabis sativa L.*, which is high in the psychoactive ingredient Δ^9-tetrahydrocannabinol (THC) (Roulac, 1997). Hemp was associated with marijuana and its cultivation eventually fell under the US Drug Enforcement Administration (DEA) (Roulac, 1997). It was technically not illegal to grow hemp under the new tax act but it did require a license from the DEA and the red tape surrounding its cultivation became so cumbersome that most farmers stopped growing it (Roulac, 1997). Canada quickly followed the American lead and outlawed *Cannabis sativa* L. in its 1938 Opium and Narcotics Control Act (Blade *et al.*, 1999). According to Wool and Khot (2001), the US DEA stopped granting hemp licenses in 1958. Many European and colonial nations also made hemp cultivation illegal after World War II (Merfield, 1999).

In more recent history, the prohibition surrounding hemp cultivation has been lifted in all developed nations save the USA. There does remain, however, a ban on the consumption of hemp food products in New Zealand and Australia. Again, due to marijuana association, hemp seems to have been put under prohibition recently in the southern Chinese province of Yunnan (Clarke, 1999b). It appears that two major reasons are behind the elimination of hemp prohibition in developed countries. The first is environmentally driven, fueled by unsustainable agricultural practices, non-renewable resource use and depletion resulting in a renewed interest in renewable resources. The general knowledge of environmental issues has been growing since the 1972 UN Conference in Stockholm on the Human Environment and furthered by the Earth Summit in Rio de Janeiro in 1992. The second reason lies in agricultural demand. Food crop prices in Europe have been falling along with subsidies due to an over production of food (Wötzel *et al.*, 1999; Harris, 2002; Ranalli & Venturi, 2004). The need for alternate sources of fiber is also becoming apparent (Roulac, 1997, Kamat *et al.*, 2002, Ranalli & Venturi, 2004). As well the demand for natural products has grown in developed countries alongside ecological agriculture initiatives. This cumulates in farmers searching for viable alternative crops that can be used in combination with crops for rotational purposes. Preliminary hemp research by Du Bois[3] in 1982 and Herer's original

[3] The original reference is in Dutch, and according to van der Werf (1995a), Du Bois claimed the benefits of hemp and proposed hemp as a valuable raw material for the paper industry.

edition of the 'Emperor Wears No Clothes' in 1985 made great claims on hemps' usefulness and brought further attention to the crop (van der Werf, 1995a).

4.2 Taxonomy and Botany

This section will present the taxonomical and botanical information on *Cannabis sativa* L. The physical characteristics and life cycle of the plant will be included as well as modern breeding information. The main cannabinoids or carbon alkaloids, found in differing quantities in *Cannabis sativa*, will be introduced and their physical and chemical properties mentioned.

In 1753, the famous Swedish botanist and father of taxonomy, Carl Linnaeus[4] recognized and named the species *Cannabis sativa (C.sativa)* meaning cultivated as a crop, in his principle work on the classification of living things, *Systema Naturae* (Matthews, 1999; Iverson, 2000). The official taxonomy used today is *Cannabis sativa* L., where the L refers to Linnaeus himself. The genus, *Cannabis* is a member of the Cannabaceae family along with hops (Roulac, 1997; Clarke, 1999a). According to Clarke (1999a), in modern science the assignment of *Cannabis* species remains unclear among botanists, which is further compounded by semantics and legalities. After a numerical taxonomic analysis involving over 2,000 individual plants, Small *et al*. (1976) claims that all *Cannabis* plants belong to the species *sativa*. However, more recently, it seems generally accepted that the genus *Cannabis* includes three species known as *Cannabis sativa*, *Cannabis indica* and *Cannabis ruderalis* (Clarke, 1999a; Matthews, 1999). The species most suited for fiber production is *Cannabis sativa* L. or industrial hemp.

A decimal code for hemp was described by Mediavilla *et al.* (1998) which divided the life cycle of hemp into 4 main growth stages. The first stage consists of germination and emergence. The second stage is vegetation, in which most of the plants growth (or height) takes place. The third stage involves both flowering and seed formation. The last or fourth stage is senescence in which the leaves drop and stem dries out. (Mediavilla *et al.*, 1998)

The first stage of germination and emergence can take place in under a week for hemp cultivars sown outdoors in early spring provided the right conditions are present (Clarke, 1999a). During the second or vegetation stage the plants can reach heights of up to 5 m in 4 - 6 months (Clarke, 1999a) under optimal conditions. During the longest days of summer with favourable conditions the plant can grow up to 10 cm/day (Clarke, 1999a). However, for temperate climates average heights are around 2 m. The stock can be from 4 to 20 mm in diameter (Lewin & Pearce, 1998). During the growth stage the stock grows straight up with a pair of opposing leaves at each node or leaf branch (Clarke, 1997).

The beginning of the third growth stage is indicated by the leaflets changing from opposing to alternate position and the sexual organs start to emerge (Mediavilla *et al*., 1998). Most often, *Cannabis sativa* L., appears as a dioecious plant, meaning the male and female reproductive structures grow on separate plants (Clarke, 1997). Figure 2 shows an illustration of *Cannabis sativa* L. by Elmer Smith[5] (as cited in Small & Marcus, 2002). The numbers on the picture bear the following descriptions as provided by Small and Marcus (2002) "1. Flowering branch of male plant. 2. Flowering branch of female plant. 3. Seedling. 4. Leaflet. 5. Cluster of male flowers. 6. Female flower, enclosed by perigonal bract. 7. Mature fruit enclosed in perigonal bract. 8. Seed (achene), showing wide face. 9. Seed, showing narrow face. 10. Stalked secretory gland. 11. Top of sessile secretory gland. 12. Long section of cystolith hair (note calcium carbonate concretion at base)" (p.287).

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[4] Also known as Carolus Linnaeous and after 1761 was granted nobility and henceforth became known as Carl von Linné.

[5] Year not given.

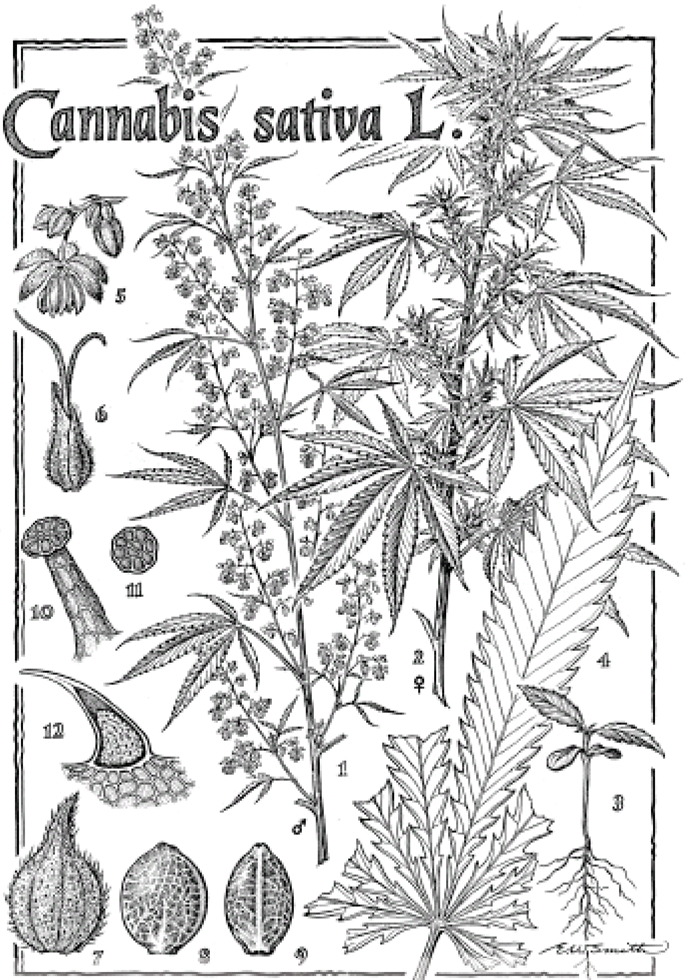

Figure 2. Illustration by E. Smith depicting the Dioecious *Cannabis sativa* L. Plant and Reproductive Structures (as cited in Small & Marcus, 2002)

Sex expression may be difficult to determine in dioecious cultivars but according to Clarke (1997) it is typical that the male staminate flowers appear 14 days before the female inflorescences flower (as cited in Mediavilla *et al*., 1998). *Cannabis sativa* L. is anemophilous, which means that the female flowers are fertilized from wind blown male pollen (Clarke, 1999a). After fertilization, the female plants develop seed which matures after 3 to 6 weeks (Clarke, 1999a). The seeds can weigh 3 -60 grams depending in the variety and growing conditions (Clarke, 1999a).

The fourth and last growth stage occurs at different times for depending on the sex and if fertilization has occurred. The male plants begin senescence after the pollen is shed. Whereas the female plants mature for another 3 - 6 weeks if fertilized or 5 months if unfertilized before senescence begins. During this last stage, the leaves fall off first, then the stem starts to dry. Frost in some temperate areas can initiate bast fiber separation from the core (Mediavilla *et al*., 1998).

The above information presented has described the dioecious state for *C.sativa* L., however, monoecious cultivars are more common in for modern industrial hemp cultivation. European breeding programs, have selected monoecious cultivars (Blade *et al*., 1999) to contain a higher ratio of female than male flowers on the same plant. The theory is to reduce the sexual dimorphism of the crop in order to optimize the growth and production of the economically valuable female plants. The female plants produce the seed which matures after the male plants have already entered the fourth growth stage or senescence leading to a loss of male fiber. Most of the monoecious breeding programs have taken place in France and Eastern Europe therefore they have lead to a gene pool of *Cannabis sativa* L. varieties that have been bred specifically for European conditions (especially French cultivars) and may not produce the same expected crop yield elsewhere (Clarke, 1999a).

In addition to the widely discussed psychoactive ingredient, THC; cannabis plants contain at least 66 known cannabinoids (Pertwee, 20004; Lachenmeier & Walch, 2005). These compounds are a group of terpenophenolic (oxygen containing aromatic hydrocarbon) compounds and are unique to the cannabis plant (Lachenmeier *et al*., 2004; Pertwee, 2004). The highest concentration of cannabinoids is found in the *Cannabis* resin, secreted by the epidermal secretory glands (Small & Marcus, 2003); but cannabinoids can be found in all plant parts except for the seeds (Lachenmeier & Walch, 2005). Other than THC, the main cannabinoids in *Cannabis sativa* L. are cannabidiol (CBD) and cannabinol (CBN) (Lachenmeier *et al*., 2004). CBD is also known as being an anti-psychoactive ingredient because it moderates the effect that THC has (Roulac, 1997; Pertwee, 2004). Figure 3 shows the chemical structure of the three main cannabinoids present in *Cannabis sativa* L. (Lachenmeier *et al.*, 2004).

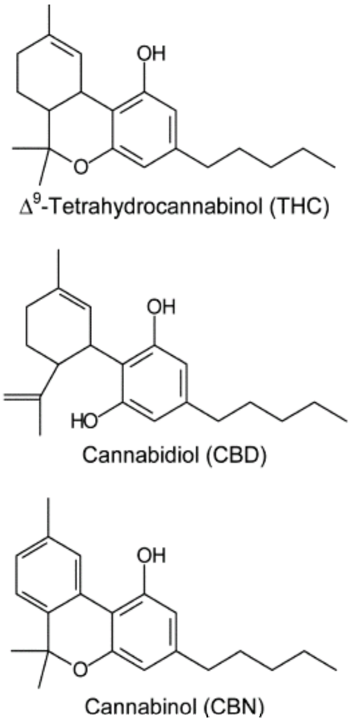

Figure 3: Chemical structures of the main cannabinoids in *C.sativa* L. (Lachenmeier *et al.*, 2004)

From the ratio of these particular cannabinoids, one can determine what phenotype the plant is (Lachenmeier *et al.*, 2004). Fetterman *et al.* (1971) provided the formula for such determination, given by Equation (1) which is known as the *Cannabis*-phenotype-ratio (as cited in Lachenmeier *et al.,* 2004). A phenotype value greater than 1 indicated the plant is grown or bred for marijuana or high THC content (Lachenmeier *et al.*, 2004) which is usually in the range of 5 to 20 % (Lachenmeier & Walch, 2005). On the other hand a phenotype less than or equal to 1, indicates that the plant is of low THC variety (i.e. hemp) and has typically less than 1% THC (Lachenmeier *et al.*, 2004). In addition to breeding programs for monoecious cultivars, low THC varieties have also been the target of European (mostly French) breeding programs. The development of THC free cultivars has been claimed by some breeders but has yet to be truly reached (de Meijer, 1995; Small & Marcus, 2003).

$$Phenotype \cdot ratio = \frac{(THC + CBN)}{(CBD)} \tag{1}$$

The reason for the secretion of THC in the resin is not completely clear but at least one plausible theory has been identified in literature. Rothschild *et al.* (1977) suggested that THC was a natural insecticide, hence why *Cannabis sativa* L. is pest tolerant (as cited in McPartland, 1996a). This theory can also be supported by the fact that *C.sativa* leaves either whole or as a sprayable concoction, have been used as a natural insecticide throughout India (as cited in McPartland, 1996a).

4.3 Agronomy

Agronomy is the branch of agriculture dealing with field crop production and soil management. Therefore, this section is broken into subsections discussing the climate, soil conditions, pests and diseases, cultivation practices, harvesting technology and expected yield for industrial hemp crops. Taking the following factors into consideration it should be noted that hemp's agronomic qualities vary from site to site and that they are contingent upon specific environmental conditions (de Meijer, 1995). Furthermore, the genotype-environment-crop management interactions are very important and successful hemp cultivation relies on an optimal balance between these factors (Struik *et al.*, 2000).

4.3.1 Climate: Sunshine and Temperature

Cannabis sativa L. is herbaceous annual plant that requires sufficient sunshine during the first and second growth stages (Clarke, 1999a). However, in order to encourage the transition to the third growth stage of flowering, hemp requires less sunlight each day because it is a short day photoperiodic plant (Ranalli, 2004). The flowering date will affect the harvest yield and is dependant upon both latitude and cultivar (van der Werf *et al.*, 1995a). In terms of the climate types that hemp flourishes in, Matthews (1999) declares that industrial hemp is more suited for growing in temperate regions. Clarke (1999a) concurs and states that, "[n]o hemp fiber or seed cultivars exist for subtropical or tropical regions" (p.1). This may be a consequence of the European breeding programs, which focused on breeding hemp varieties for northern latitudes and temperate climates. The majority of the current hemp gene pool stems from European and Russian efforts and therefore, the climatic suitability may only be due to a lack of suitable genes. This issue has been raised by Ditchfield *et al.* (1999) who have investigated tropical and sub-tropical hemp cultivars for cultivation in Australia in order to improve yields.

According to Ceapoiu (1958), the optimal germination temperature is 24^{o}C (as cited in Mediavilla *et al*., 1998), furthermore, van der Werf *et al*. (1995) find that germination can occur at temperatures as low as 0^{o}C (as cited in Mediavilla *et al*., 1998). Plants in the second growth stage can manage -5^{o}C for short periods of time but cold temperatures will severely reduce crop height (Merfield, 1999). Growing degree days (GDD) is a measure of the heat required for a crop to reach a certain point in its life cycle (usually the optimal harvest time) and is useful in comparing different crops (Merfield, 1999). After only 400 GDD, hemp crops will show full ground cover[6] (Struik *et al*., 2000). In southern Europe approximately 2,000 GDD are required for fiber production and an extra 1,000 GDD for seed production (Merfield, 1999). It has been suggested that more than one fiber harvest per season is possible in some temperate regions (Kamat et al., 2002). On the other hand, some northern regions do not have adequately warm or long enough summers to reach the required GDD for seed production (Merfield, 1999).

4.3.2 Soil Conditions: Nutrients and Moisture

Hemp requires moist, nutrient rich and well drained soil conditions for optimum growth (Clarke, 1999a). Hemp is very sensitive to poor soil structure (Struik *et al*., 2000) and therefore usually requires agricultural quality land for optimal growth and production. Insufficient or abundance of water can be fatal to hemp seedlings, as has been observed by Struik *et al*. (2000) in European agronomic experiments.

The three most critical nutrients for high hemp production are nitrogen, potassium and phosphorus. van der Werf (2004) has defined the Good Agricultural Practice (GAP) techniques for successful fiber hemp crops, including the anticipation of fertilization needs[7]. According to GAP, hemp crops require 75 kg nitrogen (N), 38 kg triple super-phosphate (P_2O_5), and 113 kg potassium chloride (K_2O) per hectare in France (van der Werf, 2004).

Typically, biomass is returned to the soil during cultivation and after harvesting of hemp; which adds nutrients to the soil. Hemp crops grown for seed will require additional nutrients, due to later harvesting time. In either case, if hemp is grown in the same soil every season, the nutrients profile of the field will require replenishing. However, according to most available agronomic literature, industrial hemp is suggested as a key rotational crop (Ranalli, 2004; Roulac, 1997). This is based mostly on hemp's weed-break abilities but may also be due to improved soil conditions and therefore subsequent yields when used in combination with other, mostly food crops. Therefore, the nutrients profile of the soil under consideration requires attention every season and is dependant on soil type and the previous crop.

According to Bòsca and Karus (1998), the water requirements for fiber hemp range from 500-700 mm of rainwater per growing season in the UK (as cited in Cherrett *et al*., 2005). Lower water requirements of 250-400 mm were reported for Mediterranean regions (Ranalli & Venturi, 2004). The variability between the two can be attributed to differences in soil type, climate or cultivar. Hemp crops are also prone to water logging, and flooding will cause

[6] Compare this to sugar beets that require 600 GDD to reach full ground cover (Struik *et al*., 2000).
[7] In addition to fertilization requirements, the utilization of integrated pest management reduces the need for synthetic pesticides (van der Werf, 2004).

crop damage. No information was found to indicate how much water is required by hemp for seed or dual purpose crops but it can be assumed that more water is required than for fiber production due to longer growing season.

In case of a drought, hemp crops can draw from ground water sources, given good soil structure and established roots (Roulac, 1997). Still, if water is available, irrigation may be required in drier climates. Hemp fields irrigated in the early 20th century in California and Wisconsin saw a significant increase in yields (Roulac, 1997). Although beneficial to yields, irrigation adds costs and environmental concerns which must be considered.

4.3.3 Pests: Insects, Diseases and Weeds

Industrial hemp is often promoted as being 'pest' free by hemp advocates, however, there are up to 100 identified diseases (McPartland, 1996b) and almost 300 pests (McPartland, 1996a) that afflict the *Cannabis* plant. Although weeds competing for sunlight and nutrients can be a problem when growing sparsely sown hemp seed crops, this is rarely the case. Typically hemp for fiber or dual purpose hemp crops are sown at high densities and therefore tend to choke out competing weeds naturally, making herbicidal applications unnecessary.

McPartland (1996b) suggests that less than a dozen of the diseases, including gray mould and hemp canker, are a serious threat to the crop yield (McPartland, 1996b). Gray mould is the most serious as it causes stem injury and is problematic during rainy seasons (van der Werf *et al.,* 1995a). In agronomic research trials, van der Werf *et al.* (1995a) suggest that spraying fungicides is not a viable option for gray mould reduction because yields were barley improved and costs incurred. Abiotic diseases such as genetic mutations, nutrient deficiencies, and environmental stress due to monoculture cultivation can also become a source for disease and subsequent crop loss (McPartland, 1996b). Soil borne diseases or pathogens are also of concern for agriculture crops. In a 1994 study by Kok *et al*., it was found that fiber hemp was effective in suppressing two major Dutch soil pathogens. However, a third pathogen may remain a concern to hemp health (Kok *et al*., 1994).

Pests are organisms that damage plants, thereby reducing economic value. Few of the 300 described *Cannabis* pests are actually of concern for economic losses. Most of hemp's known pests are insects and the most destructive are the European corn borers and hemp borers (McPartland, 1996a). Some non-arthropods such as mollusks (slugs and snails), domestic and non-domestic mammals, and birds have become minor pests by devouring seedlings, flowering tops, or mature seeds, respectively (McPartland, 1996a). van der Werf (1996) has also noted a relatively new pest category, adolescent *Homo sapiens*, uneducated in the difference between *Cannabis sativa* L. phenotypes, have been reported to cause crop losses in some cases (as cited in McPartland, 1996a).

4.3.4 Cultivation Practices

Cultivation practices refer to the manner in which seeds are sown and product harvested. Depending on the desired product, seeds may be sown at different densities and crops harvested at different times during the growth stages. To illustrate the difference in the resulting crop, when different densities are sown, Figure 4 from Small and Marcus (2002) has been included. Both density and harvest timing are useful methods to observe the difference between hemp and marijuana. The density and harvesting times of hemp

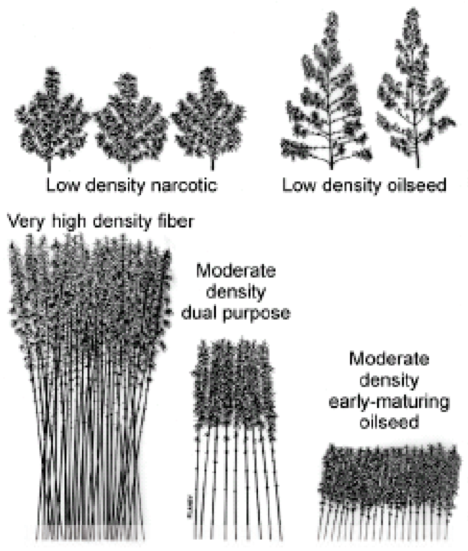

Figure 4. Different *Cannabis sativa* L. crop densities, depending on intended use (Small & Marcus, 2002)

cultivation will be described first, following that for marijuana.

For high fiber yield, it is desirable to sow the seeds in high density to produce tall, quick growing, straight stocks and full covering leaf canopies. In an attempt to optimize fiber quality and quantity, optimal sowing density lies between 90 - 250 plants/m^2, dependent on cultivar, fertilization and environmental conditions (van der Werf, 1995). At higher densities, quantitative yield is lost due to self-thinning from competition between individual plants as well as a qualitative reduction in bark content (van der Werf, 1995b). At lower densities the crop is shorter, grows slowly and may tend to branch which is an undesirable trait for maintaining high fiber quality. If fiber quality is not of concern then higher plant densities up to 500 plants/m^2 can be grown for increasing yields (Roulac, 1997). For maximum seed yield, plant density should be much lower than for fiber production (Pate, 1999), typically between 30 -70 plants/m^2.

A compromise has to be made, if the farmer wishes to use hemp as a dual purpose crop for harvesting both fiber and seed. A mid-density sowing rate should be picked, which optimizes fiber and seed production with the location, soil conditions, and *Cannabis* cultivar. This may shorten stock height and thereby reducing fiber quality, and lower seed yield, but it will reduce weeds inevitable if sown too sparsely. High quality fiber is not necessary when the fiber is used for building materials or biomass. There currently exists research into breeding monoecious varieties that can be optimized for both fiber and seed production from industrial hemp cultivars (Roulac, 1997; Clarke, 1999a).

Hemp oilseed crops are typically grown sparsely in order to promote branching and therefore seed formation. However, due to lack of appropriate cultivars this practice is restricted to few hemp farms, mostly in Canada.

When grown for high quality fiber, industrial hemp plants are harvested shortly after flowering, before the seeds have time to set which reduces fiber quality and quantity (Cherrett *et al*., 2005). This is especially important if the crop is dioecious, because the male plants will die after the pollen has been shed, leading to further fiber losses (Clarke, 1999a). When grown for seed production, hemp plants are harvested when the seeds are approximately 50% mature for optimal yield (Mediavilla *et al*., 1998). During seed harvesting only the upper portion of the stock is cut, where the seeds are located.

When the desired harvest is flowers from a high THC variety (marijuana), the plants are sown quite far apart, with as few as 1-2 plants/m^2 (Roulac, 1997). The reason for the low density of marijuana plants is so that the plants can branch out so that more female flowers can form and a higher yield will be harvested. Marijuana plants will tend to grow much shorter than hemp plants due to the low density and plant energy and resources put into branching and flower formation. Marijuana harvesting would occur about 6 weeks after hemp fiber has been harvested.

4.3.5 Harvesting Technology and Expected Yields

Traditionally, the harvesting of hemp relied on manual labour. Few if any technological developments were advanced during the mid 20th century, due almost entirely to prohibition in developed countries, save France. Recently, interest in reducing labour costs and increasing hemp areas under cultivation has lead to an interest in the development of hemp harvesting technology. Harvesting practices differ depending on harvesting intentions: for non-textile grade fiber, textile grade fiber, or dual purpose non-textile grade fiber and seeds.

In the case of hemp cultivated for non-textile grade fiber, the fiber quality is not of utmost concern. In addition, it is likely that the crop may be of a shorter stature if high quality fiber was not aimed for. Therefore, it is possible to use conventional combines provided the height is not too great as this will lead to difficulties with the rotational parts of the machinery.

The situation is more complex when high quality fiber is desired. Traditionally, the harvesting of textile grade hemp has relied on cheap manual labour in Eastern Europe and Asia where the majority of modern hemp fabrics hail from. This is due to the absence of any hemp specific harvesting machinery that take into account the larger biomass and height of the stocks. In order to maintain the high quality of hemp fibers the stalks cannot be bent or broken during the harvesting process without significant reduction in quality and therefore profit. Furthermore, due to the sparse quantity of hemp cultivation areas, the development of large machinery for this purpose hardly seems economically viable considering the current state of the hemp industry.

In the most likely case, where a dual harvest is desired, it is important to maintain high seed quality by harvesting the seed heads as gently as possible. It is also of interest to separate the products to ease subsequent processing. The current harvesting technique for dual crop products is to harvest the crops twice (Chen & Lui, 2003). The first harvest uses a conventional combine raised off the ground (up to 1 m) to cut the seed heads off. The second harvest uses a more robust tractor to swath the stalks. This is an energy intensive method and results in both qualitative and quantitative crop losses.

The combination of the above mentioned issues, especially for dual crop harvesting has lead Chen & Lui (2003) to develop a dual purpose windrower. A windrower is a machine used to form the windrows or rows of the cut crop. Chen & Lui (2003) use a modified, "conventional self-propelled windrower" (p. 2.2) that is adapted for the formation of separate windrows; one for the seed heeds and the other for the hemp stalks. To reduce the need for more machinery, the adapted header can be removed in order to use this harvester for more traditional crops.

Expected yields from these harvesting techniques vary according to the agronomic conditions as described earlier. However, average values and ranges can be given. According to van der Werf (2004) the average French hemp crop production is 6.7 t/ha of dry matter. Furthermore, van der Werf et al. (1995a) states that under European growing conditions and cultivars, yields do not normally surpass 8.0 - 10.0 t/ha of dry matter. If cultivated strictly for seed production, hemp can yield from 0.5 - 1.0 t/ha of hemp seed (Pate, 1999). Up to 2.0 t/ha has been reported from a Finish variety specifically adapted for seed production in northern climes (Callaway, 2004).

4.4 Hemp Products

The variety of applications for hemp as raw material is seemingly endless, according to most hemp advocates. However, hemp is not and will not always be the best material of choice for many products. There are some niche areas where hemp products have been successful. New applications for hemp as a raw material are constantly being researched, tested and developed. Different components of the hemp plant need to be processed and manufactured according to intended product specifications. Hemp fiber, seed, and oil can be used as raw materials for products whose categories include food, fuel, fiber and medicine. This section will highlight the variety of hemp product lines.

4.4.1 Hemp Fiber: Primary Processing and Products

Either dew or water retting is a post harvesting process, lasting 1-6 weeks, where either natural bacteria or chemicals, respectively, are used to break down the fiber binding pectin's which separate the bast fibers from the inner hurds (Cherrett *et al*., 2005). Dew retting is a more time and labour consuming process where the windrows are let to 'rot' in the field and require regular turning for even retting. Dew retting is a traditional process that is more labour intensive than water retting. Water retting is faster yet a more resource intensive process which requires large ponds or pools of fresh water and chemical treatments to sped up the process. After the water retting process is complete the waste water needs to be treated and disposed of which can be costly.

Approximately 30 % of the stock is bast fibers which consist of 25 % long fibers and 75 % medium fibers. The remaining 70 % consists of short core fibers or hurds. Long fibers are also referred to as the long line fibers, outer stock or bark. Both the long, strong bast fibers and medium fibers or tow have anti-mildew and anti-microbial properties. The short core fibers are also known as hurds or shives which are highly absorbent. (Roulac, 1997)

Paper Products

Hemp paper production uses the bast fibers to manufacture value added paper products such as bank notes, specialty papers such as cigarette papers, and thin book paper such as bibles (Roulac, 1997). This is due to the low lignin content of these fibers, which requires less processing (Roulac, 1997). However, removing lignin from hemp has not been perfected for large scale operations (Rosenthal, 1994). Like other non-wood pulping processes, the manufacturing of hemp paper, uses modified conventional wood pulping processes. Research into the use of the whole hemp stock is underway in order to reduce processing and improve the economics for using hemp as a source of pulp. Although not typically done on a large scale, other less specialized hemp paper products such as printing paper[8], technical filter paper, newspaper, cardboard and packaging materials are also produced (Roulac, 1997).

Textiles

After the retting process, the stems go through two more processes: breaking and scotching where the stocks are broken and beaten respectively, to further remove the fibers from the core (Cherrett *et al.*, 2005). Hackling or combing, roving and spinning of the subsequently produced hemp fibers are the final processes before textile manufacture can begin (Cherrett *et al*., 2005). These are the same processes that flax goes through during linen production. In general there are two qualities of hemp textiles that can be manufactured. High quality fine fibers are required in textiles such as clothing, diapers, fabrics, apparel, working uniforms, denim, socks, shoes, lace, and handbags (Roulac, 1997). Whereas technical textiles such as twine, rope, nets, canvas bags, tarps, carpets, and geo-textiles can be manufactured with lower quality hemp (Roulac, 1997). Due to anti-mildew and anti-microbial properties medium fibers or tow, are useful in non-woven textiles such as medical and hygiene products (Roulac, 1997).

Biocomposites

Hemp biocomposites use fibers for added reinforcement, light weight, and shatter resistance or flexibility. The fibers used usually tend to be the short core fibers or hurds as they are abundant, however low quality bast fibers (or whole plant) can also be used, if chopped. Hemp biocomposites include building and construction materials as well as plastics; either as a composite natural fiber, hemp cellulose plastic composites or hemp plastic resin. As composite material, hemp can replace fiber glass, wood particles/chips, or other natural fibers such as flax. In this situation, the quality of the fibers is not as important as it is for textiles. (Roulac, 1997)

Hemp building materials include non-structural fiberboard, insulation, fiberglass replacement, cement blocks, stucco and mortar (Roulac, 1997). To make concrete blocks, hemp hurds are mixed with lime (Roulac, 1997). France even has a few hemp building

[8] All attempts were made to obtain hemp paper for the printing of this study; however, none was available in Skåne, Sweden. This is attributed to a lack of hemp pulp and paper mills in this region of Europe.

companies that manufacture insulation and construction material that can be used to construct entire hempen homes (Rosenthal, 1994; Roulac, 1997).

As a biofiber additive to plastics, hemp replaces fiber glass, allowing for more flexibility (flexural strength) in the finished product (Pervaiz & Sain, 2003). The most common use of this product lies in the automotive industry where biocomposites can be used in car parts such as parcel shelves, door and instrument panels, arm and head rests, and seat shells (Wool & Khot 2001). However hemp fibers have also been used in recreation and sporting goods such as snowboards, skis, and canoes.

When used as composite in a biopolymer matrix, derived from soy beans (or maybe even hemp oil!), the bioplastic product (biocomposite and biopolymer combined) offers advantages such as biodegradability, lightweight and reduced energy intensity for similar strength requirements (Wibowo *et al.*, 2004). Hemp cellulose from the hurds can, and in fact historically was, used to manufacture cellophane (Roulac, 1997).

Animal bedding

One of the most common uses for hemp hurds in Europe right now is for animal bedding. This is due to the high absorbency rates of these fibers (Roulac, 1997) and has been used in race horse stables and increasingly for smaller animals such as cats, rabbits, mice, hamsters and even birds (Karus, 2005).

Biomass: Fuel, Heat and Electricity

Whole plat hemp, low quality fibers, or hurds alone can be used as biomass for energy applications to provide heat, electricity or as fuel (Small & Marcus, 2002). The direct combustion of hemp biomass (in pellet form) can be used to generate heat in conventional wood stoves in residential areas. An example from Sweden is presented in section 5.1.1 which describes using hemp for an energy crop in this manner. This method of utilizing hemp as an energy crop can be done on a larger scale, if the biomass is converted into charcoal, for the production of 'green' electricity from generating stations. This could be used to supplement coal combustion in what is known as co-generation which is currently done with forestry and agriculture by-products. However, the scale of the industry and value added uses for hemp fibers, does not allow for this type of usage at this point in time. Other methods include fermentation, pyrolysis or destructive distillation to process biomass and produce methanol, ethanol or gasoline (Small & Marcus, 2002).

4.4.2 Hemp Seeds: Whole and Meal, Processing and Products

The majority of the seed uses end up in the edible arena but there are some alternative industrial uses for hemp oil, derived from the seeds, which will be addressed in the following section. Technically hemp seeds or grains are nuts (Callaway, 2004). The only processing that is required for hemp seeds is thorough cleaning to remove any contaminants, particularly THC residue, from the outer shell. In some cases the seeds are also hulled and/or crushed. Hemp meal or cake is what remains after the seeds have been cold pressed for oil extraction. Hemp seed products consist of foodstuffs such as roasted seeds, raw seeds, cereals, muesli bars, chocolate, lemonade, beer, wine and flour (Lachenmeier *et al*., 2004). Hemp tea is also considered a hemp food product but it is made from the leaves not from the seed (Lachenmeier & Walch, 2005), this topic will be revisited in section 6.2.2.

The nutritional value of hemp seeds is based on protein content of the nut and essential fatty acid profile of hemp oil. Hemp seeds are the second highest source of protein in the plant kingdom at 25 %, with soybeans coming in first at 32 % (Callaway, 2004). The protein from hemp seeds contains levels of 8 essential amino acids that are nutritionally vital and comparable to egg white and soy bean profiles (Callaway, 2004). Hemp seeds are as versatile as the soybean (in terms of food product diversity) but easier to digest by humans (Roulac, 1997). Hemp oil has the highest proportion of polyunsaturated fatty acids (PUFAs) in addition to the most complete and balanced essential fatty acid (EFA) profile known in the plant kingdom (Callaway, 2004; Lachenmeier & Walch, 2005). Hemp seeds also contain important vitamins (Small & Marcus, 2002; Callaway, 2004) and minerals (Callaway, 2004).

Hemp meal remains high in protein and still contains some hemp oil thereby useful in both human food and animal feed (Roulac, 1997; Callaway, 2004). For example hemp meal can be mixed with wheat flour for baking (Roulac, 1997). In a 2002 study conducted by Silversides *et al*. (as cited in Callaway, 2004), it was determined that hemp seed meal was an outstanding food source for laying hens and that the subsequent eggs had an improved *omega*- EFA profile. Favourable results were also obtained for feeding hemp meal to cows, sheep and fish (Callaway, 2004).

4.4.3 Hemp Oil Products

Typically, hemp oil is extracted from hemp seeds, via cold pressing at 45-50 ^{o}C (Pate, 1999; Callaway, 2004). This is the same method and utilizes the same technology that has been established for conventional oil seeds such as linseed. Hemp oil is useful as a food product, cosmetic, medicine[9] and for various industrial uses which are detailed below.

Body Care Products and Cosmetics

Hemp body care products and cosmetics include soap, shampoo, bath gels, and cosmetics such as lip balm, massage oil, and oil based makeup products. The high oil content and favourable unsaturated fatty acid profile including linoleic, α-linolenic and γ-linolenic acids, makes hemp oil desirable in skin care products (Vogl *et al*., 2004). These acids are well known in skin care and have influence over numerous cell membrane functions as well as immunological cell stimulation (Vogl *et al*., 2004). The most publicized line of hemp body care products is carried by The Body Shop, whose founder, Ann Roderick, has been known for making controversial stances on a variety of environmental and social issues and who is actively involved in the promotion of the hemp industry.

Industrial Grade Oil Uses

Industrial grade hemp oil has a wide range of uses both historic and modern ranging from inks, paints, varnishes, sealants, cleaners, and lubricants (Robinson, 1996; Herer, 2000; Small & Marcus, 2002). Hemp oil is useful in these applications because it has good surface penetration and drying properties (Rosenthal, 1994). Hemp sealants are produced by polymerizing the oil, or by making it into polyurethane for finishing (Robinson, 1996). Hemp oil was also popular as lighting oil prior to the 19th century (Herer, 2000).

Lately there has also been some discussion in using hemp oil as a base for bioplastics (Robinson, 1996; Herer, 2000; Small & Marcus, 2002), instead of a polypropylene matrix, like is currently done for soy-based plastics (Wool & Khot, 2001). It has been suggested that hemp based bio-plastics could be used in applications such as plastic piping for plumbing systems (Robinson, 1996; Herer, 2000). Technical issues with further development include interfacial compatibility with composite fibers and the recycle-ability or biodegradability of the finished product (Wool & Khot, 2001).

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[9] Not referring to medicinal marijuana; which uses the medicinal benefits of the cannabinols found in the leaves, flowers and resin, not the fatty acids, as found in the oil.

Bio-diesel

Hemp oil can be used as fuel in the form of bio-diesel and can be burned in the same manner as conventional diesel currently with fewer emissions (Vantreese, 1997; Rawson, 2005). The diesel engine was originally designed to run off of vegetable sourced oils such as soy and hemp oils (Roulac, 1997).

Food and Medicine

Hemp seeds are 30 % oil of which at least 80 % are PUFAs that contain important EFAs such as linoleic acid and α-linolenic acid (Calloway, 2004). These two acids represent the *omega*-6 and *omega*-3 EFAs respectively and exist in hemp at an optimal balanced ratio of 3:1 for human health (Callaway, 2004). EFAs are not produced in the human body and therefore must be acquired through dietary means (Callaway, 2004).

A drawback of hemp oil as a food product is that the PUFA content allows for easy oxidation when exposed to heat and light. Therefore, as with other fragile edible oils, hemp oil should be refrigerated (Roulac, 1997). Cooking hemp oil over high temperature causes the formation of trans-fatty acids that detract from the health benefits and disintegrate the oil quality, therefore hemp oil should not be used for frying (Pate, 1999). Typically, hemp oil is used in salad and pasta dressings, as an alternative to margarine and butter, or in nutritional supplements (Pate, 1999; Callaway, 2004).

As a medicine, hemp oil has been known and used for centuries, albeit mostly in China and other eastern countries (Callaway, 2004). Hemp oil can be ingested for the relief of inflammatory related illnesses such as arthritis and for lowering blood pressure and arterial cholesterol (Callaway, 2004). Applied topically, hemp oil is used as treatment for the healing of open wounds, burns and skin irritations (Callaway, 2004) such a psoriasis and neurodermatosis (Vogl *et al*., 2004). In addition, the excellent fatty acid profile has been shown to have positive effects of the strength of one's immune system (Callaway, 2004).

4.5 The Competition

To identify where hemp products will come into play, major 'hemp competitors' and their characteristics should be reviewed. The competing crops and resources have been divided into flax, wood, cotton, and synthetic products. Land competition has also been considered. There are more products that hemp is in competition with, however only the perceived major competitors have been included. Refer to 6.1.2 for environmental impact comparisons.

4.5.1 Flax: Linen and Linseed

In terms of competing bast fibers[10], flax (*Linum usitatissimum* L.), is hemp's largest competitor based on the market share and that flax can also provide both fiber (linen) and seed (linseed). Linseed oil is used in paints, varnishes and technical coatings (Callaway, 2004). Linseed oil has a larger market than hemp oil but hemp oil has a longer shelf life and a more desirable balance of EFAs (Roulac, 1997). Flax has a slightly higher tensile modulus (i.e. strength) than hemp for use in biocomposite applications such as car parts (Wool & Khot, 2001). But flax as a crop requires higher inputs, such as fertilizers, when compared to hemp (Boyce, 1912). According to Lewin & Pearce (1998), flax and hemp have comparable mechanical properties but flax has better elastic recovery. In agricultural terms, flax is harder on the soil, and has more significantly more disease and pest issues when compared to hemp (Roulac, 1997). Also when used as a rotation crop it could only be grown in the same soil

[10] Other competing bast fibers include jute, kenaf, sisal and abaca although they hold smaller market shares and do not produce oilseed.

every 5 or 6 years (Roulac, 1997). Angelova *et al.* (2004) discovered that flax has a somewhat better ability for reclaiming polluted soils, when compared to hemp.

A comparative analysis of world hemp and flax fiber and tow production shows the trend of growth in flax production has been exponential[11] (FAOSTAT data, 2005). In the 1960's hemp yields were greater than flax, but now the situation is reversed (FAOSTAT data, 2005). This is most likely due to a wider cultivation and therefore experience with flax. When a comparison between the two oilseed products is made, hempseed production has remained less than 5 % of the total world linseed production from 1961-2004 (FAOSTAT data, 2005).

4.5.2 Wood

An often debated fact is the amount of biomass that hemp actually produces when compared to trees. Kamat *et al.* (2002) claim that, "[t]he biomass produced by hemp on an annual basis (biomass per unit area) is higher than that of woody plants used in the pulp and paper industry" (p.289). However, due to the seasonal nature of hemp crops, the required input (although less than other agricultural crops) are larger than for managed forests, on an annual basis.

In terms of wood industries hemp's largest competitor is pulp and paper. Tree free paper has been increasingly favoured especially in North America where concerns over primary forest depletion are rising. Hemp paper has comparable physical properties or characteristics to hardwood paper (Kamat *et al*., 2002), therefore quality would not be sacrificed. In addition, hemp contains higher levels of cellulose and lower lignin content than either hard or soft wood species, which are both desirable properties for the pulp and paper industry in terms of reducing inputs and processing (Kamat *et al*., 2002). In addition, hemp paper resists decomposition and discolouration in comparison to wood paper products (Roulac, 1997).

For building and construction materials hemp hurds provide high strength composites such as fiberboard and flooring providing similar or better properties than the same wood products (Roulac, 1997; Small & Marcus, 2002). Hemp hurds beat wood chips for absorbency properties (Roulac, 1997) for animal bedding or in other scenarios in which absorbency is a critical characteristic such as chemical spills or leaks (Roulac, 1997).

4.5.3 Cotton

Both cotton production and yields have been rapidly increasing in the last century. Cotton can also be grown in many different world regions, but more southerly than hemp (Cherrett *et al.*, 2005). Cotton is a desirable textile material, especially for garments and households fabrics, due to its ease of laundering, and abilities to breath, dye, and manufacture into fine textures. Even though cotton is today's preferred fiber for clothing and many other personal textiles, it requires a larger amount of fertilizers than hemp does and yields less fiber, per plant weight (Boyce, 1912). Cotton is considered a resource intensive crop and yields only one third of the amount of useful fiber per hectare that hemp does (Cherrett *et al.*, 2005). The long length of hemp's bast fibers are superior textile fibers compared to cotton in terms of strength (Roulac, 1997). Although hemp technology for spinning finer yearns is currently improving (Rosenthal, 1994), it is still decades behind the head start that cotton had since the invention of the cotton gin.

4.5.4 Synthetics

In this case, synthetics include petroleum products such as plastic, polyester, nylon, and materials such as fiber glass. Hemp based composites are considered for replacing inner

[11] Dividing the flax production by hemp production, shows exponential factor of increasing flax production over time.

automobile linings (Wötzel *et al*., 1999). Synthetic fabrics such as polyester and nylon also see some competition to hemp fibers due to the lower energy requirements of hemp fiber production (Cherrett *et al*., 2005). However, synthetics have some unique benefits that cannot be replaced. The desirable characteristics of polyester include stretch resistance, low moisture absorbency and thermal stability (Cherrett *et al*., 2005). Fiber glass, however, is by volume is the largest competitor, for insulation and composites applications. Fiber glass is non-recyclable, causes severe abrasion to manufacturing equipment and can be a danger during car accidents as glass fibers can splinter (Pervaiz & Sain, 2004). In terms of insulation, fiber glass has been known to cause lung damage (Wool & Khot, 2001). Hemp fibers are advantageous over fiber glass due to low weight, cheaper price, better impact absorbance, and added noise insulation for automotive composite applications (Pervaiz & Sain, 2004).

4.5.5 Food: Arable Land Competition

Concern may be raised that using more arable land for non-food crops, as is the case for fiber hemp cultivation, may cause a conflict between land uses for food vs. fiber crops. However, as has been previously mentioned one of the reason behind the recent increase in hemp as a crop in developed countries is precisely because there is an over production of cereals, potatoes, sugar beets and other food staples in Europe and North America (Harris, 2002). In addition, hemp seeds (although not always produced) will also provide a valuable food product that is a goal of the dual purpose crop. If the agronomic benefits of hemp are realized with good crop management, soil conditions may even be improved for subsequent crops that can result in increased yields and/or reduced initial inputs (such as herbicides). In addition, less agriculturally suitable land (marginal or polluted soils), can be used to grow hemp for energy, animal bedding or construction purposes. Therefore, arable land competition should not be an issue but could be a limitation if the market were to reach certain grand proportions in the long term future.

5.0 The Reality: Global Outlook

This section is meant to present information on where hemp is cultivated. Industrial hemp flourishes in temperate climates and can be found in Europe, the Balkan countries including Turkey and Romania, the Commonwealth of Independent States (CIS) (formerly the Former Soviet Union), China, Japan, Chile and Canada (Lewin & Pearce, 1998). According to the agricultural database provided by the Food and Agricultural Organization (FAO) of the United Nations (UN), world hemp fiber and seed was 76,000 ha in 2004 (FAOSTAT data, 2005). Figure 5 shows the world production of hemp fiber and tow and Figure 6 shows the world production of hempseed (FAOSTAT data, 2005). Both figures present production in metric tons (Mt) and the data is from 1961 to 2004 inclusively.

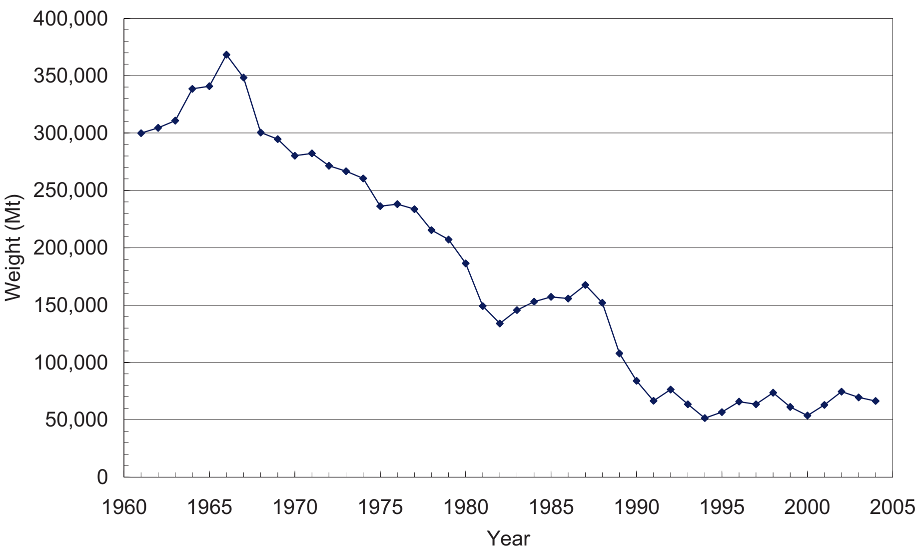

Figure 5. World Hemp Fiber and Tow Production (FAOSTAT data, 2005)

Figures 7 and 8 display the 2004

hemp fiber and tow and hemp seed production data, by the largest producing countries, respectively. In both figures, the CIS category includes data from Russia and the Ukraine, with Russia being the largest contributor in both scenarios. The accuracy of the FAO data can be questioned however, due to exclusion of data from some countries that are known to produce hemp, such as Canada, Sweden and Australia. In addition, each country submits their own data to the FAO and therefore inconsistencies, assumptions, estimates and other such statistical errors could affect the quality of this data. However incomplete, this data is currently the best of its kind and it is apparent from the literature reviewed that the major producers are represented by the FAO statistics.

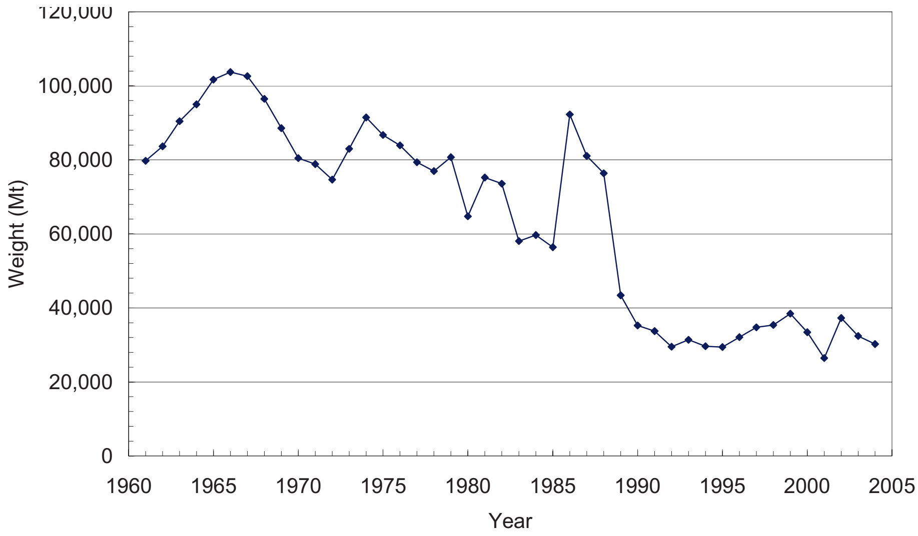

Figure 6. World Hemp Seed Production (FAOSTAT data, 2005)

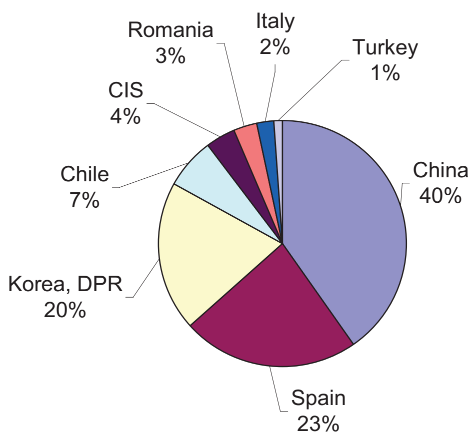

Figure 7. 2004 World Hemp Fiber and Tow Production by Country (FAOSTAT data, 2005)

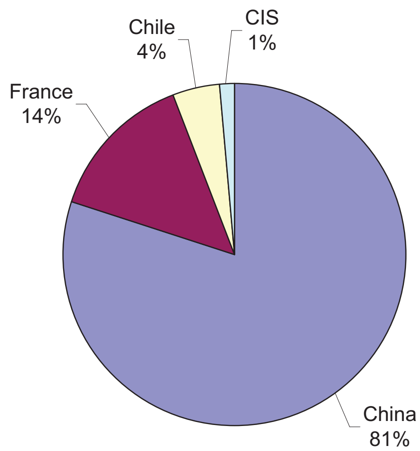

Figure 8. 2004 World Hemp Seed Production by Country (FAOSTAT data, 2005)

There are over 30 countries in the world that sustain domestic hemp production. Due to this larger number it is not possible to explore each one. Therefore, the most prominent geographic regions where hemp is cultivated will be presented. This will provide the reader with a general understanding of the world hemp industry in the last decade and where the hemp industry stands today. First the European Union (EU-15) countries will be explored where much of the modern hemp research and cultivation has been happening. A section for Sweden is separated to detail a on-site visit. Hemp was never in prohibition in the majority of the Eastern European countries, the CIS and Asian Pacific which is discussed next. North America will follow where recent hemp production in Canada has met some problems with the American trade barriers. A brief mention of hemp activities in South America and Africa comes last.

5.1 Europe (EU-15)

In 1970 the European Communities, adopted a regulation for the organization of the European flax and hemp markets due in part to an over production of food in the Community and an underproduction of flax and hemp (Council Regulation (EEC) 1308, 1970). However, due to prohibition, hemp cultivation in Europe was limited almost exclusively to France in the eighties and nineties. With the renewal in hemp interest and a lifting of hemp cultivation, the hemp industry in the EU tripled in the late 1990's (Karus, 2005). It was also at this time that the EU hemp production subsidies began to decrease (Karus, 2005). In order to be approved for these subsidies certain restrictions were imposed and they changed over time as the industry grew and political climate changed. The most relevant conditions are that the hemp cultivar used must be of certified seed from the EU's approved list containing less then 0.2 % by weight of THC and harvest must occur at the end of the flowering period (Council Regulation (EC) 1420, 1998). This last point has been a thorn in the side of farmers and academia as it restricts the fiber quality and quantity and, therefore value of the crop (Bòsca, 1996). In addition, the EU regulations for hemp aid require a ratio of CBD:THC larger than 2 (Callaway, 2004). It was also mentioned in the original regulation (No 1308/70) that if supply/demand inconsistencies are encountered then additional aid for long term storage may be provided. There is also an EU supported hemp breeding program involving France, Britain and the Netherlands in an effort to completely eliminate the THC content of industrial hemp varieties (Matthews, 1999).

Although overall world hemp seed and fiber production have decreased since the 1960's, hempseed production in France has increased over this time and hemp fiber production in Spain has also seen significant gains in the last decade (FAOSTAT data, 2005). The hemp industry in France has been long established due to the fact that hemp cultivation was never prohibited here. French hemp is used to produce cigarette papers as well as for English race horse bedding (Matthews, 1999). French certified hemp seeds almost have a monopoly in this market due to decades of breeding to reach low levels of THC that fall under the EU eligible cultivars. Spain is the second largest hemp cultivator in Europe, contributing mostly to a specialty paper industry (Matthews, 1999). Italy has also been a major player in hemp production in Europe during the last forty years, although producing more hemp fiber than seed, especially in the last decade (FAOSTAT data, 2005).

5.1.1 Sweden and a Swedish Field Visit

In Sweden hemp was traditionally cultivated for textiles that were used for sailing supplies or for household use. By the 1960's, hemp cultivation had almost halted in Sweden, and the government soon banned hemp due to association with marijuana. In 2001, a Swedish farmer took the issue of hemp cultivation to EU, where it was ruled that according to the Council Regulation (EC) 1420 (1998), the national government cannot preclude farmers in Sweden from cultivating industrial hemp (Judgment of the Court, 2003). In 2003, the Swedish regulations were finally amended. Currently there a hundred hemp farmers throughout Sweden, who still remain frustrated about the amount of government imposed barriers surrounding cultivation.

Hemp as a biomass for energy crop is the largest market for hemp fibers in Sweden right now. Theoretically hemp fibers are worth more in market value, but there are no processing or manufacturing facilities in Sweden. Therefore, the farmers do not have many options for their harvest and using biomass for heating purposes is traditional in Sweden. This is a problem for EU aid as well which requires farmers to have a contract with a fiber processor in order to bypass Swedish 'Control of Drugs' regulations (Rolandsson, 2005). This results in a sanction of support from the EU (Rolandsson, 2005).

On September 12th, 2005 a field visit was made to a hemp farmer outside of Lunnarp in the landscape of Skåne. Here, Thomas Jacobsson grows hemp along side sugar beets, corn and wheat. At the time of visit the stocks were approximately 2m in height. Figure 9 shows the local fields at the time of visit.

Figure 9. Hemp for Energy Fields in Skåne, Sweden

On this farm, hemp is used as a rotational crop and has been cultivated for the last three seasons. The size of this hemp crop in 2003 was only 1 hectare (ha.) and he added another hectare each subsequent year. Prior to his hemp cultivation, Thomas was looking for a new crop that would be compatible with his other crops, to provide extra income. As a newly legalized crop in Sweden, hemp was an interesting experimental energy crop. The seeds are planted in March along with the other crops. They are imported from France through a Swedish company, Bionics. The seeds are a monoecious type which has the male and female flowers on the same plant. Only existing farmers can cultivate hemp and that the Jordbruksverket (Agriculture Agency) had to be notified of the farmers' intention. No herbicides, pesticides or water are added during cultivation and only pig manure is used for fertilization. The hemp is harvested after the first frost in December so that all the leaves have already fallen off and the stocks have dried, therefore no heat treating is necessary. A canola harvester is used to harvest the hemp stocks. With sufficient rain it is possible to yield 10 tons/ha, but a dry a summer may only yield 6 tons/ha, in this area. After harvesting, the stocks are baled and stored in a warehouse for further processing. Figure 10 shows the machinery that is used to chop the hemp bales. (Jacobsson, 2005)

Figure 10. Machinery used for chopping hemp bales and blowing resulting fibers into pellets

Post chopping, the hemp fibers are forced into a tube where 'pellets' or logs are formed for easy use in a stove/fireplace. The log that is produces is very dense and has a superior energy content of 5.2 MWh/ton (Jacobsson, 2005) compared to wood's energy content of 4.3 MWh/ton (WEA, 2000) used in heating stoves. The logs are sold in bundles[12] to nearby residents who still use a central stove as their heating source. These logs have more value (in terms of the energy content) than the current market prices allow for. Thomas hopes to diversify the future crops by harvesting for both fiber and seed at the same time, but perhaps earlier in the year to reduce loss of hemp seeds to the local bird population. (Jacobsson, 2005)

[12] 55 SEK for 25 kg or 2 SEK/kg (Jacobsson, 2005).

When asked how his farmer neighbours felt about him growing hemp he replied that most of them were just curious about what he was doing and how it would turn out. He stated that there were some who disapproved but also one neighbour who had started growing it for himself this year. (Jacobbson, 2005)

5.2 Commonwealth of Independent States, Eastern Europe, and Asia Oceania

Most Eastern European and CIS countries as well as China did not prohibit hemp cultivation; therefore, the landraces from these regions are fairly well adapted to the local environments. Traditional labour intensive retting techniques used a century ago are still being used. The countries in these regions that currently report hemp cultivation include Hungary, the Russian Federation, China, Republic and Democratic People's Republic (DPR) of Korea, Poland, Serbia and Montenegro, Romania and the Ukraine (FAOSTAT data, 2005). As was shown earlier in Figure 9, the majority of hemp grown in these countries is in China, Korea (DPR) and Romania. In addition, most of this hemp is used for the production of high quality textiles for export (Fortenbery & Bennet, 2004). Upon detailed analysis, the DPR of Korea has been steadily increasing hemp production since 1980 (FAOSTAT data, 2005). In terms of hemp research and breeding, much work has taken place in Hungary and some popular varieties have hailed from there.

Hemp fiber cultivation has been legal in some Australian states in the last 10 -15 years; however, the consumption of hemp derived food products is not (ANZFA, 2002; Olsen, 2004). This can be attributed to remaining confusion in Australia's state laws with respect to the differentiation of hemp product and narcotic substances (ANZFA, 2002). Hemp cultivation is allowed in New Zealand, but similar to Australia, hemp derived food products have not been approved by the mutual food authority.

5.3 North America

Currently, all of the hemp production in North America comes from Canada because Mexico and the US still remain under hemp prohibition. Health Canada (1998), the responsible regulating body, announced that the commercial cultivation of industrial hemp cultivars would be permitted as of the 1998 growing season. All stakeholders (farmers, importers, exporters, processors, manufacturers, retailers and distributors) involved in the newly found Canadian hemp industry are required to obtain permits from Health Canada in order to ensure the legitimacy of the industry (Health Canada, 1998). Canada's Industrial Hemp Regulations fall under the Controlled Drug and Substances Act (CDSA), and according to the Department of Justice (DoJ, 2004) hemp is defined as any variety of *Cannabis sativa* L. which contains less than 0.3 % by weight of THC in the flowering heads, leaves, and viable seeds of the plant under question. In addition the Canadian regulations also state that no hemp derived product should contain more than 10 µg/g of THC (DoJ, 2004).

The land area licensed for production in Canada has fluctuated since 1998. A dramatic drop in production was seen in 2000 and 2001 (AAFC, 2005) after a 1999 peak of 14,261 ha, due to export issues with the US over trace amounts of THC, see below. Although hemp food products are legal in the US and a legitimate agricultural commodity according to the UN Single Convention Treaty on Narcotics and the North American Free Trade Agreement (NAFTA) (Vantreese, 1997), THC is a schedule 1 controlled substance and falls under the authority of the DEA and the Office of National Drug Control Policy (ONDCP). These authorities are using the inconsistencies in their own laws to suffocate the North American hemp industry. For example, in 1999, the US DEA and ONDCP temporarily closed the American border to Canadian hemp seed products and even seized a large shipment of birdseed (Rawson, 2005). Nevertheless, domestic demand of hemp products has increased and exports to the USA are allowed again (Rawson, 2005). In 2004, 3,531 ha were licensed for hemp production in Canada (AAFC, 2005).

In the last decade there have been several individual states interested in hemp cultivation, and legislation initiations have taken place (Fortenbery & Bennett, 2004). In spite of the federal ban, 25 states have passed legislation concerning the cultivation hemp for industrial purposes (Rawson, 2005). However, because the DEA and ONDCP are federal and executive ruling bodies, their regulations overrule those of the individual states, making the new state legislation redundant while the federal ban remains in effect. In 1999, for the first time in 60 years, the DEA issued a hemp cultivation permit to Hawaii for a 0.5 acre (0.2 ha) experimental industrial hemp farm (Gee, 2000; Hanks, 2000). In order for the permit to be approved, the DEA required high levels of security for this research plot including a 10 foot high (3 m) electrically secure perimeter chain link fence with barbed wire and infrared surveillance, which at $30,000 (USD) was a significant expense (Gee, 2000; Hanks, 2000; Morris, 2002).

5.4 South America and Africa

Chile is one of the world's major hemp producers that has been producing a stable supply of hemp since the 1960's with 4,550 ha harvested in 2004 (FAOSTAT data, 2005). Some experimental plots have occurred in South Africa, however commercial hemp cultivation has yet to take off (Roulac, 1997).

6.0 Hemp's Contribution to Sustainability

This chapter combines the background information and geographic industry overview and utilizes the theory and methodology as previously defined in Chapters 2 and 3 to determine whether hemp fits into sustainable agriculture and to present the variables affecting the industry. The three pillars of sustainable agriculture will be explored first. Specific major issues that the hemp industry currently faces will follow. The section on synthesis offers an analysis of the affecting variables and their relationships to each other in addition to an insight into the future of the hemp industry, recommendations in order to increase market demand and finally conclusions.

6.1 Three Pillars of Sustainable Agriculture

As mentioned in the introduction, the three main aspect of sustainability and how they translate to sustainable agriculture are important for a holistic approach. Sustainable agriculture includes sustainable agronomy, social responsibility of the farming communities and stakeholders, and bioregional economics or eco-commerce. This section will explore these three topics and evaluate how hemp aligns with sustainable agriculture systems.

6.1.1 Hemp Economies: Local to Global

Like any industry, the economics surrounding hemp play an important role in determining the future market shares that any hemp derived products might have. This includes the local economics for the farmers and farming communities and the international export-import trading markets. The economics (and therefore profitability) of any given industry can vary substantially if analyzed from the perspective of conventional, environmental or ecological economic theory. In order for the industry to contribute to sustainability, sustainable economics must be present. This section will focus on exploring these economic issues. First a brief review of economic theories is discussed before getting into the details of hemp economics.

Neoclassical economic theory is the current dominant economic paradigm. Environmental economics is a subfield which includes externalities, such as social and environmental issues, that are not normally considered. An externality is a cost or benefit that is not reflected in the product price (Harris, 2002). Only by internalizing externalities such as pollution costs and subsidies given to non-renewable resources, for example, will the 'true' product cost and therefore, price, be realized. Unlike neo-classical or environmental economics, ecological economic theory places the economy inside the environment instead of the contrary (Harris, 2002). In this manner ecological economics has a more sustainable approach as it considers input from other disciplines such as biology, ecology and social systems. In terms of a specific resource, the carrying capacity (or ability to sustain) of the environment is also an important aspect in ecological economics (Harris, 2002). Ecological economics values natural capital and argues that it is not interchangeable with human capital as conventional economics asserts (Harris, 2002).

The local economics of hemp farming includes the costs and profitability to the farmer, to the local community, and the availability of infrastructure in order to transport, process, and manufacture hemp products. The profitability to the farmer (farm gate profitability) depends on the yield, cultivar, national permit requirements, and value of the intended crop. The value of the intended crop is dependant upon the quality of the seed and/or fiber. Differences in product quality affect the cost of production and the product price. Higher quality products that met certain standards, such as certified seed, will have a higher market value than hempseed as a grain crop.

The most up-to-date and complete review of hemp crop profitability was compiled by Fortenbery and Bennett (2004) for North America. They presented five profit estimate reports from the USA and Canada during the year's 1998 and1999. The results produced a wide array of estimates, ranging from - $241.30 to $316.45 per acre (-$596.27 to $781.96 per ha) for fiber production alone and -$294.64 to $605.91 per acre for dual purpose crops (-$728.07 to $1,497.24 per ha), given in 2001 USD (Fortenbery & Bennett, 2004). These estimates do not take into account any costs that are incurred for licensing, monitoring and verification that may be legally required. In the USA these additional 'security' costs may be economically prohibitive, as hemp test plots in Hawaii have experienced. These reports were all for North American hemp production, which requires the importation of certified seeds from Europe (Vantreese, 1997). A North American based gene bank would significantly reduce the cost of certified hemp seeds for local producers and positively affect the economics. No subsidies are currently available for Canadian or Australian hemp farmers. In comparison, a look at European hemp economic reveals that given the current EU subsidies of 90 Euro/ton (Council Regulation (EC) 1673, 2000) for hemp cultivation, it is currently profitable. Due to cheap labour and traditional, low tech techniques employed by the CIS, China and Chile; subsidies are not necessary in these areas to reach profit margins.

The economics for rural farming communities is dependant largely on transport and proximity to processing and manufacturing facilities. The bulk nature of hemp crops requires that processing facilities are located nearby hemp fields. The decentralization of hemp production will reduce transport costs and hence product manufacturing costs. Bioregional production and processing of hemp would be beneficial to rural commerce and contribute to rural community self sufficiency. Although local hemp economies would rejuvenate rural regions, small scale processing and manufacturing facilities require more capital costs than fewer large scale facilities would. Due to economies of scale returns from larger scale facilities would probably be greater, however; these profits would have to be offset with transport requirements and the reduction in social benefits.

To make hemp an economically viable industrial crop; uses, markets and technologies need to be identified to use the entire plant. This means for example, using a paper making process that can handle the entire stock or securing markets for the hurds and seeds if bast production is the priority. Dual crop production seems to be the most economically viable situation given the high value of hemp seed, derived oils and bast fibers particularly. Marcus (1996) states that hemp grown for only fiber or seed is more likely to result in negative returns than dual crop production. However, climatic, genetic and regulatory issues may negatively affect the possibility of this option.

The majority of the hemp industry could currently be described as being a cottage industry with many relatively thin markets (Vantreese, 1997). As was shown in the previous section, both world hemp fiber and tow and seed production rates have decreased more than a third of the production of the early 1960's. With this is mind, global hemp commerce has still managed to become a multi-million dollar industry (Roulac, 1997; Vantreese, 1997). The production of higher quality, value added products with superior properties is the main reason behind a growing market.

Currently, little hemp fiber is actually traded internationally, with only 11 % of 2003 world fiber production exported (FAOSTAT data, 2005). Due most likely to smaller bulk, hemp seeds are traded more readily. In 2003, a third of the world hemp seed production was exported (FAOSTAT data, 2005). According to the FAO statistics (2005) most seed exports (from largest exporter) down in 2003 come from the Netherlands, France, Belgium and Germany. In 2003, the largest fiber exporters were the UK, Romania, the Netherlands and France (FAOSTAT data, 2005). Subsidies in the EU have been cited as the key reason behind continued hemp production in the EU. However, subsidies have fallen recently (Karus, 2005) and production continues to rise slowly (FAOSTAT data, 2005). In terms of the natural fiber market, a relatively small volume of hemp is being sold on the international market, hence fluctuations due to climatic variables or product costs can result in volatile price swings.

Fortunately, due to the qualities of hemp both as a crop and a product, the goal of eco-commerce is practically naturally achieved. This is due to the requirement for regional processing facilities and the fact that locally produced and manufactured goods carry a novelty value and are certain to capture a market aimed at locals and tourists even at increased prices (Roulac, 1997). Product costs are also positively affected due to local production as transportation costs need not be in excess. If environmental and ecological economics can be applied more to markets for renewable and non-renewable resources, low input and low intensity crops such as hemp will positively benefit. Even though hemp may be beneficial when looked at from environmental and ecological economics, its competitors typically remain in the traditional paradigm, and therefore tend to have an advantage. If hemp continues to be included in environmental economics considerations, and the same can be done for its counter parts, the economic outlook will significantly improve. The point in the future at which we have adapted to this form of economic approach remains unknown. Market demand is a critical driving factor in the hemp industry and the associated current economic state remains uncertain. Therefore, is it appropriate to conduct a future hemp market analysis as given in sections 6.3.2 and 6.3.3, after the industry limitations and issues have been identified in sections 6.2 and 6.3.1.

6.1.2 Environmental Aspects

This section will evaluate the degree of environmental sustainability that hemp can contribute to sustainable agriculture. In terms of sustainable agriculture, this means continued status quo or even improved environmental health of the local ecosystems. Comparative data will be used to illustrate the point including several recent environmental studies such as an ecological footprint (EF) and life cycle assessments (LCA).

Alden *et al.* (1998) performed an analysis of the potential impact that the establishment of domestic USA industrial hemp production would have, if permitted, on American environmental quality and the economies of the competing raw material industries[13]. The methodology was an adjusted EF in addition to three future scenarios identified as 'States of the World'. The results obtained in this study suggest what the author's termed a 'double dividend', meaning that allowing industrial hemp production in the USA would both improve the overall environmental quality in addition to decreasing land use required to maintain economic levels. (Alden *et al.*, 1998)

There has been some interest in the reclamation potential of hemp crops, especially heavy metal (lead, copper, zinc and cadmium) remediation of polluted soils (Angelova *et al.*, 2004; Arru *et al.*, 2004). The technical term used for the environmental restoration of polluted soils with plants is called phytoremediation (Arru *et al.*, 2004). The possibility of using the fibers post-remediation is also considered to be a bonus if the quality is not affected. Arru *et al.* (2004) found that hemp was well suited for phytoremediation and that the fiber quality was not negatively affected by the uptake of metals and therefore could be harvested afterwards. Angelova *et al.* (2004) arrived at similar results and suggested products that can be manufactured with this hemp include paper, geo-textiles, biocomposites and building materials, but not garment quality textiles due to the possibility of health risks. The recycle-ability and final waste disposal of the products manufactured from hemp fiber with elevated levels of heavy metals should also be considered.

The carbon storage potential of agricultural crops and forests has been receiving more attention lately as the debate on greenhouse gas emission, climate change and meeting Kyoto Protocol targets heats up. In a study completed to evaluate the environmental performance comparison between hemp and fiber glass composites for the automotive industry, Pervaiz and Sain (2003) arrived at two major conclusions:

1.) The carbon storage potential of hemp crops is comparable with (USA) urban trees and naturally regenerating forests, although below that of a managed plantation.
2.) Energy savings up to 60 % can be realized if hemp instead of fiber glass reinforcements is used.

Energy and hence emission savings occurs from: offsetting the volume of polypropylene base, substituting the high energy fiber glass, reducing the weight of the auto and thereby saving fuel, and by saving landfill requirements (Pervaiz & Sain, 2003). A LCA was used in a similar study by Wötzel *et al.* (1999) to evaluate replacing petroleum based thermoplastic car linings with hemp fiber. The results indicated that the hemp composite had better environmental performance and the reduced car weight adds fuel savings during use (Wötzel *et al.*, 1999). Wötzel *et al.* (1999) also revealed that although there may be some concerns with ozone depleting substances, these were all from the "epoxy resin hardener blend" (p.126) which could be corrected with further trials or by using bio-based resins (e.g. Wool & Khot, 2001).

One of the more published hemp researchers, van der Werf (2004), completed a LCA on the cultivation of fiber hemp and compared it to seven (sunflower, rape seed, pea, wheat, maize, potato and sugar beet) field crops under French GAP growing conditions. Eutrophication, global warming, acidification, and terrestrial ecotoxicity potentials were evaluated along with energy and land use for all eight crops. As low input crops, hemp and sunflower were ranked the lowest impact crops. It was also determined that substituting pig slurry for mineral fertilizers was not an added environmental benefit. Although the use of pig slurry decreased the energy use and global warming potential it significantly increased eutrophication, acidification and terrestrial ecotoxicity. Reduced tillage and reduced

[13] The industries included in the study were textile fiber, oil seed, pulp logs and pulp and paper industries, however the synthetic textile fiber industry was not included in this report (Alden *et al.,* 1998).

fertilization are currently the best options for reducing hemp's impact. Future consideration should be given on how to reduce hemp's eutrophication potential. Once again, future breeding programs may also shed light on this issue. (van der Werf, 2004)

A thorough EF and water analysis was recently completed by Cherrett *et al.* (2005) which compared the environmental impacts of different textiles scenarios of cotton (organic and non-), hemp (organic and non-), and polyester. In this context, Cherrett *et al*. (2005) provided a definition,"[t]he Ecological Footprint represents the amount of land area (measured in global hectares) required to provide all the necessary resources and absorb associated CO_2 waste to produce a given unit of textile, within the context of the Earth's biological capacity to regenerate those resources" (p.1). Cotton is by far the largest natural fiber produced in the world (FAOSTAT data, 2005), and yields are highly dependant on petrochemicals and irrigation (Cherrett *et al.*, 2005). Therefore, cotton's environmental impact is of great interest. On the other hand, organic cotton, which does not use petrochemicals, has very low production volumes, representing only one tenth of hemp fiber and tow production in 2001 (Cherrett *et al.*, 2005; FAOSTAT data, 2005). Polyester (polyethylene terephthalate or PET) is a synthetic fiber that is produced from by cracking long chain hydrocarbons from petroleum sources (Cherrett *et al.*, 2005). According to Stepanski and Rutti (2003) polyester accounted for a third of world fiber production in 2001 (as cited in Cherrett *et al.*, 2005). Due to the large amount of non-renewable resources and energy required to produce this amount of PET, many environmental concerns have been raised.

The results of the study showed that traditional[14] organic (1.46 gha) and non-organic (value not given) hemp had the smallest EF. Three out of four cotton scenarios had the largest EF, with only organic USA cotton lower than USA PET. Interestingly enough, European PET ranked the third lowest EF, below experimental and semi-experimental organic and non-organic hemp. The EF from all hemp and cotton scenarios had a larger proportion attributable to crop cultivation (i.e. land area) than fiber production. The water analysis (for crop cultivation and fiber production) revealed that cotton requires between 9.8 -10 m^3, hemp requires 2.1 m^3 and polyester approximately 0.01 m^3 to manufacture 1 kg of useful fiber. Overall, hemp had the lowest energy requirements and EF. Hemp specific technologies were identified as being a hindrance to lowering the associated CO_2 emissions. (Cherrett *et al.*, 2005)

According to Montford and Small (1999), hemp is ranked relatively high in biodiversity friendliness when compared to 22 other agricultural crops, based on 26 indicators. Figure 11 presents the relative biodiversity of the agricultural crops considered, including organic hemp (Montford & Small, 1999). Following alfalfa and timber trees, hemp for oil crops are third, ginseng is fourth and hemp fiber crops fifth. It is

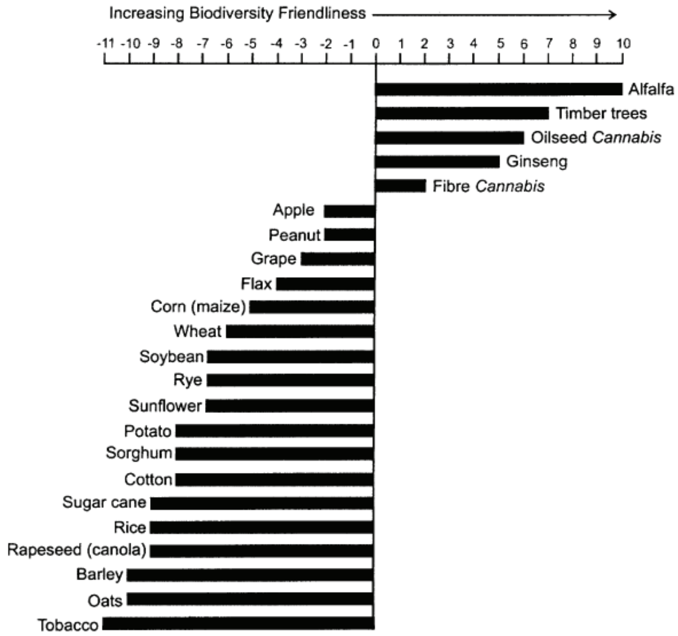

Figure 11. Comparison of Agricultural Crops Biodiversity Friendliness (Montford & Small, 1999)

[14] In this study traditional hemp refers to using the dew retting process while experimental hemp refers to using a decorticator and caustic soda fiber separation technique (Cherrret *et al.*, 2005).

also interesting to note that some of hemp's competing crops such as flax, soy and cotton are further down the list in terms of biodiversity potential.

It would have been desirable to compare the environmental impacts of wood and hemp paper processes although no specific environmental impact literature studies focusing on pulp and paper were found. However, hemp is generally thought to be more environmentally friendly because wood has a higher lignin content which requires chlorine bleaching, whereas hemp's low lignin content makes it conduscive for hydrogen peroxide bleaching (Roulac, 1997; Kamat *et al.*, 2002). The environmental impact on waterways and marine ecosystems is a concern of wood pulp and paper mill effluent (Roulac, 1997). In addition deforestation leading to erosion, siltation of waterways, and the loss of carbon sinks, old growth forests, and biodiversity have been concerns plagueing the forestry and hence the pulp and paper industries for decades.

Although not an environmentally impact-free crop, as some hemp advocates claim, it appear as though hemp has lower environmental impacts than most alternatives crops or competing raw materials. The use of hemp as a renewable resource can offset emissions and reduce stress on depleting non-renewable resources. Agronomically, hemp can reduce fertilizer and pesticide use, improve soil aeration and reduce soil loss or erosion due to its extensive root system and be a good rotational crop (Roulac, 1997). Overall, hemp places less stress on the surrounding environment than most alternatives, and this will furthermore be improved with advances in harvesting technology and breeding. Considering the above information it is safe to say that hemp is indeed an environmentally sustainable crop.

6.1.3 Social Aspects

This section will investigate the social aspects of the hemp industry, specifically academic hemp research, the current political climate, and the societal perception surrounding the hemp industry. This section is important because without an understanding of the variables contributing the current social and especially political climate, a holistic analysis of the industry would be incomplete. In addition, necessary changes surrounding the industry cannot be made if people are uninformed without the opportunity to form their own opinion; this goes for scientists, politicians and the general public as well. Farming communities are mentioned in the section on societal perception and this is where the social sustainability of the industry will be judged because social sustainability begins at the local level.

Academic Hemp Research

Although the hemp industry is small there are a growing number of researchers focusing on area such as breeding, harvesting and processing technologies, product applicability, as well as economic and environmental comparisons. Throughout the current research efforts, certain hemp researchers surfaced time again indicating the small circle of academic inclusion. Still, there are multiple annual hemp conferences in North America and Europe and well as a number of hemp specific publications. Since the mid-1990's, two journals (the Journal of Industrial Hemp and the Journal of the International Hemp Association) that focus on hemp research have been introduced to the academic community. Furthermore, growing environmental concerns are sure to bring an increase in renewable resource including sustainable agriculture studies.

Political Situation: Legality

Cannabis sativa L. has been legal, illegal, and back to legal again in most developed countries within the last 70 years. This has mounted to confusion regarding the current classification and regulation pertaining to *Cannabis sativa* L. and its derived products. In many governments, the regulations on the hemp industry fall under not the agricultural ministry but other departments such as Health Canada, the United Kingdom's Home Office, and the American DEA. This lack of appropriate government management, both vertically and horizontally, has complicated the regulations and restricted industry integration with appropriate departments, further limiting the promotion of industrial hemp potential within domestic and furthermore global markets.

The Unites States is the last remaining country in the developing world, not to readily allow hemp cultivation. Unfortunately for American farmers, hemp and marijuana were not distinguished from each other under the 1937 Marihuana Tax Act (Rawson, 2005). Whether this lack of differentiation was intentional or not is a matter of contention for hemp supporters who claim a variety of conspiracy theories that has brought hemp under the DEA's modern 'War on Drugs' (Herer, 2000). Technically speaking, it is not illegal to grow hemp in the USA, but strictly controlled by DEA permits (Rawson, 2005). Only one such permit for hemp cultivation has been issued since 1958, for a Hawaiian test plot in 1999. Although hemp cultivation has not been made allowances for, hemp imports for manufacture, distribution and retail are permitted under NAFTA. In June 2005, a legislative proposal was made to the federal government in order to remove hemp from inclusion under the Controlled Substance Act (CSA) (Rawson, 2005). The introduction of the Industrial Hemp Farming Act would allow individual states to pass their own legislation (many of which have already done so, perhaps in anticipation) regarding hemp cultivation without having to obtain permits from the DEA (Rawson, 2005).

It is interesting to note the influence that American domestic policy on *Cannabis sativa* L. had on shaping the attitude towards hemp in other countries such as Mexico, Canada, and many European countries that followed suit after the USA defined hemp as a schedule 1 controlled substance. There is no doubt that the US is the largest 'drug control' country in the world which imposes their own drug agenda on other, perhaps even unsuspecting, nations that the USA offers aid to. Unfortunately, in the case of *C.sativa*, drug control policies have relied on conventional wisdom instead of scientific research. European governments realized this and amended their laws starting in the early 1990's to permit hemp cultivation. There are many pro-hemp universities, agricultural and environmental organizations in the USA that would jump at the chance if given to expand the hemp industry in the USA. Even 25 states have endorsed industrial hemp research, in spite of the federal ban. The continued American ban presents an obstacle for the credibility of the industry which furthermore affects investment and research not only domestically but internationally as well because the USA is such a large player in world markets.

Even though prohibition has been lifted in other developed countries, the regulations surrounding *Cannabis sativa* L. as an agricultural crop remain unclear in much national legislation. According to Small & Marcus (2002), "[s]imply displaying a *C.sativa* leaf on advertising has led to the threat of criminal charges in the last decade in several G8 countries" (p.321). Furthermore, restrictions surrounding hemp food either domestically or as an import, present obstacles for the hemp industry. In Germany, the acceptability of hemp tea is in question due to the possibility for higher levels of THC (Lachenmeier & Walch, 2005). This is due to the fact that hemp teas are made from hemp leaves, not the seeds or oil which contains less levels of THC (Lachenmeier & Walch, 2005). Refer to section 6.2.2 for more hemp food issues. In Sweden there are still politicians who remain unconvinced of hemp's association with marijuana and are concerned about sociological problems (Jacobsson, 2005). This comes as a great frustration to the farmers who are not activists but looking for an alternative crop in an effort to save the family farm (Jacobsson, 2005).

The political situation in Australia seems even more confusing, as it appears as though amendments to the state rather than the federal drug control laws oversee the cultivation of hemp (Olsen, 2004). Ambiguity between the *Cannabis sativa* L. phenotypes in Australian legislation has resulted in hemp cultivation being at different stages in each state. Commercial fiber hemp production is occurring in Queensland, Victoria, Tasmania, and Western Australia (Olsen, 2004). The South Australian and Northern Territory states do not allow for commercial hemp cultivation due to lack of commercial viability in these regions and New South Wales is restricted to field trials for research purposes (Olsen, 2004). Although hemp fiber production is allowed in some states, hemp food products remain banned under regulations from the Australia New Zealand Food Standards Council, despite recommendations from the Australia New Zealand Food Authority (ANZFA)[15], to the contrary (ANZFA, 2002; Olsen, 2004).

Societal Perception

This section is intended to present the view of the general public in relation to industrial hemp production. This may come from media sources, educational institutions, agricultural organizations or other less direct sources. In addition, both government stances and NGOs position on hemp have influence on public opinion. There are many misconceptions surrounding *Cannabis sativa* L., especially in developed countries. Current or recently lifted hemp prohibition is a huge social obstacle to overcome and strongly influences societal perception. It has been an uphill battle for many individuals involved in the hemp industry in terms of justifying their research, interest and faith in the crop. No peer reviewed scientific articles which focuses on the social perception of hemp could be located for review here. Therefore, the following information is based in large part on the author's experience and should be considered subjective.

Misconceptions turn into misrepresentation of the hemp industry especially in term of food products and medicinal uses when hemp is connected with marijuana which remains an illicit drug in most countries. This is based on the fact that few people actually know the difference between hemp and marijuana, as described earlier. Those individuals who come from countries which have recently lifted prohibition also tend to be naïve but those who are from countries where there was never prohibition or where prohibition has been lifted for some time seem to be more informed and supportive of the hemp industry.

The hemp industry began as a grass roots movement and is supported by the current cultural (if only peripheral) movement back to more naturally derived products. This is one of out two groups of consumers who are attracted to hemp due to its counterculture appeal. The second group may be loosely identified as a 'drug-culture' following. This group's consumption patterns contribute to reinforcing the association with marijuana. Not that long ago, many hemp foods and other products (such as garments) were only available from esoteric shops which usually carry marijuana paraphernalia. This fact alone has been enough for the DEA to confirm their suspicions that legalizing hemp cultivation will necessitate a rise in drug use. However, now that health benefits of hemp foods and body care products are being more widely published, the market is expanding away from esoteric shops and towards more health food and natural product stores as per the first (and larger) consumer group.

The general social perception of the hemp industry has been changing in developed countries in the last decade. This can in part be attributed to an information revolution and the power of the internet. There are literally hundreds of online hemp networks and associations, sharing both academic and non-academic information on the hemp industry. The public voice can only contribute to a push for further research, initiatives and changes in the bureaucratic process for cultivation, especially from the farmers who require alternative crops in order to maintain their businesses.

[15] The ANZFA is now Food Standards Australia New Zealand (FSANZ) (Olsen, 2004).

It is important to consider the social role that hemp cultivation plays in the lives of farmers. First of all, family farms have been on a decline since the industrial revolution (Roulac, 1997). Factory farming has practically eliminated competition from small farms that cannot compete economically, especially in North America. Therefore, where small farms still exist, farmers are looking for new valuable crops, especially good rotation crops that require little tending or resources. Farmers are interested in hemp for many reasons, including but not limited to, the ease of cultivation, minimal required inputs and perhaps most importantly the variety of possible markets for the raw material, dependant on the quality. By its very nature hemp promotes sustainability in rural communities by providing work to locals for transporting, processing and manufacturing hempen products. Any remaining issues regarding the social sustainability lie in securing the economics which is further addressed in section 6.3.3.

6.2 Issues Currently facing the Hemp Industry

This section is meant to discuss and expand on some of the on-going issues right that the industry is dealing with such as the marijuana connection, the THC content in foods, breeding difficulties, problems in technology development and lack of hemp knowledge. This information will be used in the following section where the mental model or CLD will be presented to show the interactions between the variables limiting the industry.

6.2.1 The Marijuana Connection

One of, if not the strongest argument against the cultivation of industrial hemp is due to the assumption that it will lead to an increase in marijuana cultivation and result in a drug epidemic (Roulac 1997; Rawson, 2005). In addition, according to Rawson (2005) the DEA's main three arguments against hemp cultivation are that it, " would increase the likelihood of covert production of high-THC marijuana, significantly complicate DEA's surveillance and enforcement activities, and send the wrong message to the American public concerning the government's position on drugs" (p. 9).

Any veteran marijuana grower would not bother attempting to hide marijuana plants in hemp crop due to agronomic and regulatory barriers. Because hemp and marijuana are from the same species, cross pollination[16], will result in a severe decrease of THC levels and therefore drug potential in the marijuana plant (Roulac, 1997; ANZFA, 2000). In addition, as was previously mentioned in section 3.3.4, the cultivation practices and harvesting times differ. Hemp crops draw enough attention on their own, plus regular testing of THC levels is mandatory to maintain permits in many countries such Canada and the EU.

In terms of the more social side of the issue, the American government and NGOs such as Drug Watch International (DWI), argue that allowing hemp cultivation sends the wrong message to the public, especially to youth who are easily impressed upon and this could a negative effect on the fight to reduce drug consumption (DWI, 2002). Although there has been some evidence that some of the interest in reviving hemp cultivation in the 1980's and 1990's was, and continues to be, promoted by businesses or organizations looking to legalize marijuana (Herer, 2000), today this collection has a quiet voice in the hemp industry. According to Roulac (1997), "[p]roponents of industrial hemp have made a clear distinction between 'the rope and the dope,' and many do not lobby for drug-law changes" (p.68). In addition, the fact remains that hemp is not valuable as a drug and therefore the logic that these organizations use to make their decisions on is not based on scientific proof. None of the three arguments made by the DEA has been substantiated by reports from any hemp

[16] The effects of cross pollination can reach up to 16 km surrounding a given hemp farm (Roulac, 1997).

producing countries (Roulac, 1997). Therefore, the issue here seems to be one of lack of information, knowledge and education as will be further addressed in section 5.2.5.

6.2.2 THC Content in Hemp Food Products

The emergence of hemp seed as a natural food product is following the growth of the organic food market which is becoming more mainstream (FAO, 2001). However, some countries ban hemp food products for human consumption due to concerns over the THC content. New Zealand and Australia both have banned hemp food products (Olsen, 2004) and although the USA does not have a ban on hemp foods there has been some legal discrepancies and hemp seed imports from Canada were restricted from 1999-2004 (Rawson, 2005). This concern over the THC is twofold: firstly health related issues upon ingestion of amounts of a psychoactive substance in addition to the possibility that eating hemp foods could interfere in the results of workplace drug tests routinely administered by some corporations (Leson & Pless, 2000).

Theoretically, there should be no THC content in hemp seeds, because *Cannabis* seeds are the only plant part not to contain cannabinoids (Lachenmeier & Walch, 2005). Therefore, it is concluded that any trace of THC found in hemp seeds or in hemp food products, occurred via contamination of the seed shells. Contamination can easily occur during harvesting or handling of the seeds; if they come into direct or indirect contact with plant parts such as leaves and flowering tops, which contain THC (Roulac, 1997).

The issue of THC levels in hemp food product was of concern in the early 1990's when after examination, hemp food products were found to contain higher than acceptable THC levels. Since this issue has been documented and hemp seed producers, processors and hemp food manufacturers made aware of this issue, it is now common practice for hemp seeds to go through thorough washing and/or hulling processes to reduce the THC contamination (Callaway, 2004; Lachenmeier *et al.*, 2004).

The current acceptable level of THC in hemp foods is 10 μg/g (10 ppm) in Canada (DoJ, 2004). No regulations could be found regarding the acceptable THC levels in hemp food products consumed elsewhere. A recent study done by Leson & Pless (2000) suggests that even with excessive consumption and use of modern hemp food and body care products the level of THC found in the human system afterwards would not exceed the required drug test lower limit[17].

Callaway (2004) suggests that with modern processes and restrictions, anxieties over traces of THC in hempen food is analogous to being concerned over the morphine content of poppy seeds. Even though opium (like THC) is a controlled substance, poppy seeds containing traces of naturally occurring opiates are exempt under the USA's CSA, while major barriers were faced for a period of 5 years over hemp seed imports, containing traces of THC (Rawson, 2005). Furthermore, concerns over THC content in hemp derived food products should be dismissed since both cleaning and maximum concentration standards exist and compliance mandatory.

6.2.3 Hemp Cultivars: Gene Pool and Breeding

Currently, there are two major permanent *Cannabis* gene banks with no direct commercial interest (i.e. public) where ongoing research and breeding is conducted. The first is maintained by the International Hemp Association (IHA) and is based in Amsterdam, Netherlands with counterparts in the Ukraine and Italy (Vantreese, 1997). The second is the Vavilov Research Institute (VRI) in St. Petersburg, Russia, home to the world's largest *Cannabis* germplasm bank, with over 500 accessions (Small & Marcus, 2003). According to

[17] The drug test lower limit is 50 ppb in the USA workplace drug test (Leson & Pless, 2000).

a recent summary of hemp breeding status, Ranalli (2004) states that the two largest obstacles in breeding are:

1.) Hemp is naturally dioecious and therefore cannot pollinate itself.
2.) Hemp is a short day photosensitive crop which means that the life cycle and therefore the yield and THC levels are partially dependant on and react to day length.

Research at both of these gene banks is constantly underway to develop new accessions that are monoecious and that have low THC concentrations.

Unfortunately, many hemp cultivars became extinct or were destroyed during the late 20th century, during prohibition in North America especially, and to some extent in Europe due to decreased cultivation (Small & Marcus, 2003). Therefore, modern cultivars, which have been bred for European or Russian growing conditions, are not as diverse in terms of adaptation to different climates, latitudes and soil types. In order to become more competitive; improved yields, pest resistance, and low THC levels, for example, are essential. In addition, due to the reproductive nature of hemp, cross breeding occurs rapidly (i.e. within one generation) which can reduce the desirable qualities of the crop. Therefore, new seeds need to be sown every season and consequently requires a stable supply of certified seeds. This necessitates continued hemp gene research, hemp breeding and an expansion of hemp gene pools.

The ability to completely eliminate the THC content in hemp cultivars in the future will most likely increase the public and government acceptance of hemp cultivation along with the credibility of the industry. This may also lead to a useful tool in the limitation and 'policing' of marijuana varieties due to the cross pollination between the plants as mentioned in 6.2.1 in order to reduce marijuana's intended drug value.

6.2.4 Hemp Technology and Development

If viewed from a historical perspective, it can be observed that advances in technology have generally been bad for the growth of the natural fiber market (FAO, 1989). This fact is most noticeable with the advent and subsequent growth of the synthetic fiber market. "Since hemp was suppressed just at the time when machinery would have taken hemp into the industrial age, there has never been the opportunity to take advantage of hemp as a natural resource in modern times" (Robinson, 1996, p.16). Current hemp harvesting, processing and manufacturing technology is physically limited to specific countries and the lack of large scale facilities limits processing and manufacturing capacity affecting the economies of scale.

The most important role that technology plays in the hemp industry is in terms of the economics, more specifically product cost. However, environmental pollution from mechanization and transportation as well as the social impact of larger scale facilities and farms is also of concern. The nature of industrial hemp cultivation helps to reduce these impacts when compared to conventional fiber/seed crops where transport, storage, and processing are also an issue. Technology can help to reduce product cost by:

1.) Improvements in harvesting technologies will result in higher quality raw material and may reduce processing requirements.
2.) The construction of processing and manufacturing facilities closer to farming communities will help to reduce transportation costs in addition to the associated pollution.
3.) Newer processing technologies can help to maintain high quality product while reducing both manual labour costs and associated emissions.
4.) Larger processing and manufacturing facilities will increase the throughput capacity which due to economies of scale will reduce the overall cost per unit.

Technological advances in hemp harvesting, processing and manufacturing are not going to happen over night. Neither are the construction and startup of more processing and manufacturing facilities. These things take time for research, development and demonstration (RD&D) as well as investor acceptance and risk management. Further development and adaptability of harvesting technologies needs to be explored and can improve economic viability of higher quality textile harvesting on Western European, Canadian and Australian hemp farms, in order to compete on the market with high quality textiles from Eastern Europe and Asia. Technological advances in the hemp industry can ease certain limitations and improve the economics; but ultimately will not drive the industry's demand.

6.2.5 Education and Knowledge on Hemp

Education is a key factor in the future growth if the hemp industry as it has influence on many actors involved. Education improves the general public and farmer knowledge, it can be used to better inform policy makers, it can encourage investor interest and improve the amount and level of academic research. Information should be made more readily available to individuals. There is a link between the availability of hemp information and how educated people are on hemp, which also relates in part to the present methodology which includes a literature review. First of all, the more information that is available the more informed people will be to make the best choices in terms of regulations, research direction, consumer products or crop choice. Both the quality and quantity of available hemp information affects the industry and can be identified as a key reason for slow growth. Education of this topic to the academic community, the general public as consumers and farmers, and to politicians is required if the hemp industry is to be disassociated from marijuana and given the chance to prove itself in industry as both a renewable raw material and valuable seed crop.

6.3 Synthesis

This section provides a synthesis of the previously presented information and discussion surrounding the hemp industry and derived products. The subsections include system analysis, time perspective, markets and future possibilities in addition to consideration given to developing countries and recommendations for ensuring future market growth.

6.3.1 System Analysis

Given the information pertaining to the hemp industry it is now possible to look at the industry in its entirety and evaluate how the factors and actors are affecting each other, which is important to consider at this stage. A mental model in the form of a CLD has been developed for the purposes of presenting the current situation of the hemp industry and to determine what the factors contribute to a limitation or expansion of the industry. Once that is understood, it is easier to recommend methods for further market expansion. Figure 12 gives the proposed CLD for the current industrial hemp situation. A definition of the variables will follow and then the relationships between the variables will be explained.

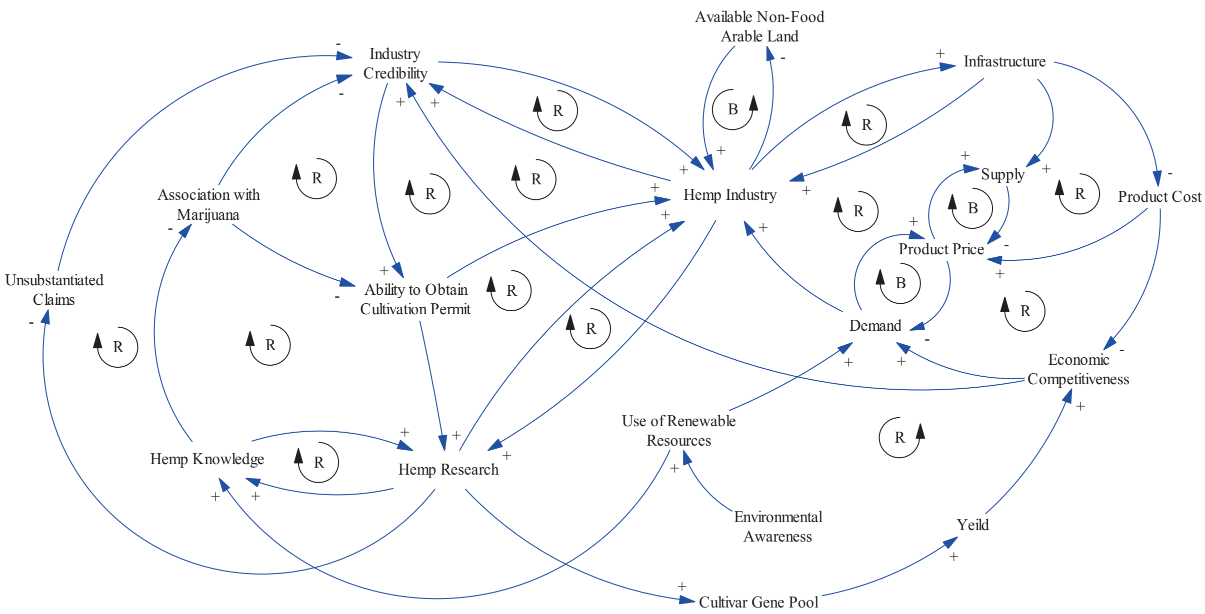

Figure 12. Factors and Actors Affecting the Hemp Industry: A CLD

<u>Environmental Awareness</u> refers to society’s concerns over issues negatively effecting the environment such as non-renewable resource depletion, climate change, water pollution, air emissions, and so forth.
<u>Use of Renewable Resources</u> includes the use of renewable energy (hydro, solar, wind, etc.) and agricultural goods such as natural fibers and bioproducts.
<u>Demand</u> is twofold and refers to a demand from consumers for hemp products and also by manufacturers for raw hemp material. Include niche markets such as health foods, beauty products and other novelty application as well as larger markets for industrial uses.
<u>Hemp Industry</u> includes all stakeholders involved in the cultivation, processing, and manufacturing of hemp derived products including farmers, businesses and investors.
<u>Infrastructure</u> is defined as the necessary technologies, including transportation, needed for operation of the hemp industry for harvesting, processing and manufacturing products. This includes the quantity and capacity of processing/manufacturing facilities and the efficiency of the technology within them.
<u>Supply</u> refers to the availability of finished hemp products in the market.
<u>Product Price</u> is the price for finished hemp products as charged to the consumer.
<u>Product Cost</u> is the expenditure per unit for the processors/manufacturers to deliver a finished good to the market.
<u>Economic Competitiveness</u> refers to hemp’s competition, in terms of product cost, with other raw material for use in manufacturing products.
<u>Hemp Research</u> includes academic peer reviewed literature carried out by universities, NGOs and/or government agencies, in relation to the hemp industry.
<u>Cultivar Gene Pool</u> is the range of different hemp cultivation varieties that are approved/certified for cultivation. Includes hemp varieties that are bred for specific traits, climates, soil types, pest resistance or anticipated product markets.
<u>Yield</u> is a measure of the agricultural productivity of a hemp crop per unit area (usually t/ha).
<u>Hemp Knowledge</u> is a general reference to the amount of hemp education gained by the general public, policy makers, investors and farmers. Hemp knowledge does not include hemp expert knowledge which is included under hemp research.
<u>Unsubstantiated Claims</u> refers to exaggerated claims by either pro- or anti- hemp advocates.

Association with Marijuana is fairly straightforward and refers to the continuation of the false association of marijuana (high THC phenotypes) with hemp (low THC phenotypes).
Ability to Obtain Cultivation Permit from government agencies that hold the responsibility for overseeing industrial hemp cultivation.
Industry Credibility in terms of the industry's reputation as seen by academics, general public, politicians and as portrayed in media sources.
Available Non-Food Arable Land is the area of agricultural land that is not dedicated for the cultivation of food crops and is location and climate dependant.

An increase in environmental awareness will result in an increased use of renewable resources in order to reduce pollution, required energy, and material input into processes as well as to reduce non-renewable resource depletion. An increase in use of renewable resources will lead to an increase in both the demand for hemp and hemp knowledge as society searches for low input and low impact alternatives to conventional resources. Increased demand will lead to a larger industry to meet consumption needs therefore more and improved infrastructure will also result. A reinforcing loop exists between the hemp industry and the infrastructure because as the industry expands, more infrastructure will be required for processing and distribution. As the infrastructure improves more investors, farmers and businesses will become interested in and thereby increase the industry. Larger hemp infrastructure leads to a larger supply of hemp product to the market.

The traditional supply and demand economic relationship, in general, will not hold true for hemp products. Increased hemp supply will decrease the product price; a decreased product price will decrease the supply with a balancing loop. However, an increased product price will not increase demand, but rather decrease demand which has balancing effect on the product price. Additionally, a larger hemp infrastructure will lead to a reduction in transport distances due to more processing and manufacturing facilities, and improvements in the processing methods, thereby reducing the hemp product cost. A decrease in product cost will lead to an increase in hemp's competitiveness to alternative raw materials, thereby increasing the demand. This will be especially true if environmental/ecological economic theory is applied. Also, if the product costs increase, product price will increase as well.

As the number of farmers, processors and manufacturers increase (with an increase in the hemp industry); the desire to improve yields and technologies becomes stronger. Therefore an increase in the hemp industry will lead to an increase in research. Hemp research then affects a number of variables in the system. Firstly, there is a positive reinforcing loop between hemp research and the industry. As research increases more people become interested in the industry and it will grow as a result. Secondly, hemp research will lead to an expansion of the hemp cultivar gene pool. An increase in the hemp cultivar gene pool should lead to better adaptability under various conditions and therefore increase the hemp yield, thereby improving the economic competitiveness of hemp as a raw material. Thirdly, hemp research will increase hemp knowledge and a positive reinforcing loop exists between these two variables as well. The use of renewable resources will also lead to an increase in the general level of hemp knowledge. As the general level of hemp knowledge increases, the association with marijuana will decrease as people learn about the differences between the plants. As hemp's association with marijuana decreases, the hemp industry credibility increases. An increase in industry credibility, in turn, will increase the action of governing bodies to allocate cultivation permits.

The factor association with marijuana also affects the ability to obtain hemp cultivation permits. As long as hemp is associated with marijuana it will be impossible or difficult to obtain growing permits from the ruling bodies. Once the association decreases, the ability to obtain hemp permits should be easier and the hemp industry and hemp research will increase due to more land under cultivation and more experience gained within the industry.

Returning to look at hemp research, it affects a fourth factor which is the volume of unsubstantiated claims. These claims turn into exaggerations of the capability of the hemp industry which negatively affects the credibility of the industry. If the industry's credibility is diminished then the industry itself will be cut back, and vice versa. Economic competitiveness can also affect credibility. If more products are made using hemp as a raw material due to manufacturer demand (rather than consumer demand) then the industry will become more appealing in general and their credibility will improve. Arable land available for non-food production is another limiting factor of the hemp industry. The larger the hemp industry, the less available non-food arable land will be. This is balanced by the fact that the less land available, the smaller the industry will be, or at least it will experience slower growth rates.

6.3.2 Time Perspective

From the CLD, the variables which affect the hemp industry directly are: Industry Credibility, Ability to Obtain Cultivation Permit, Available Non-Food Arable Land, Infrastructure, Research and Demand. Some of these factors are causing a more immediate restraint on the industry than other factors which seem to come into effect once the industry has reached a certain growth point. Therefore, in order to determine which limitations can be addressed first, in terms of a time sequence, the near, mid and long term limitations have been separated and identified in Table 1. The columns increase in time from left to right, however, the factors in rows are in given in no particular order. The variables near, mid, and long term refer to the amount of time it will take the industry to reach a certain level of 'optimum' growth. The following will consider the factors mentioned above and break the discussion down into examples based on the current situation and what the most likely outcomes will be.

Table 1.Variables to Address in Time Sequence in Order to Facilitate Hemp Industry Growth

Near Term	Mid Term	Long Term
Ability to Obtain Cultivation Permit	Infrastructure and Technological Issues	Available Non-Food Arable Land
Industry Credibility	Demand	Research
Research	Research	---

Near term can be defined as the point where the level of research has improved and spread to disciplines outside of the current topics; where industry credibility is not a concern of constant questioning; and where the ability to obtain a hemp cultivation permit is on par with other agricultural crops. To move from the current industry situation into the near term scenario, the social issues must first be addressed. This includes improving the general hemp knowledge, reducing unsubstantiated claims by making the industry more professional and in turn reducing the association with marijuana. It is anticipated that these changes can be reached within the next decade, motivated by the current growth of the industry and research efforts.

Mid term refers to a point in the growth of the industry where the number of processing and manufacturing facilities have increased and the distance between the fields and the facilities is small; where the demand for both hemp as a raw material and consumer products are significantly improved due to reduced product price and cost coupled with an increase in economic competitiveness. To move from the near term to the mid term will require an improved cultivar gene pool that can increase yields and hence economic competitiveness and an increased industrial base that has the resources to support an expanded infrastructure.

It is anticipated that this level of growth in the industry will take 10 to 30 years depending on the status or level of establishment of the hemp industry in a given country.

Long term refers to a level of optimal growth of the hemp industry or market saturation which is limited by economic factors and the amount of available non-food arable land for hemp cultivation. The transition from mid to long term growth will require significant improvement in infrastructure paired with a significant rise in demand for hemp and hemp products due to improved economic competitiveness and lowered production costs. This situation is anticipated to occur 30 to 50 years in the future.

6.3.3 Markets and Future Possibilities

Currently, the hemp industry plays a minor role in renewable resources use and its role is even smaller in the natural fiber and food markets. However as has been shown, there exists potential for hemp as a renewable resource due to many favourable qualities. During the nineties, hemp production remained fairly stable with only minor fluctuations (FAOSTAT data, 2005) that can be attributed to subsidies (Karus, 2005) and the lifting of prohibitions in many countries. According to Roulac (1997), world wide hemp sales during this time grew exponentially, not including China. In order to push the industry into a more professional and competitive role, amendments need to be made to the industries restraining forces as previous mentioned. Hemp has shown to meet social and environmental aspects relating to sustainable agriculture, but the economic aspects need more careful examination and this is the justification for the details herein.

It is difficult to predict the future trend of the hemp industry, and particular markets that it may expand into due to its thin horizontal coverage, multiple uses and inherent locality of the industry. It is suggested that markets for hemp products will follow a combination of recent market trends for organic produce, renewable resources and energy, natural fibers, and oilseed crops. Markets in both organic produce (FAO, 2001) and renewable energies (WEA, 2000) are currently on the rise, as concerns over environmental and human health issues become more prevalent. The production of natural fibers has been fairly rising steadily over the last 40 years but is almost entirely attributed to an increase in cotton production (FAOSTAT data, 2005). Primary oil crop production has been rising exponentially since 1961 (FAOSTAT data, 2005). According to Roulac (1997), hemp demand is currently outpacing supply, therefore future market growth is inevitable. According to Marcus (1998), hemp market returns are based on the following factors, "crop quality, suitability for intended end use, amount of value added processing that the crop has been subjected to, available quantity of similar crops and substitutes and proximity of producer to end user."[18] Based on market trends and limited experience in producing countries, market predictions for the near, mid and long term scenarios as previously defined, will be given below.

First of all a brief overview of the current hemp industry is necessary. Overall, world hemp yields of both fiber and seed have dramatically increased in the last 15 years (FAOSTAT data, 2005). This trend illustrates that recent advances in hemp research have been beneficial to the industry, making the economics more desirable. Hemp fiber products are the dominant goods of the European hemp industry; including pulp and paper, building and insulation, and automotive bio-composites markets given in decreasing order (Karus, 2005). In Canada, hempseed applications dominate with hemp foods and animal feed being the largest markets (Small & Marcus, 2002). This is due to the lack of fiber processing facilities in North America. China is the largest hemp producer of both hemp textiles and seeds and they continue to supply world markets with a wide array of value added products (Conrad, 1994).

[18] No page numbers given, online document.

Near Term

In the near term, markets for hemp products will experience slow growth due to the continued emergence of the industry. Conrad (1994) proposes that this 'plateau stage' will continue until profits are seen. Therefore, growth in this stage will consist mainly of vertical growth, which will be localized to further developing the hemp industry in countries that are currently involved in hemp production. In part, this is due to lag times with the development of harvesting, processing and manufacturing technology (Small & Marcus, 2002), as well as lag times associated with consumer education. The near term is the most important for hemp companies in terms of marketing tactics - to remove the image of the forbidden fruit in order to appeal to a larger audience than just the counterculture (Roulac, 1997).

According to Karus (2005), major European hemp markets are expect to see growth in the near term, except for specialty paper. These include automobile biocomposites, construction materials, horse bedding and birdseed markets (Karus, 2005). Research in Europe and North America will improve local cultivar breeding as well as the technology used for harvesting, processing and manufacturing hemp. North American markets present a unique opportunity for expansion of Canadian hemp cultivation based on the fact that North America currently holds the largest markets for finished hempen goods (Conrad, 1994). Traditional hemp textile production is expected to continue from China and Korea. Due to current community and hemp industry lobbying (Olsen, 2004), it should be expected that the ban on hemp foods in Australia is lifted in the near to mid term. The lifting of this ban is also fueled by the fact that Australia has no fiber manufacturing facilities and in order to make the hemp industry an economically viable one, hemp food production offers a low tech, but value added, starting point.

Mid Term

By the time the hemp industry reaches the mid term point, market shares are expected to have expanded and diversified both vertically and horizontally. Small and Marcus (2002) suggest that it takes at least 10 – 15 years for an industry associated with new agriculture crops to 'mature'. This would apply to countries which have recently lifted prohibition such as Sweden, Canada and Australia. In addition, this also has implications for hemp producing countries that are interested in manufacturing higher quality hemp products such as garment quality textiles. Industrial hemp markets will become more stable with advances in the gene pool (Ranalli, 2004) and have more experience to draw upon in terms of cultivation, product standards and quality, annual supply variations, markets, trade, etc.

In Europe, it can be expected that fiber markets will rise and expand offering more competitive consumer products such as garments from local producers instead of importing from hemp textiles from China and Russia. This is in part based on an EU funded three year study called HEMP-SYS started in 2002, aimed to promote the development of a competitive hemp textile industry in Europe (van der Werf, 2004). A considerable market potential is expected to remain in European car manufacturing and in the insulation industry as long as hemp fibers remain competitive with imported bast fibers (Karus, 2005).

Based on a recent USA legislative proposal to exempt industrial hemp from the CSA in addition to the number of individual states that have already implemented hemp legislation (Rawson, 2005), it is predicted that an operational domestic hemp industry in the USA will exist by this point in time. It is suggested that hemp food and body care products in North America will receive a substantial share of the natural product markets based on the existence of oilseed processing facilities, particularly in Canada. The cultivation of dual purpose crops, requires that markets be found for the fibers if the hemp seeds are to be used in food or body care products. Due to the large automotive industry in North America and the current interest in utilizing hemp as a biocomposite, it is not unreasonable to suggest that the American automotive industry, like it's European counterparts will lean towards increased hemp usage in its biocomposite production.

Long Term

Long term futures are the most difficult to predict due to unforeseen circumstances that could change the assumed path towards an increased use in renewable resources and the aforementioned environmental and social sustainability of hemp. However, long term projections include anticipating a shift towards more bio-based economies, thereby increasing the demand for hemp products, which will curb once market saturation is reached. Competitively speaking, it is possible for hemp to acquire a significant portion of the competing markets such as flax, linseed and fiber glass by this point. This is based on technical suitability, superior environmental performance and economic reasons. Cotton will be displaced by hemp production to some extent, although not significantly, as the technology required to effectively separate hemp fibers is far behind. Cotton has also become a major crop in many regions that are not suitable for hemp production and the retraining of textile industries to accept an alternate raw fiber would not be an easy or quick task. Therefore, in the case of textiles it is assumed that cotton will remain the dominant fiber crop, with organic cotton rising to larger market shares of the textile industry than hemp will.

Hemp, however possible, is not expected to replace wood for pulping purposes as the large scale technology required is not in place to indicate a trend in this direction (Fortenbury & Bennett, 2004; Karus, 2005). In terms of biomass, hemp has shown to be only average in this arena and has higher value as a material rather than a fuel source (Rawson, 2005). Therefore, biomass markets for hemp are not expected to develop past the incremental revenue expected from its use as an agricultural waste in the case of hemp seed crops (Marcus, 1998).

In the long term it is also expected that more countries, especially developing ones, will join the global hemp industry. More participation is expected at this point from areas that have suitable climates and histories of hemp cultivation such as Lao, Cambodia, Thailand, India, South Africa and South American countries as well (Conrad, 1994).

It is suggested that in the long term most of the uncertainties faced today by the hemp industry will be a thing of the past. The regulatory barriers surrounding current hemp cultivation will be practically non-existent as hemp becomes a known agricultural rotation crop in suitable regions. The industry will be more widespread, with processing facilities distributed in rural hemp communities. However, for hemp to remain profitable businesses must foster innovation and creativity in order to fiend competition from more well-established crops (Roulac, 1997; Fortenbery & Bennett, 2004).

In the end, markets do not form themselves and it is matter of question, whether these markets are output motivated or demand directed. Environmental awareness, knowledge and social and economic concerns will help to inform consumers, but ultimately it is up to entrepreneurs, small business and multinational companies to take advantage of new consumer needs. Businesses are changing fast and adapting to consumer interest, needs and demands requires being more socially and environmentally responsible. Hemp has become a marketing icon for youth, environmentally conscience and health savvy consumers. Large brand names are experimenting with hemp by incorporating hemp in their product lines. Such well known companies include: Adidas, Calvin Klein, Ralph Lauren, Giorgio Armani, Patagonia, BMW, Daimler-Benz, and the Body Shop. If these well known brands continue to carry hemp lines and cater to consumer needs with innovation, the industry will grow and become more affordable for consumers and more attractive to investors.

6.3.4 Developing Countries Consideration

The majority of this thesis has focused on issues surrounding the current state of the hemp industry in developed countries; however, further consideration should be given to the role that developing countries play. This is based on the large market share of hemp production coming from developing countries. From 1961 to 2004, the fraction of hemp fiber and tow production in developing countries has increased from 23 to 67 % of the world production volumes (FAOSTAT data, 2005). During the same period, hempseed production from developing countries also increased from 44 to 84 % (FAOSTAT data, 2005).

Due to the availability of cheap labour in developing regions, hemp production could provide an alternate cash crop for local economies. In addition remote rural villages could improve community self sufficiency by meeting fuel needs. Communities can also provide themselves with an alternate source of protein and vitamins, if the dual crop harvest is taken advantage of, as is recommended. In terms of housing, building materials made with hemp composites are more natural disaster proof than wood based shelters, due to flexibility and impact resistance. This is advantageous to developing countries that often lie in the path of natural disasters. The reduction in environmental stress would be advantageous to developing countries where soils are often stripped of nutrients due to more intensive cash crops.

The most immediate issue that developing countries face is the fact that hemp thrives in temperate climates and the majority of developing areas lie in tropical or subtropical climates. There is still hope for these areas to cultivate hemp because as previously mentioned; research into cultivars that are suitable for these climates is under investigation (Ditchfield *et al.*, 1999). In addition due to warmer climates, more than one hemp crop per year is possible and may offset reduced yields. The cultivation of industrial hemp could provide developing countries an avenue away from following the industrialization path that has proved to be environmentally and even social devastating in many developed areas.

6.3.5 Recommendations

Given the previous information it is appropriate to identify what recommendations can be made in order to ensure hemp market demand and future market growth of the industry thereby meeting the projections. These recommendations are for the current state of the hemp industry in order to move it into the near term scenario. Using the interrelationships identified from Figure 12, some methods of increasing the demand for hemp products include increasing hemp's infrastructure, reducing product cost and price, improving hemp's economic competitiveness in addition to an increased use of renewable resources.

Local profitability's are the most important issue in order to bring down the cost of manufacturing and therefore the price of finished goods. Farm gate profitability can be increased with dual purpose crop production, reducing or eliminating additional fees associated with permits, THC testing or other security measures. Hemp research focusing on breeding for varieties with better qualities will improve yields for farmers. Public outreach and awareness programs coupled with local production and retailing will encourage an increase in local consumption and thereby hemp demand. Environmental or ecological economic theory will improve the economics of hemp products considering it's sustainability on social and environmental fronts. Technological advances sparked by research initiatives will improve the economics surrounding harvesting, processing and manufacturing hemp products. At the current state of the industry, addressing social issues and stimulating hemp research are viewed as the most important recommendations in order to increase market shares.

7.0 Conclusions

The history of *Cannabis sativa* L. cultivation has been extensive and lead to numerous innovative products derived from hemp fibre and oilseed. Recently, research into using industrial hemp as a renewable resource has presented a plentitude of opportunities for improving environmental, social and economic conditions in areas where it is suitable for cultivation. This comes at a time where environmental concerns over the use of resource intensive crops, depleting non-renewable resources, resource supply, as well as the loss of the family farm due to industrialization, are national priorities. Industrialization has moved developed nations away from agricultural production, however, national economics can be made more stable if a balance between agriculture and industry can be found and taken advantage of. It is not a battle between the two, but rather a partnership that can be beneficial for both communities and industries alike.

Hemp can provide an alternative renewable resource and contribute to sustainability in developed and developing nations if based in sustainable agriculture systems. The sections on sustainable agriculture showed that hemp does indeed meet the environmental and social requirements of sustainable agriculture but the economics appeared uncertain and related to or dependant on many of the barriers and industry limitation addressed.

A holistic system analysis approach taken to evaluate the hemp industry revealed many obstacles to overcome if industrial hemp is to obtain larger market shares. Such obstacles are the remaining bureaucracy surrounding hemp which has been negatively affecting the ability to obtain cultivation permits, especially pertinent to the USA and in American-influenced nations. There also remain some technological and infrastructural related issues that are at economic odds with advances in competing product manufacturing due to prohibition time. Advances in industrial hemp research are a key actor in improving yields, technology, and knowledge associated with industrial hemp cultivation. In addition the industry's credibility is an important factor to overcome in terms of consumer and investor acceptance.

Further investigation into the market potential of hemp, reveals future economic opportunities. It is suggested that near term growth of the hemp industry will consist mainly of vertical rather than horizontal growth, while areas that are currently cultivating hemp improve methods and expand hemp related industries. In the mid term, it is expected that more nations will have begun to experiment with hemp cultivation and the infrastructures will be in place to sustain a considerable increase in hemp cultivation. Also at this time, is it projected that hemp seeds and oil products will play a much larger role in natural foods and body care, due to the excellent nutritional and dermal characteristics. In the long term, hemp as a raw material is expected to gain significant market shares of competing products. Developing nation participation will also have increased, both in shear number of producing countries and harvests, leading to improved sufficiency of rural communities.

Recommendations to accelerate industry's growth include a variety of initiatives, but most immediately relevant are the need to address the social stigma to improve demand as well as research efforts aimed at improving farm gate profitability. The hemp revival is currently in its early stages but gaining momentum. Renewed academic, public and government interest is expected to lead to increased demand and expansions of the industry. If the recommendations are applied and effectively used to reduce the industry's obstacles, the economic outlook for the industry will substantially improve in the near term, especially if bioregional economics is employed. In conclusion this study has shown that industrial hemp can indeed play an important role in sustainable agriculture - environmentally, socially and ultimately economically.

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