Hemp (*Cannabis sativa* L.) as an Alternative Fibre Source for Nova Scotia

by

Sara K. Francis

Submitted in partial fulfillment of the requirements for the degree of Master of Environmental Studies

at

Dalhousie University
Halifax, Nova Scotia
December, 1996

0-612-24965-4

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The forest industry and the pulp and paper industry have been under attack in recent years for unsustainable and environmentally degrading practices. There has thus been a call for alternatives to these practices in Canada.

There is also concern within the agricultural industry in regard to soil loss and degradation, an increased dependence on chemicals, the environmental effects of using such chemicals, and the vulnerability of monocultures to disease and pest outbreaks.

Hemp, the industrial variety of the plant *Cannabis sativa* that has no narcotic value, is presently banned in Canada under the Narcotics Control Act. However, hemp has been identified as a potential alternative fibre source for the pulp and paper industry due to its high potential yields, resistance to disease and pests, and industrial quality. Hemp is further being promoted as a crop that could fit into farmers rotations, improve soil conditions, and decrease the need for chemical inputs, in addition to being a source of non-wood fibre.

This thesis research consisted of three goals: to collect information on the cultivation of industrial hemp, to determine the suitability of hemp as a crop for Nova Scotia; and to compare the potential of hemp to contribute to a sustainable agricultural system.

The main findings revealed that hemp is a suitable crop for Nova Scotia and also has a high potential to contribute to a sustainable agricultural system. Hemp also has high potential fibre yields in comparison to other fibre sources. However, there is a severe lack of information available on the cultivation and processing of industrial hemp.

Presently the greatest barrier to the development of a hemp industry in Canada is the legal aspect. When industrial hemp is legally distinguished from recreational *Cannabis* it will make way for a Canadian commercial industrial hemp industry.

GLOSSARY

Agri-pulp: pulp made from agricultural crops or residues

Breaking: process to break the hurds into smaller pieces in order to allow scutching

Decorticator: machine used to separate hemp bast fibre from the inner woody core

Dioecious: having separate male and female plants

GIS: Geographic Information Systems

Hurds: inner woody core of the hemp plant

Intercropping: two or more crops in one field at the same time

Mcnoecious: having both male and female organs on the same plant

Polygon: small map unit that is coded with attributes of the area it represents

Relay cropping: overlapping of crop cycles

Retting: decomposition of substances that bind hemp bast fibres and hurds together

Scutching: semi-mechanical 'combing' process to separate the bast fibre from the hurds

ACKNOWLEDGEMENTS

This thesis was facilitated by numerous people and their belief that this was a topic that needed to be addressed. Over the past two years a quirky idea turned into a full-scale project that has miraculously been completed.

I thank my committee for supporting my desire to investigate hemp; Ray Côte for attempting to convince industry and government that this was a timely topic; Dr. Ken Beesley for contributing that Social Science perspective; and especially Dr. Ralph Martin for providing continuous support, challenging my thinking, and always keeping me on track.

There were numerous people who patiently answered a multitude of my e-mail requests. Included in this list are: Gary Patterson, for teaching me everything I wanted to know about Nova Scotia's soils; Trevor Ruthman, for explaining the secrets of forestry and pulp and paper production; Patrick Girouard, for sharing his knowledge of switchgrass; Dave West and Hayo van der Werf for clarifying the intricacies of the hemp plant; and many other 'hempsters' around the world.

A thesis has proven to be a rewarding experience, and this completion would not have been achieved without the encouragement from friends and family. So I thank: 'the core' for providing me with inspiration and showing me the way; my mom for suggesting this topic in the first place, and doing extra work so that I didn't have to; my dad for those endless queries, edits, and grammar lessons; and Terry for believing in me and teaching me to persevere. The Eastern star shines brightly tonight.

1. Introduction

1.1 The Issue

The forest industry and the pulp and paper industry have been under attack in recent years for unsustainable and environmentally degrading practices. There has thus been a call for alternatives to these practices in Canada. Hemp has been identified as a potential alternative fibre source for the pulp and paper industry due to its high potential yields, resistance to disease and pests, and industrial quality.

There is also concern within the agricultural industry in regard to soil loss and degradation, an increased dependence on chemicals, the environmental effects of using such chemicals, and the vulnerability of monocultures to disease and pest outbreaks. Hemp is further being promoted as a crop that could fit into farmers rotations, improve soil conditions, and decrease the need for chemical inputs, in addition to being a source of non-wood fibre.

1.2 Statement of Purpose and Objectives

The purpose of this paper is to evaluate hemp as an alternative fibre source that reduces the current impacts of forestry and agriculture on the environment while meeting the fibre needs of the Nova Scotia pulp and paper industry.

The objectives of this thesis are to examine the environmental and economic potential for industrial hemp as an alternative and additional fibre source for the pulp and paper industry in Nova Scotia. The evaluation of hemp's sustainability will be facilitated by comparing and contrasting hemp fibre to other sources of fibre. Hemp is an annual crop and its fibre will be compared to that from: trees, straw, and switchgrass (a perennial crop). This will be done in order to determine the amount of material and financial inputs each source of fibre requires, the yields produced, the various applications of the final outputs, the economic returns of these outputs, and the environmental impact of producing the fibre.

1.3 Research Question

The research question for this thesis is thus: To what extent can hemp fibre be an alternative, sustainable, source of fibre for the pulp industry in Nova Scotia?

The hypothesis states that hemp fibre will be a more sustainable source of fibre than fibre derived from trees, and other annual crops available in Nova Scotia.

1.4 Background Information on Hemp

Cannabis sativa, is an annual plant that thrives in temperate climates. It is a plant that has industrial, therapeutic, and recreational attributes. When referring to its industrial qualities it is often referred to as hemp. Though the word hemp is often used to describe other long agricultural fibres such as abaca, manila and indian hemp, its true meaning refers to the Cannabis fibre (Dewey, 1913). Marijuana, the slang term for recreational Cannabis, is considered a horticultural plant and not an agronomic one. Furthermore, marijuana plants are not useful for fibre production (West, 1996). Hemp has been used for a multitude of purposes for thousands of years and is thought to be the earliest plant cultivated for textile fibre, evidenced by remnants of hemp cloth, found in China, dating back 8000 years before present (BP) (Small, 1979).

It is believed that hemp originated as an Asian plant and made its way westward to Europe around 3500 BP with the Scythians' migration during the Bronze Age. The hemp cutting tool, the scythe, also migrated at this time as did the technology to use hemp (Conrad, 1993). From that time forward, it was used by many countries and cultures for cloth, paper, fishing nets, ships' sails, caulking between ships' boards and anchor ropes. Its resistance to rotting made it an excellent maritime fibre and facilitated exploration of the Western World in the 16th and 17th Centuries (West, 1996). *Cannabis sativa* was also used for religious and medicinal purposes by many cultures, though it is thought that these peoples distinguished between plants for industrial uses and those for recreational or medical uses.

The first people to recognize the potential of hemp for papermaking were the Chinese, around 2150 BP. Buddhist documents have been found that were created from a mixture of bark and hemp rags. The knowledge and art of papermaking spread west with the expansion of trade routes to Egypt (Conrad, 1993).

It is postulated that hemp was introduced to Canada by Jacques Cartier's apothecary, Louis Hebert, in 1606, in the Acadian region of Nova Scotia (Le Dain, 1972) In Canada, during the 1800s, farmers were forced by the King of England to grow hemp in order to supply fibre to make sails for the Empire's ships. Bounties were offered to grow hemp and penalties imposed if hemp was not grown. Hemp cultivation was encouraged in Canada in order to benefit the new settlers. Hemp was even considered to be legal tender. In the Canadian Maritimes, bounties were offered by the provincial governments as the provinces attempted to realize the competitive advantages of growing hemp (Howe, 1892). There were various government schemes to encourage farmers to grow hemp including the distribution of seeds. In 1803 there was a resolution passed in the Nova Scotia Assembly:

> "whereas, the growth and culture of hemp in this province would be of great national advantage" and "a bounty of 30 pounds would be granted to the person who within four years shall in any one year raise the greatest quantity of merchantable hemp in this province, provided the same exceed one ton" (p.2, Howe, 1892)

Technological developments encroached on the hemp market by making other fibre sources cheaper to produce. The cotton gin was invented in 1793, thus eventually reducing the price of cotton and providing a more efficient crop to process for textiles (Le Dain, 1972). The invention of steam power meant that ships powered by steam would no longer require hemp sails and ropes. In addition to technology, in the US, tariffs were lifted against foreign fibres, thus making it more economical to import cheaper tropical fibres than produce domestic ones (West, 1996).

Until 1883, 75-90% of all paper in the world was composed of hemp fibre (Guthrie, 1994), since most paper was made from recycled rags and clothing which were commonly made from hemp. By the turn of the century, more economical and efficient methods for pulping wood chemically had been developed, such as the sulphite/sulphate pulping process patented by the DuPont petrochemical company in 1937, thus further impinging on the demand for hemp (Herer, 1993). Chemical companies had also developed synthetic fibres such as nylon and rayon which were lighter and again less expensive (West, 1996).

During this time hemp was grown almost exclusively for fibre purposes in North America, though there were some reports of the seeds being used for birdseed (Dewey, 1913). In Canada, by 1923, there were six established hemp mills and a seventh was being government financed in Manitoba in order to develop the market in that area (Guthrie, 1994). Hemp's fibres were difficult to extract from the stem and separate from the interior woody core (hurds). The lack of breaking technology needed for the mass production of hemp was a setback in world commerce (Herer, 1993). Hemp was perceived as too labour intensive to process, in comparison to other fibre sources, and hemp production continued to decline.

A renewed hope for hemp was aroused by the development of the decorticator, a machine designed to separate the various hemp fibres more efficiently, in 1914 (West, 1996). This machine could increase the possibilities for hemp processing and allow hemp to compete with cotton and trees (Conrad, 1993). The decorticator would allow much easier separation of the fibre and the hurds. The hurds, once considered a waste product, could now be efficiently recovered to such a degree that they could be pulped for paper production, and the rest of the fibre from the stem could be used for textiles (Dewey, 1916). A Popular Mechanics article in 1938 described hemp as the 'new billion dollar crop', and reported that hemp was the "most profitable and desirable crop that can be grown". At the same time that the decorticator was revealed, hemp became subject to a new public perception that was not able to distinguish between industrial and recreational uses of the *Cannabis sativa* plant (Herer, 1993).

There are several theories about how hemp became illegal in North America, ranging from conspiracy on behalf of the chemical and pulp and paper industries, to racially motivated immigration policies. Herer (1993), in his widely read book "The Emperor Wears No Clothes" on hemp prohibition, describes what he believes to be a conspiracy between Lammot DuPont-head of the DuPont Petrochemical Company and

Randolph Hearst, the timber baron and newspaper publisher. Herer (1993) claims that they conspired with the US government to eliminate the threat of hemp on the wood pulp industry and the new synthetic textiles industry. Furthermore, there were reports published in Hearst's newspapers of Mexicans and African Americans committing crimes while under the influence of marijuana. Whether these reports were accurate or not they inflicted terror on the American public. Herer further describes how these men used their political influence to have marijuana (recreational) equated with hemp (industrial) in order to protect their business interests. The result, in the USA, was that hemp was to be subject to the Marijuana Tax Act, promulgated in 1937. This was to be a prohibitive tax and act as a disincentive to growing hemp. There was a tax for the permit as well as a transfer tax for hemp production and it is thought that these were not equally applied (West, 1996). Though American hemp farmers were reassured that their industry would be protected, this was not to be the case. New evidence suggests that a hemp entrepreneur in Wisconsin may have been part of the legal negotiations as his hemp business continued without interference from the Federal Bureau of Narcotics until 1958, while all other American hemp enterprises were successfully destroyed (West, 1996).

Canada quickly followed the American example, banning hemp under the Opium and Narcotics Control Act of 1938. This was largely due to the influence of Emily Murphy and her book the Black Candle. The book was published as a serial in Maclean's magazine and described the evils of narcotics on Canadian society (Murphy, 1922).

Interestingly, in the initial Opium and Narcotics Control Act, it was *Cannabis indica* that was banned and not *Cannabis sativa*. At the time it was believed that *Cannabis indica* was its own species, originating from India, and was used solely to produce narcotics, while *Cannabis sativa* was used solely for fibre production. Though the species debate continues, it is generally accepted that *Cannabis sativa* is a single species and the indica classification denotes an ecotype or a group (de Meijer, 1992) . This classification will be elaborated upon in the Literature Review. It was not until the 1960s that the chemical tetrahydrocannabinol (THC) was discovered to be the active narcotic agent in *Cannabis sativa*. It is now known that fibre varieties naturally have lower THC levels while the converse is true for recreational varieties. This has allowed genetic engineers to manipulate the Cannabis plant and develop strains that are low THC, but on the same note it has also allowed for the development of high THC plants.

Industrial hemp farmers were caught off guard by the new legislation, and were often not aware that the crops they were growing could be used for recreational purposes. A thesis written by a student of the Ontario Agricultural College, in 1918, outlines the potential for industrial hemp in Ontario. In his thesis there is but a brief mention of Indian hemp (*Cannabis indica*), and only to explain how it is different from fibre hemp. There is no discussion of the legality of growing industrial hemp (Maxwell, 1918).

Howard Fraleigh was one of the first recorded commercial hemp growers in Canada. In the early 1900s he began an experimental project on using hemp for weed suppression after hearing that this was being done in the United States. His experiment was progressing well and he had a goal of moving toward large-scale production until he was forced out of production by the government in 1937 (Guthrie, 1994).

In Canada, it became illegal not only to grow hemp but also to possess hemp, and any products derived from hemp. Interestingly, hemp fibre was still imported into Canada for cordage production and the Department of Supply and Services continues to list several products for government use that must be produced from hemp fibre.

The ban on hemp was lifted during the Second World War, as shipments of tropical fibres were cut off. The ban, however, was re-instated immediately following the end of the war. During that time the USA saw a resurgence of the hemp industry as farmers were encouraged to apply for a special marijuana[1] growing permit to aid the war effort. Several new hemp mills were built in the USA to process hemp (Herer, 1993). In Canada, although commercial production of hemp did not resume, research on yields, breeding, and agricultural characteristics was undertaken at research stations across the country (Gehl, 1995).

[1] By this time, hemp and marijuana came to be synonymous in the eyes of the government and public.

Many European countries lifted the ban on hemp in the early 1990s and now France, England, Germany, and the Netherlands are reviving their hemp industries. In countries such as China, Russia, Hungary, and the Ukraine, hemp was never prohibited and while production had declined in these countries they now have the edge over others just entering the market. Imported products from these hemp growing regions have provided an impetus for Western countries to revitalize their hemp industries.

In 1961, the Canadian Narcotics Control Act, which replaced the Opium and Narcotics Control Act, was modified to allow Cannabis to be grown for research purposes only at the discretion of the Minister of Health. It was this modification that paved the way for hemp to be grown in Canada again. However, it was not until 1994 that industrial hemp was again grown legally in Canada. Joe Strobel, a tobacco farmer in Southern Ontario decided that he wished to grow industrial hemp to supplement his farm income. In 1994, he, and his business partner Geof Kime, were granted a research permit- the only permit type currently available, for 18 acres of industrial hemp (Sumach, 1995). Though they had originally requested 100 acres to be spread over 18 plots of land, the government limited their request due to concerns over the legal enforcement and management of the crop. The seeds were imported from Hungary and were certified to be a low THC variety. Based on the success of their crop, other farmers followed suit. In 1995, there were 35 acres of industrial hemp grown in Canada, in 4 provinces, Ontario, Manitoba, Saskatchewan, and Alberta (Langtry, 1995). In 1996, many of these farmers applied again to continue the research on growing hemp in Canada. Health Canada continues to regulate all permits, which are granted on an annual basis and granted only after fulfilling certain conditions. (Appendix A).

1.4.1 Hemp in Nova Scotia

Aside from being the first location in Canada where hemp was cultivated, Nova Scotia has an interesting hemp history. Early settlers of Nova Scotia regarded both flax and hemp as important crops to cultivate and often selected the agriculturally favourable conditions of the Annapolis Valley as reason to settle there (Hockey, 1967). In 1873, it was reported that Queens County in Nova Scotia was "admirably adapted for the cultivation of hemp" (More, 1873).

The Federal Division of Economic Fibre Production was established in 1918 and during the period of 1922 to 1936 the equivalent of 235 site years of field research on hemp and flax were conducted across Canada (Hockey, 1967; Gehl, 1995). Hemp and flax trials were conducted at the Agriculture Canada Research Stations in both Nappan and Kentville during the period of 1923 to 1929.

This research indicated that both flax and hemp gave satisfactory yields of fibre when they were well fertilized. The main factor that limited the development of a large scale hemp industry in the Maritimes was the lack of local processing facilities. The fibres had to be shipped to Quebec or Ontario, thereby reducing the value of the crop to Nova Scotia growers (Gehl, 1995). These experimental plots were discontinued after 1929.

The research concluded that the areas in Canada with the highest hemp fibre production potential were in Nova Scotia and the Eastern Townships of Quebec (Gehl, 1995). This was due to the high moisture availability for both growth and retting purposes, as compared to the Prairies.

1.4.2 The Legal Issue

The legal issue is currently the main obstacle to a large-scale hemp industry in Canada. The legal debate focuses on the presence of THC (delta-9-tetrahydrocannabinol) in *Cannabis sativa* plants. THC is generally accepted to cause the psychoactive properties of Cannabis preparations. In recreational hemp (marijuana), the THC amount ranges from 3% to 30%, while in industrial hemp it is below 0.3%. Below 0.3% the narcotic potential is deemed to be negligible (de Meijer, 1995). The ability to distinguish between THC levels within varieties is part of the debate over the classification of *Cannabis sativa*.

It was originally believed, at the time of Linnaeus, that there were three distinct species of *Cannabis*; a fibre species (sativa), a narcotic species (indica), and a wild species (ruderalis). It is now believed that there is only one *Cannabis* species that may possibly have subspecies. It is not known whether these subspecies really do exist or if they are simply ecotypes (Small, 1979). An example of *Cannabis sativa* consisting of ecotypes as opposed to multiple species is apparent in the fact that there have been estimates of higher concentrations of cannabinoids in the same varieties when grown in a continental climate rather than in a maritime climate (de Meijer, 1995).

Genetic researchers have succeeded in developing low-THC varieties, and they have no qualms that these new varieties, while having a stable minimum THC content, or even absence of THC, will continue to have high-yields, and resistance to pests and infections (Virovets, 1996).

The Controlled Drugs and Substances Act was passed by the House of Commons, on October 30th, 1995 and by the Senate in May, 1996. At the time of writing, the bill is still waiting for Royal Assent before it becomes law. This Act, while increasing the penalties for possession of marijuana, allows the Minister of Health to develop a framework for the commercial cultivation of industrial hemp in Canada. An amendment to the bill was included by the Senate, thus when the Bill becomes law it will no longer be illegal to be in possession of mature hemp stalks, and products derived from industrial hemp. While this could be seen as a landmark victory, it was hoped that the Government would remove industrial hemp altogether from the Controlled Drugs and Substances Act.

Farmers immersed in the newly emerging hemp industry wish to be able to grow commercial crops of hemp as opposed to crops for research only. They claim that they have now done their research and want to apply it on a large scale (Guilford, 1996). However, the debate continues as the Canadian government states that it requires the support of industry to demonstrate demand for hemp products (Charest, 1996), while industry hesitates to deal with a substance that is regulated by the Criminal Code. Until this can be resolved, no commercial permits for hemp will be granted. The amendment to the bill, however, means that industries wanting to do tests on hemp stalks will no longer have to apply for a permit and thus they may be more willing to perform hemp trials and invest in research and development of hemp products.

The inability for some people or groups to distinguish between hemp and marijuana continues to frustrate the hemp industry. There is an apparent hesitation to accept the fact that hemp varieties cannot be diverted for drug use. According to an industrial hemp researcher; "Hemp does not become smokeable, no matter what you do to it. We must be careful not to give credence to the rampant world-wide belief that hemp is divertible, or ever was." (West, 1996). This perception needs to be overcome in order for an industrial hemp industry to flourish in Canada.

1.4.3 Current Hemp Initiatives

Hemp advocates claim that any product made out of wood or petroleum can be made out of hemp. Hemp is also a crop that overall requires less chemical inputs than other crops, and can be processed less intensively (Conrad, 1994). Thus, as consumers look for more environmentally friendly products, hemp appears to be a part of the solution, whether it be for clothing, shoes, cosmetics, or paper products, to name a few.

There are several hemp organizations that have developed throughout the world over the past few years and none of them would dispute the fact that a market for hemp products exists. The fact that numerous publications dedicated to the advancement of hemp and its products have been initiated in the past few years documents the reality of the hemp market. Magazines such as *HempWorld* and *Hemp Times* are forums for the promotion of hemp products and the industry, while the International Hemp Association Journal contains original hemp research and proclaims itself as 'dedicated to the advancement of Cannabis, through the dissemination of information'. Organizations have also developed in several countries to lobby the respective governments to change the regulations governing industrial hemp. In the United States, groups are lobbying individual States to pass legislation to allow the commercial cultivation of industrial hemp. In Canada, the Canadian Industrial Hemp Council was formed to "champion the development of a regulatory framework for industrial hemp in Canada".

2. Literature Review

The Literature Review consists of a discussion of; the availability of wood and non-wood fibres in Canada and the implications of using these fibres for pulp and paper production, botanical characteristics of the hemp plant, the agricultural and economic characteristics of growing hemp, and the components of a sustainable agricultural system.

This section introduces the characteristics of selected wood and non-wood fibres in order to allow an evaluation of the economic and environmental sustainability of these fibres in the Discussion section.

2.1 Forestry & the Pulp and Paper Industry

Hemp is often promoted as 'the crop' to save the forests (Herer, 1993; Conrad,1993). Aside from why hemp is 'the crop' this statement begs the question 'why do the forests need to be saved'? Information will be presented in this section about forestry and its association with pulp production in an attempt to answer the aforementioned question. While some general information about forestry will be included the focus will be on forestry within Nova Scotia.

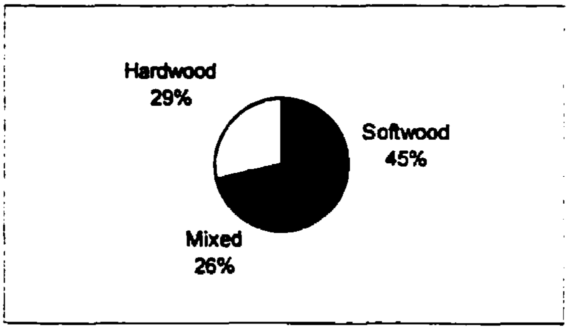
It has been customary for environmentalists to accuse the forestry industry of 'not seeing the forest for the trees'; implying that trees are the only element of value within forests. It is reported that in the 1950s and 1960s a decision was made in Nova Scotia to manage forests exclusively for pulpwood (Orton, 1983). An action such as this reinforces the fact that trees are only valuable for the fibre they produce. The views of the forest industry are countered by environmental groups who perceive that forestry is becoming increasingly intensive and decreasingly sustainable. Environmental groups are demanding that value be assigned to the whole forest and its components not simply the trees (Orton, 1991).

In most forests, over 95% of the biomass is in the woody tissue. This material is both shelter and food for a large array of organisms (Hunter, 1990). When trees are removed so to is the habitat for many organisms. This is often interpreted to be a negative action, yet one can argue that:

> ...when you destroy the habitat of species X you create habitat for species Y. Forestry practices do not destroy ecosystems; they only alter them and thus change the assemblage of species comprising the ecosystem (Hunter, 1990).

For some, this practice of altering ecosystems is seen to be negative when the changed landscape must be doused with chemicals in order to get rid of the species which are viewed as undesirable. Since the decision was made to manage Nova Scotia's forests primarily for pulpwood, the Acadian mix of trees has changed in some parts of the province from what used to be a mix of hardwood and softwood species to a predominantly softwood composition (Figure 2-A), especially in Eastern Nova Scotia (Eaton *et al*, 1994). The development of tree plantations has also led to an increase in the

Figure 2-A. Nova Scotia Forest Mix



amount of herbicides used to maintain these plantations. Over the past 10 years the amount of herbicides used in the Atlantic Region has increased by over 50% (Eaton *et al*, 1994). In Nova Scotia typical hardwood species are sugar maple, red maple, yellow birch, beech, and white birch, while the most prevalent softwood species are red spruce, balsam fir, white spruce, white pine, and red pine (Coalition of NSFI, 1996).

The preponderance toward softwoods results in a composition ideal for the Spruce Budworm. In the past, the mixed forest stands offered a natural barrier against Spruce

Budworm invasion, now with even-aged stands of similar species this barrier has been removed (Orton, 1991).

In order that the forest industry does not lose substantial quantities of fibre to this pest, controls are used to eliminate the Spruce Budworm. Chemical preparations have been the most popular control method used, however, these preparations often kill more than the target species (Pimmental, 1995). In the most recent outbreaks, a bio-control has been used in Nova Scotia to control the Spruce Budworm. The bacteria *Bacillus thuringiensis* variety kurstaki (Bt or Btk) was at one point even supported by environmentalists (May in Orton, 1983). It is now known that Bt, was not dealing with the underlying cause of the Spruce Budworm population (even-aged stands of mature balsam fir and spruce trees) and, furthermore, it causes blood-poisoning in the Lepidoptera family (moths and butterflies), thus entering the food web (Orton, 1983). Examples such as this are only fuel for the environmentalists' fire.

In fact, planting monocultures of trees is not a recommended practice, though it conflicts with pulp fibre maximization. A book written expressly for forest managers suggests that substantially increasing the extent of conifer stands should be avoided. (Hunter,1990). Nova Scotia's Forest Policy indicates that it wishes to double the forest production by the year 2025 yet does not suggest how this can be attained without maximizing softwood stands (NSFI, 1996).

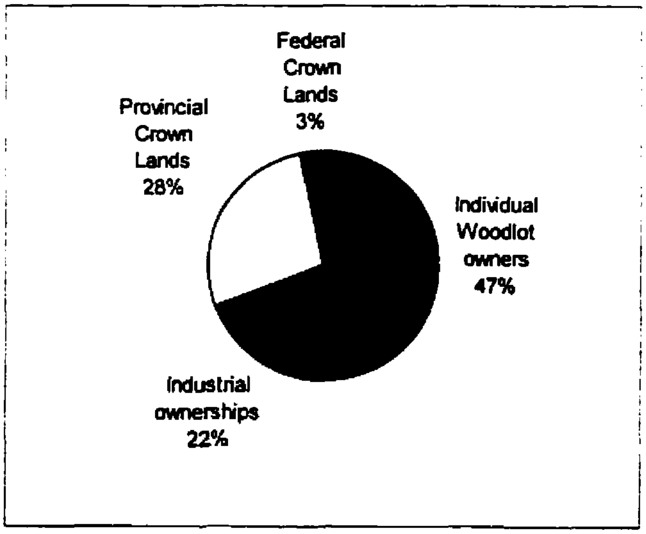
Although the Nova Scotia government has not formally designated any tree plantations in the province, stands managed exclusively for softwoods are essentially this (Eidt, 1996). When natural forests are replaced with plantations the diversity of flora and fauna is reduced, decreased diversity can lead to a lower resistance to environmental stresses (Hunter, 1990).

Diversity is also expressed in terms of the age composition of forests. Old forests represent the most biologically diverse portion of forest succession. Hunter (1990), recommends that, ideally, old forests would occupy a significant part of the landscape, and yet Nova Scotia's old forests[2] represent only 0.6% of the province's forested area. The principal reason for this lack of old forests is that forests become economically mature before they become biologically mature (Hunter, 1990).

The forests are extremely important to Nova Scotia's economy. Seventy-five percent of Nova Scotia is forested, and 95% of this is considered productive (NSFI, 1996). These forests support pulp and paper mills, sawmills, and secondary wood product manufacturing facilities. A significant amount of Nova Scotia's forests and forest products are also exported. The fibre industry in Nova Scotia is doing well evidenced by the doubling of production in two mills: Stora Forest Industries and Minas Basin Pulp and Power Company.

An interesting fact of Nova Scotia's forest industry is that, in Nova Scotia, the forests are primarily owned by the private sector (Figure 2-B). In most Canadian provinces, the forests are owned by the province. This has implications for how the forests are managed. The provincial Crown Lands that do exist, are leased by the pulp and paper industry for indefinite periods of time (Orton, 1991).

Figure 2-A Nova Scotia Forest Ownership[3]



[2] old forests are defined as greater than 100 years

[3] Coalition of Nova Scotia Forest Interests, 1996

Nova Scotia's Forest Policy aims to increase productivity and jobs, while at the same time protecting or enhancing wildlife habitat and improving water quality. These goals would appear to be mutually exclusive, however, the plan is to intensively manage certain portions of forested land while leaving other stands unmanaged. The following statements outline the objectives of the Nova Scotia Forest Policy (NSFI, 1996):

- to achieve a healthier, more productive forest, capable of yielding increased volumes of high quality products;
- to encourage the development and management of private forest lands as the primary source of timber for industry in Nova Scotia;
- to support private landowners to make the most productive use of their forest lands;
- to achieve more effective management of all Crown lands;
- to maintain or enhance fish and wildlife habitats, water quality, recreational opportunities, and associated resources of the forests;
- to enhance the viability of our forest-based manufacturing industries;
- to double forest production by the year 2025; and
- to create more jobs immediately and in the long term through improved productivity.

The Coalition of Nova Scotia Forest Interests, a privately organized association, published a Discussion paper, in 1996, about sustainable practices and a new forest strategy. It purports to protect a reliable source of wood fibre. Its critics, however, believe that the Coalition is more concerned with sustaining the industry than the forests. It has become apparent that the Nova Scotia forest industry has increased clear cutting, relied upon biocides to support softwood monoculture tree plantations, practices which cause destruction of both wildlife habitat and wildlife itself (Eaton *et al*, 1994; CCFS, 1993).

The Coalition acknowledges that there is "an unprecedented demand for wood fibre resulting in a recent surge of harvesting [which has] added to concerns about forest sustainability" (NSFI, 1996). The Coalition's paper, however, ignores any alternative sources of fibre which could support the forest products industry. The oversight is not surprising, for the Coalition represents the interests of the private woodlot owners, and some of the larger ones may find it difficult to make all the changes required to produce fibre from other sources. Furthermore, the Coalition wishes to see an end to Government involvement in regulating harvesting practices on private woodlots.

The Coalition goes further in asking government to retreat from its role in protecting the public interest through regulation of harvesting practices. The existing regulations are only enforced on Crown lands, and on the lands of private woodlot owners who have received provincial funding (Eidt, 1996). According to the theory that private owners are more likely to protect their interests than is the state, it is possible that the smaller private owners are more likely to protect their interests through sustainable forestry, than is the government (McIsaac, 1996).

This theory is more applicable to smaller owners than larger ones. Thus, a large trans-national operator such as Stora Forest Products, believing that it can sustain itself indefinitely by moving from forest to forest, in country to country, actively seeks lands subjected to minimum or negligible regulation. Governments, afraid to discourage the investment that such corporations bring to an economy, are reluctant to impose stringent resource management practices. Stora, for example, sprays herbicides on its trees, although it would not be able to do so on those in its Swedish homeland (Genovali, 1995). Nevertheless, the Coalition's New Forest Strategy, has succeeded in encouraging much needed public discussion and it may even result in more detailed reports on the state of forestry in the province of Nova Scotia.

Another example of the lack of commitment to sustainable forestry within this Strategy is in the management of dead wood. Timber extraction, especially intensive, short-rotation management, tends to minimize the number of snags and logs in a stand. Logs may be so important to nutrient cycling that some lengthier cutting cycles should be instituted, as policy, to assure their presence (Hunter, 1990). These recommendations for sustainable forestry are met with the following recommendation from the NSFI:

> The code will encourage maximum utilization of the timber resource at the time of harvest in order to minimize the amount of merchantable material left on-site. Salvage of damaged (insect, disease, blowdown) stands will be recommended for early harvest to increase fibre utilization (p.29, NSFI, 1996).

Though there appears to be a commitment of sustainable forestry production in Nova Scotia, after reviewing some of the existing and proposed guidelines, it is apparent that there is a strong tendency to sustaining forestry instead of the forests.

2.2 Wood Fibre Shortages

The possibility of severe fibre shortages is one of the main reasons behind the push for the development and use of non-wood fibres (IIED, 1996; US Paper Task Force, 1995). There are numerous doomsday predictions that the world will soon run out of fibre. In documents published as early as 1916, when the forest-based pulp and paper industry was still in its infancy, there were predictions that the current rates of harvest were not sustainable. Statements such as the following appear to echo concerns that are currently expressed about the future of the wood supply.

> There seems to be little doubt that the present wood supply can not withstand indefinitely the demands placed upon it, and with increased scarcity economy in the use of wood will become imperative... Thus naturally, a balance will be established between production and consumption, but as this condition approaches its limiting values the price of wood may rise to such levels that there will be a demand for other raw materials (Dewey & Merrill, 1916).

In addition to population increases and the associated increase in demand environmental regulations are also believed to be affecting the future supply. Resources Information Systems Inc. projects declining Canadian softwood plywood capacity after 1995 as a reduced timber harvest in BC comes into effect (Plackett, 1995). This loss in forest area, while reducing supply, will cause an increase in cost and could affect the quality of raw material (Apsey & Reed, 1995). A shortage is not predicted in Nova Scotia, as it is believed that the fibre yields from intensively managed forests can be increased four to five times (Eaton *et al*, 1994). The environmental effects associated with intensively managed forests appears to be of little concern.

The FAO (UN Food and Agriculture Organization) projects that globally the industrial roundwood consumption will increase at a rate of 2.7% annually. In addition, regional deficits are increasingly serious and widespread, especially in North America, Russia, and Southeast Asia (Apsey & Reed, 1995). It is further predicted that by the year 2010 there will be a gap of 257 million m^3 between consumption and production of industrial wood. Apsey and Reed (1995) suggest two methods for closing the coniferous gap, the common 'depress the demand' or 'raise the supply' scenarios. In their depress demand scenario, the prices for standing timber, logs, pulpwood and other forest products will rise, and non-wood substitutes for forest products will become more attractive to both industry and consumers. In their supply scenario, an increase in intensive silviculture is predicted as well as; more investment in tree plantations, increased recycling, re-design of building codes to economize in wood use, and non-coniferous substitution (Apsey & Reed, 1995).

Using non-wood fibres in the pulp and paper industry is not a new concept. However, industries based on alternative fibres have generally developed where there has been no forest resource on which to base a wood fibre industry.

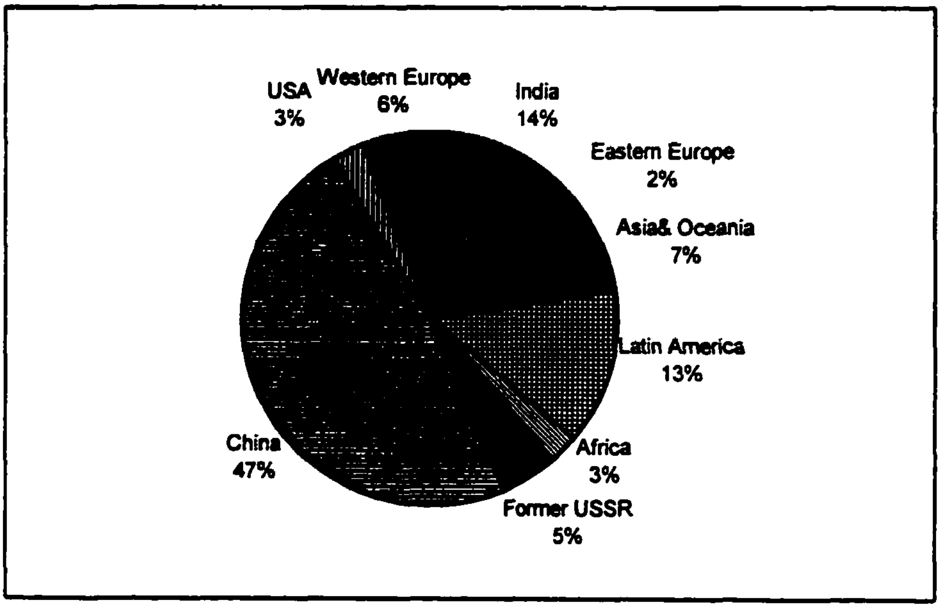
Both the supply and demand scenarios suggest the use of non-wood fibres will be an important part of closing the coniferous gap. This paper will examine the ability of hemp fibre to be an additional source of fibre. Furthermore, some of the environmental effects of growing trees for pulp and paper purposes will be evaluated.

2.3 Non-wood fibres

Non-wood fibres are usually considered to be any fibre not derived from trees. Examples of non-wood fibres are: hemp, flax, kenaf, bamboo, bagasse, esparto, and various types of straw and grass (Croon, 1996). Pulp derived from straw and other agricultural residues are often referred to as agri-pulp (Domier, 1996). Kenaf is common to warmer climates, as are bamboo, esparto, and bagasse, and thus will not be evaluated as sources of local fibre for Nova Scotia. Flax, a fibre and oilseed crop similar to hemp can be grown in Nova Scotia, but it is not profitable to do so currently. Its specific evaluation will thus not be undertaken in this thesis, though if a non-wood industry were to develop in Nova Scotia it could also be a suitable source of fibre.

There are presently 330 mills in the world producing about 12.5 million tonnes per year of non-wood fibres. This figure is expected to increase to more than 17.5 million tonnes by 2005. Currently China produces half of the world's non-wood pulp while India, Europe, and the Americas combine to produce the remainder (Figure 2-C, Croon, 1996). The production of non-wood fibre has been limited mainly to countries without access to large timber resources. Using trees for paper also appears to be an industrialized country phenomenon, as only 1% of the pulping capacity in industrialized countries produces paper from non-wood sources (Girouard, 1994).

Figure 2-B Estimated Regional Distribution of Production Capacity for Non-Wood Fibre-Based Paper Pulp[4]



Non wood fibres can be used to make high quality printing paper, corrugating medium, and linerboard (Croon, 1996). Bast fibres, such as those from flax and hemp, are frequently suggested as a new raw material for paper production (Herer, 1993; Conrad, 1993; Rosenthal, 1994; Girouard, 1994). They are lower in lignin than wood fibres, therefore offering better opportunities for non-chlorine bleaching and the production of

[4] adapted from Croon, 1996

unbleached pulp (Van der Werf, 1994). The qualities of hemp for paper production will be examined in Section 2.5.

There is also a great deal of interest in using straw residue from grain crops for paper production. The Alberta government is investigating building straw-based pulp mills in Alberta. As Canada's pulp source is dominated by wood there has been a lack of research into the processing of non-woods. For this reason companies such as Weyerhaeuser are investigating the processes to prepare straw pulp for use in making linerboard and corrugating medium (Croon, 1996). A Vancouver company, Arbokem, is proposing the development of a portable mill to process agricultural fibres directly on the field, returning the effluent to the land as fertilizer (McMillan, 1994). REAP (Resource Efficient Agricultural Production) has recently partnered with Domtar, in Quebec, to investigate the use of switchgrass (*Panicum virgatum)* as a supplement to its hardwood pulp (Rodden, 1996).

Switchgrass is attracting increased attention lately and it has the benefit of being both a fibre source and an energy source (Rodden, 1996). It is a perennial crop that can be harvested for fibre every year. It has the ability to grow on marginal lands, or lands that would not be suitable for other crops (Rodden, 1996). Yields of switchgrass range from 1-10t/ha depending on climatic and soil conditions (Samson,1991). In terms of paper production, laboratory results have shown a 45% yield with a quality similar to that of hardwoods. Paper would probably not be produced with a 100% switchgrass content, but rather it could replace 15-20% of the hardwood furnish (Rodden, 1996).

This concept of non-woods contributing to wood or recycled fibres is also gaining popularity. There is much discussion these days about the suitability of non-wood fibres for papermaking. Non-wood fibres are often regarded as only filler pulp except where paper smoothness is required (Croon, 1996; US Paper Task Force, 1996). Other reports state that non-woods are ideal for making paper and that trees are often the least desirable source of fibre for paper (Herer, 1993). Statements such as these often appear to be motivated by self-interest. These claims are usually unsupported by scientific claims thereby making it difficult to form valid conclusions.

There are some disadvantages to using non-wood fibres. One of the most cited is that non-woods are not competitive with trees mainly because of the high cost of the delivered fibre due to the bulky nature of these fibres and limited experience with handling and storage geared for the pulp industry (Girouard, 1994; Plackett, 1995; US Paper Task Force, 1996). The increased attention for using non-woods has also led to improvements for the handling of such fibres making previous constraints less of an issue (Girouard, 1994). The Results section will provide some of the physical characteristics of both wood and non-wood fibres in order that some comparisons can be made.

2.4 Recycled fibre supply

Prior to the thrust for non-wood fibres came the push for recycled fibre. Instead of shipping waste paper off to landfills it is now often repulped into paper. The supply of recycled fibre has increased steadily but not as rapidly as demand (Shearin, 1995). The North American market has been motivated by the US Government law requiring 20% post-consumer recycled content in paper intended for Government use (CFS, 1993). The supply of waste paper is so limited in Canada, that we must often import waste paper from the US in order to meet the needs of US customers. The current consumption of recovered paper, in Canada, is about 4 million metric tons/year, much of it imported from the US (Williamson, 1996).

One of the main concerns with the use of recovered fibres is the stability of fibre properties, or the loss of mechanical strength of paper made from recycled fibres (Law *et al*, 1996). Travers (1996), of the Minas Basin Pulp and Power Company reported that while it is often quoted that paper can be recycled up to seven times, three to four times is more common in practice.

The addition of small amounts (as low as 10%) of non-wood fibre to recycled pulp could extend the life cycle of the paper (Domier, 1996). In fact, contributing to the life of recycled paper is seen as a positive step toward sustainability as the demand for wood fibre is further reduced. Due to its physical characteristics hemp is being investigated as one of the fibres that could contribute added strength to recycled pulp (Byrd, 1996).

2.5 The Characteristics of Hemp

2.5.1 Botanical Characteristics

Cannabis sativa is an annual plant, that grows each year from seed. It has a rigid herbaceous stalk that reaches average heights of one to five metres, however, reports have been made that hemp has reached up to 12m in height (Small, 1979).

The thickness of the stalk depends on the density of planting. When planted densely the thickness of the stalk is approximately 2cm, and the stalks are devoid of branches and leaves except at the top. When the hemp plants are not crowded branching occurs and the stalk is 2.5-cm thick. The hemp stalk is hollow, and in high quality fibre the hollow space occupies at least one half the diameter (Maxwell, 1918).

Traditionally hemp is a dioecious plant, however, monoecious varieties have now been developed. Monoecious varieties are important as they allow for greater uniformity and increased seed yields (West, 1996) Furthermore, this development is important for efficient fibre production as it is necessary to harvest hemp as soon as the plants are mature, as the fibre deteriorates after maturation. In dioecious varieties the male plants mature three to five weeks prior to the female plants, a situation that can create harvesting problems as it becomes difficult to harvest only male plants (Robinson, 1943). Manual harvesting is the only feasible method to do this, but is no longer practical for efficiency and cost reasons. Monoecious varieties may be best used when the production of both fibre and seed from the same crop is desirable. A breeder of hemp varieties claims that the dioecious varieties produce higher fibre yields, and are more stable genetically (Bócsa, 1994)

The glands of the female inflorescence produce the resin that contains the narcotic substances, however, in the case of low-THC hemp this would be minimal. The seeds can be eaten as nuts, or crushed to release either a food grade or an industrial grade oil. This oil can be consumed as a food or processed into cosmetics, or for industrial purposes as a drying agent for paints. The seed-cake, left over from crushing is often used for animal and fish feed (Small, 1972).

The hemp plant is made up of two types of fibre, the bast fibre and the hurds. The bast fibre, sometimes referred to as the bark, consists of tow and line fibre. The tow fibre is from the long thick-walled bast fibres in the phloem, and considered to be the primary fibre. The line fibre consists of the short thin-walled libriform fibres in the xylem, and is referred to as the secondary fibre (Dewey, 1916). The bast fibres are most commonly used in the production of rope, paper, and textiles.

The hemp hurds, or the woody core, a by-product of fibre extraction are now considered to be an important source of cellulose. In the past, hurds were often considered a waste product and thus burned. They are now being used for paper production, construction materials, as a super-absorbent animal bedding, and other cellulose based products (Low, 1996). Hemp hurds correspond to the shives found in flax, however, they are coarser and usually softer in texture (Dewey, 1916).

Hemp fibre is often referred to as the strongest and longest natural fibre. This premise is often debated by fibre experts. The fibre length is an important factor as the strength of paper increases with fibre length. The cellulose content of a fibre directly relates to the pulp yield. In hemp the cellulose content is reported to be between 65-70%. Lignin is the organic glue that holds the fibres together, and it must be dissolved by retting, or other means, prior to processing. The lower the lignin content, the less processing required to dissolve it. Hemp has a lignin content of approximately 4%, a figure much lower than the 20% for tree fibres.

These two different types of fibre each have unique properties. The primary bast fibres are longer, the cellulose content is higher, and the lignin content is lower than in the hurds (van der Werf, 1995). These factors make the hemp stems a more valuable raw material for paper production, and thus the quality and quantity of the primary bast fibres reflects the value of hemp stems.

2.5.2 Agricultural characteristics/requirements

Hemp is reported to be a plant that can grow anywhere, however, it thrives in certain climates and agricultural conditions. The following section sets forth the ideal conditions and the limitations for growing hemp.

2.5.2.1 Climate

The hemp plant is known for its ability to grow in varied climates, however, it thrives in temperate ones. An advantage of hemp over crops such as corn, is that hemp can endure light frosts in the spring and survive frosts in the fall (Robinson, 1943; van der Werf, 1996). While hemp plants may survive occasional frosts, if spring growing conditions are cooler than normal, hemp seedlings will not be competitive with weed species adapted to growth at low temperatures. Ensuring optimal sowing dates should prevent this problem.

There are many claims made that hemp is drought tolerant (Herer, 1993; Conrad, 1993). In fact, hemp is intolerant of drought and while it may continue to grow under such conditions, the yields will be severely depressed (Hackleman & Domingo, 1943). Maxwell (1918), reported that in order to produce good quality fibre a climate with a long and moderately warm growing season that is not liable to drought is desirable. Furthermore, when drought conditions are accompanied by high temperatures early maturity results before full growth has been achieved (Robinson, 1943).

Frequent rains are beneficial as hemp grows best when well supplied with moisture throughout its growing season and especially in the early stages of growth. However, flooding and excessively saturated soil can affect the uniform growth of the crop, thus posing problems for harvesting (Robinson, 1943).

2.5.2.2 Soil Requirements

Fifty years ago farmers were advised that only land in a very productive condition, capable of yielding a minimum of 50 bushels (3.1t/ha) of corn to the acre, should be chosen for growing hemp seed (Morazain, 1942; Robinson, 1943). Furthermore, soil capable of growing 75-80 bushels (4.7-5.0t/ha) of hybrid corn under favourable growing conditions could reportedly produce profitable hemp crops of 2.8 to 3.4 tonnes of fibre per hectare (Hackleman & Domingo, 1943).

In order to achieve good, uniform yields in terms of both quantity and quality, hemp must be grown on the very best soil. A rich, moist soil, with good drainage is ideal. Flat, heavy, impervious soils are not suitable for hemp as there is too much water retention thus affecting the uniformity of the crop (Hackleman & Domingo, 1943). Hemp is particularly adapted to heavy clays and loams rich in organic matter provided the organic matter is reasonably well decomposed. Hemp should not be grown on light soils, especially light sandy soils, nor on acidic soils (Maxwell, 1918). The addition of lime can overcome any pH limitations. The land should be undulating to gently rolling and have no low or 'soggy' spots (Hackleman & Domingo, 1943). Silt-loams and clay loams were reported to produce a satisfactory crop without special fertilization, particularly if the hemp followed clover or alfalfa, or a corn crop planted on clover or alfalfa sod (Hackleman & Domingo, 1943).

It was the custom in Kentucky to grow hemp only on new land i.e. land that had been in pasture and preferably on woodland which had been in pasture for years. Old land could not be improved simply by adding fresh barn-yard manure. While the quantity of the fibre may be high on such soils, the quality would be coarse and of inferior quality (Kentucky Agricultural Experiment Station, 1889). While hemp may grow well on clay soils, it may provide problems for processing, as Dewey (1916) reported "clay may cling to the butts of the stalks which may cause processing problems".

If it is decided that the hurds are to be a marketable product of the hemp crop, then it might be beneficial to grow the hemp on a peaty soil, as Dewey (1916) reported that the hurd weight, while usually about five times that of the fibre weight, is somewhat greater on peaty soils. Peaty soils have also produced satisfactory results in France (Van der Werf, 1996).

It is difficult to extrapolate from the Literature to conditions suitable for growing hemp in Nova Scotia. For instance, while the peaty soils of France may be suitable for hemp, this would not be the case in Nova Scotia. An extensive knowledge of soils is necessary to make recommendations in this area. Though hemp can reportedly grow on any soil there are obviously some that are optimal and these need to be determined for Nova Scotia. The GIS work undertaken in this thesis attempts to determine those soils that would be suitable for growing hemp in Nova Scotia, based on an amalgamation of the above recommendations.

2.5.2.3 Fertilizers

Hemp requires very fertile soil to facilitate its rapid growth in a short time. Barnyard manure is reportedly the best single fertilizer for hemp and supplies sufficient nitrogen (Robinson, 1943; Hackleman & Domingo, 1943). The manure should be applied to the preceding crop, or at the latest in the autumn previous to the sowing of hemp. In the past it was recommended that when manure was turned under for corn a year before the hemp was grown it gave excellent results. For fall-plowed land it was advised that the manure be spread during the winter and worked in during seedbed preparation in the spring (Hackleman & Domingo, 1943). If the manure is applied just ahead of hemp, it needs to be thoroughly and evenly distributed over the land, or an uneven growth will result (Hackleman & Domingo, 1943; Maxwell, 1918). While many reports indicate that animal manure is sufficient for hemp production, many recent research reports indicate that chemical fertilizers are also used successfully (van der Werf, 1994a).

It has been estimated that 175 kg N/ha, minus the reserve of soil mineral nitrogen, would allow optimal crop growth and yields of up to 15t/ha of above ground dry matter (deMeijer, 1995). The amount of nitrogen has been found to be the major cause of differences in slenderness of hemp plants. Van der werf (1994a) found that high levels of nitrogen (200kg/ha) contributed to many more slender individuals than at lower levels (80kg/ha). The higher nitrogen level also led to more suppressed plants. Van der Werf concluded that a reduced nitrogen fertilization leads to finer and less variable hemp stems. This is important as minimizing variability among stems facilitates efficient harvesting. Commonly cited amounts for fertilizer are: 80-120 N, 80-120 P_2O_5, and 160-200K_2O kg/ha (van der Werf, 1994b)

The possibility of severe fibre shortages is one of the main reasons behind the push for the development and use of non-wood fibres (IIED, 1996; US Paper Task Force, 1995). There are numerous doomsday predictions that the world will soon run out of fibre. In documents published as early as 1916, when the forest-based pulp and paper industry was still in its infancy, there were predictions that the current rates of harvest were not sustainable. Statements such as the following appear to echo concerns that are currently expressed about the future of the wood supply.

> There seems to be little doubt that the present wood supply can not withstand indefinitely the demands placed upon it, and with increased scarcity economy in the use of wood will become imperative... Thus naturally, a balance will be established between production and consumption, but as this condition approaches its limiting values the price of wood may rise to such levels that there will be a demand for other raw materials (Dewey & Merrill, 1916).

In China, fertilizers are applied prior to sowing and again when the crop is approximately 50cm tall. Animal manure and soybean meal (up to 1.5t/ha) are spread on the fields and plowed or spaded in the Spring well before sowing. Mixtures of chemical fertilizers are commonly used, when manure is not available, and are applied at a total application rate of up to 1t/ha (Clarke, 1995).

Hemp takes a large amount of nutrients from the soil. A good crop takes about as much fertility from the soil as a 4.7-5.0t/ha crop of corn (Hackleman & Domingo, 1943). This extraction of soil nutrients does not appear to be too much of a concern. Hemp producers in the past believed that the weed control and soil conditioning provided by hemp crops outweighed the negative effects of nutrient removal (Hackleman & Domingo, 1943). This factor is further compensated by the fact that hemp can also return up to 70% of nutrients used back to the soil. This high nutrient cycling rate is attained when the roots decompose, the leaves are allowed to fall to the ground, and retting is conducted on the same fields (Reichert, 1994).

The concept of tightening nutrient cycles within hemp rotations has been apparent for several decades as is apparent by the following situation. Although it was not routine to sow a small grain cover crop after the hemp was cut and shocked, this practice was recommended to prevent nitrogen leaching from the soil (Morazain, 1942). Sowing cover crops after hemp also protects the soil surface and reduces the potential for erosion.

Because of hemp's rapid growth it requires a plentiful supply of fertilizing elements. Many of these fertilizing requirements can be met by other preceding crops. Sufficient nitrogen can be obtained if hemp succeeds clover, peas, or grass sod (Maxwell, 1918).

In one study, the yield of hemp varied markedly with the level of available nitrogen present in the soil from green manure crops (Vessel & Black, 1947). The residual effects of alfalfa on hemp appeared to last for 3 years. Clover had a definite effect on hemp grown the second year following, but little or no effect in the third year. Hemp crops also contributed to the yields of subsequent corn and hemp on the same plots of land. Thus the use of effective rotations may be one strategy to reduce the amount of synthetic fertilizer required by hemp crops.

2.5.2.4 Rotations

Crop rotations are important to provide fertilizing elements and disease breaks between crops. Crops commonly used in hemp rotations include; cereals, sugar beets, and potatoes. Short rotations (minimal variety), while economically desirable, are not beneficial for the environment. Longer rotations (greater than 4 years) allow for the soil to recover between crops , and allows crops to complement each other.

Crop rotations, however, are often dependent on local economic conditions. In economically depressed areas crop rotations are limited to a few crops which are relatively profitable or agronomically indispensable in the rotation (van der Werf *et al*, 1995a). In the Netherlands, potatoes and sugar beets are profitable to grow and cereals are a staple, thus these are the predominant crops in their rotations. Unfortunately this practice has led to increased diseases and a resulting increase in the use of biocides (van der Werf *et al*, 1995a).

Rotations can often provide benefits to other crops. Hemp accomplishes this as it leaves fields free from weeds for successive crops thereby cutting down on the use of herbicides. The condition of the soil is enhanced thus improving yields for following crops.

2.5.2.5 Pests

Many reports claim that no pesticides are required for hemp crops, however, this is not entirely true (Herer, 1993; Conrad, 1993). There are some pests specific to hemp, however, there are certainly fewer hemp pests than are common to other crops.

It is frequently reported that the only serious pest of hemp is broom rape, *Orobanche ramosa*, a leafless yellowish parasite that grows on the roots of hemp and tobacco and causes wilting (Dewey, 1914; McPartland, 1996; Morazain, 1942). When hemp was grown commercially in Kentucky, a number of fields became badly infested with broom rape. This was largely as a result of raising hemp for several years in succession and using poorly cleaned seed. It is recommended that hemp not be sown in fields known to be infested as this pest can linger for 20 years.

Another pest is the European corn-borer, and other similar stem-boring insects, and they may occasionally kill a hemp stem (Robinson, 1943). In Manitoba in 1995, the experimental crops were attacked by Bertha Army Worm, a pest that also attacks canola and happened to be in a peak phase that year (Moes, 1996).

At least 88 species of fungi attack *Cannabis sativa*. The most significant of these is *Botrytis cinerea*, a gray mold that thrives in temperate regions with high humidity and cool to moderate temperatures. Under ideal conditions, the gray mold can reach epidemic proportions and completely destroy a *Cannabis* crop, by attacking the stems, within a week (McPartland, 1996).

Another notable fungus is *Sclerotinia sclerotiorum*, a hemp canker. This fungus has attacked fibre cultivars in Europe and has also caused losses in North America, Australia, and Tasmania (McPartland, 1996; Moes, 1996). Both *B. Cinerea* and *Sclerotinia* are more prevalent in the presence of excess moisture.

In many cases pesticides are not used on pest infestations as the cost of the chemicals outweighs the economic losses by the pests. Such is the case in China where hemp crops are often infested with a flea-beetle (*Psyloides attenuata)* that is not kept in check by any chemical preparations (Clarke, 1995). De Vries *et al* (1995), reported that losses from *Botrytis cinerea*, in the Dutch hemp project, and other pathogens were insignificant and not worthy of treatment (de Vries *et al*, 1995).

The fact that hemp has less pests than other crops is of great importance when considering the environmental implications of using pesticides. Growing a crop that is naturally resistant to pesticides reduced the need for synthetic pesticides.

2.5.2.6 Herbicides

Maxwell (1918) writes that Wisconsin hemp has attained the reputation of being the best smother crop for Quack Grass and Canada Thistle, and that it was due to experiments with hemp as a weed eradicator that hemp was grown on a commercial scale in Wisconsin.

> This does not mean that hemp planted on a poorly prepared seed bed will clean badly infested land, however, if sown on properly prepared soil, hemp will successfully compete with these weeds. By thorough disking and spring-tooth cultivating right up until planting time suitable conditions for the smothering out of weeds by the hemp will result (Maxwell, 1918).

There is general agreement that when the above conditions are followed there is no need to use herbicides on hemp crops (Moes, 1996a). The main requirement is for hemp to achieve a rapid and uniform emergence.

Hemp itself is known as a weed a fact which instils fear in some people. However, Illinois farmers who were growing hemp for the war effort were reassured that when hemp is harvested before the seed is formed, there is not much danger of it escaping and becoming a weed itself (Hackleman & Domingo, 1943). If care is taken when harvesting seed, this problem would also be minimized.

2.5.2.7 Seed Sowing

Seeding rates vary according to whether the hemp is being grown for fibre or for seed. Fibre crops are sown much more densely than seed crops. These higher seeding rates may increase stem yield, but not necessarily bast fibre yield (van der Werf, 1994b). The seed may be sown broadcast by hand or drill, or may be sown in with an ordinary grain seed-drill. A seed drill is the preferred method for sowing as it minimizes variation in the depth at which the seeds are planted, thus minimizing the possibilities of non-uniform growth (Maxwell, 1918). Birds also consume less seed from drilled plots (Gehl, 1995).

Broadcast seeds may not be evenly covered, and thus upon the later emergence of the deeper set seeds they are confronted by the shade of the shallower set seeds. This affects the yields of the later plants and they are often lost in harvesting (Maxwell, 1918).

Early seeding results in higher total fibre yields which include a high percentage of valuable line fibre versus the less valuable tow fibre (Meijer *et al*, 1995). Earlier seeding also permits the crop to mature and be cut comparatively early in the fall so that retting can occur before freeze up. Successful early seeding is dependent, however, on suitable climatic conditions at the time of seeding.

In addition to the time of seeding, the rate of seeding is also important. The proportion of stem in the above-ground dry matter and the proportions of the valuable bast fibres in the stem dry matter increase with plant density, so a high density is desirable (VanderWerf *et al.* 1995a in VanderWerf *et al* 1995b)

Seeding rates vary, as will be seen in the Results section. The literature also supports this claim. In Florida the recommended amounts were 37-40kg/ha for fibre, and 1.7kg/ha for seed (Seale *et al*, 1957). Even though a rate of 50 kg/ha (1 bushel) was deemed to produce a small hemp stalk that could be cut easily and broke rapidly for fibre processing (Morazain, 1942); under the War Crops Program, US farmers were issued 62kg/ha (Hackleman & Domingo, 1943). Following several research studies, it was found that in Canada 80kg/ha was the most economic seeding rate for fibre (Gehl, 1995)

2.5.2.8 Harvesting/ Machinery

The time for harvesting depends on the purpose of the crop. For fibre production, when the pollen of the male plants is mature and being blown about by the wind, the hemp is at the proper stage to cut (Maxwell, 1918).

It is important to harvest a hemp crop for fibre immediately following flowering. After flowering losses of dry matter can be extensive as dead leaves are shed rapidly and many plants die as a result of inter-plant competition (Meijer *et al*, 1995). This can affect the value of the hemp stems as the price received for fibre is primarily dependent on the proportion of bark in the stem.

In the Netherlands it was reported that the most practical method for harvesting was swath mowing, followed by dew retting and a subsequent turning of the swath (deVries, 1994). Many of the new hemp farmers have used modified mowers and balers as they await development of new harvesting equipment (Guilford, 1996; Moes, 1996)

The International Harvester Company of New Jersey spent a large amount of money, in the 1930s, to perfect and manufacture hemp machinery. Hemp harvesters were developed which cut the crops and laid it on the ground in a continuous swath in good position to be picked up after the stalks were cured. (Morazain, 1942).

As previously mentioned, breaking hemp manually was reportedly the hardest job known to humans, thus lowering the cost of the breaking and scutching operations was identified as critical to expansion of the hemp fibre industry in Canada (Gehl, 1995).

2.5.2.9 Yields

Reports on fibre yields were quite varied in the literature. In past commercial hemp production in Ontario fibre yields varied from 0.5 to 2.2t/ha depending upon the soil and seasonal conditions, with an average of around 1.1t/ha, which could be increased by a larger use of fertilizer (Morazain, 1942).

In the Netherlands, the average amount of total dry matter was 13.3 t/ha. The researchers, however, have put forth a more conservative estimate for farmers fields of 8 to 10 t/ha. This would result in about 2.5 tonnes of bast fibre per hectare (WJM Meijer *et al*, 1995).

Using late-flowering cultivars is one method of increasing yields. Due to a longer growing season, yields can be increased by about 30% (van der Werf, 1994a). These late high-yielding hemp crops, however, require some agronomic modifications as they are not compatible with the traditional high plant density. As a result of severe inter-plant competition, many plants die after maturation in these late crops. Due to self-thinning, a lower density can lead to a higher final fibre yield (van der Werf, 1994a).

The proportion of bark in the stem depends mainly on genotype, however, it can be increased slightly with plant density (Meijer *et al* , 1995). The proportion of secondary bast fibre increases with stem weight. A higher proportion of secondary fibre may be expected at low plant densities and in late flowering cultivars (Meijer *et al* , 1995).

In Nova Scotia, during the 1920s research, the highest reported yields were around 6.5-7.2t/ha. Often the highest stem yields did not correspond to the highest bast fibre yield. In fertilizer experiments it appeared that a combination of nitrogen and potash produced the highest stem yield, however, when muriate of potash was added to this mixture the quantity of the bast fibre increased (Kentville Agricultural Research Station, 1924-1929).

2.5.2.10 Retting

Retting is the technical term for rotting and hemp must undergo this process in order that the lignin is dissolved and thus the bast fibres can be separated from the woody core. Traditionally retting is done in the field (dew retting) or in ponds (water retting) and takes from a minimum of one week for water retting, to a maximum of five weeks for dew retting (Maxwell, 1918). Investigations are underway to mechanize this process (Clarke, 1996). Nova Scotia is believed to have a suitable climate for retting unlike the dry post-harvest conditions on the Prairies. This lack of moisture in the Prairies commonly prevented proper dew retting in the field (Gehl, 1995). Until completely mechanized retting is available, field retting will most likely continue to be used.

During dew retting plants lose about 60% of green weight and 40% of dry weight (Dewey, 1916). Hurds from water retted hemp are cleaner and softer than dew retted hemp, though the process of water retting is often more expensive and may involve the use of a weak solution of chemicals or oil in hot water. This process may lead to traces of chemicals or oils and also soluble gums in greater degree than those of dew/water retted hemp (Dewey, 1916).

New methods for separating the bast fibre from the hurds involve steam explosion (Nebel, 1996) and an enzyme process (Clarke, 1996). It is in this area that there is the greatest need for technological improvement, it is believed that some of the processing developed for flax fibre may also be suitable for hemp (Mackie, 1996).

2.5.3 Paper Properties

The intricacies of paper production will not be a major component of this thesis. However, the properties of various fibres that make them suitable for paper production will be introduced in order to allow for some comparisons to be made. The hemp plant has several characteristics that make it a suitable fibre for pulp and paper production. Hemp is in the unique position of having two types of fibres suitable for different types of pulp production, both the bast fibres and the hurds.

The tear strength of paper increases with fibre length, and as hemp bast fibre is one of the longest fibres it can be cut to desirable lengths (Meijer *et al*, 1995).

Hemp's low lignin content is advantageous as less chemicals are required to dissolve it resulting in less chemical-laden effluent. Hemp fibres are also lighter in colour than other fibres and thus bleaching is less of a necessity. When hemp pulp was produced on a laboratory scale, unbleached and bleached pulps were produced at about 80% recovery and at about half the energy inputs of mechanical softwood pulping (Meijer *et al*, 1995).

A new process for pulping hemp is being investigated in the Ukraine. It is an alcohol-based ammonia-sulphite process to be used for pulping the hemp hurds and the bast fibre together. The solvents are organic and it is believed that when they mix with water at the pulping stage they will not degrade into toxins that react with the lignin contained in the raw material (Krotov, 1996).

2.5.4 Economics of Hemp

As with any new product entering the market its success depends on the supply and the demand. It has been claimed that a demand for hemp products has not yet been established (Baxter, 1996). In contrast, owners of successful hemp businesses purvey the opposite claim as they believe that while the demand for hemp products is high, the supply is low and prohibitively expensive (Wirschafter, 1996). While many hemp advocates would like to see hemp used as a tool for local development, there are others who would like to see support from the large multi-national paper companies. These large companies, however, are waiting to ensure that hemp is not simply a fad and that the products that can be made from it are of good quality and profitable (Baxter, 1996).

As hemp is being presented as a multi-use crop, the economic analysis can focus on any or all of hemp's raw materials. Every region across Canada and the US views different products as the key to a successful hemp industry. In Western Canada the focus is mainly on oil production from the seeds and to a smaller degree on the fibre (Guilford, 1996). Ontario hemp farmers are more interested in making construction materials from the hemp stalks (Kime, 1996). Opportunities for Nova Scotia would lie mainly in the fibre area as the growing period for seed is probably not long enough, and in addition there are no oil pressing facilities in the Maritimes.

A government agronomic analyst in Ontario suggested that "the farm-gate price of dew-retted hemp stalks for paper manufacturing will not exceed the cost of production. The future seems to hinge on the demand for higher priced textile-grade fibres" (Baxter, 1996). For the State of Vermont it was concluded that due to low wood prices, subsidies, and technical hurdles, hemp paper does not compete price wise except for speciality papers (Roulac, 1996). However, a lot of attention is focussing on hemp's ability to strengthen recycled paper (Byrd, 1996).

In the United States it is believed that the largest potential market is in textiles as a replacement for cotton. Markets are not well developed due to little research and development over the past 50 years (Roulac, 1996). Cotton, however, is not grown in Canada so hemp could develop its own textile niche in Canada without too much competition. This is in fact what may have to happen as market prices are high and therefore market penetration is restricted to niche areas (Crawford, 1996)

The hemp hurds are now attracting an increased amount of attention in comparison to the days when they were considered simply a waste product. The hurds are being produced for animal bedding, packaging, fibreboard, peat moss replacement, an additive to cement, road building, and niche uses in paper making (Roulac, 1996).

In the United States the hemp seeds are attracting the most attention. In a report about hemp's potential in Vermont it was announced that the hemp seeds could provide the highest potential market with the least amount of barriers for processing and marketing for Vermont farmers and businesses (Roulac, 1996). The cost of entry for many of the seed or oil products is low compared to fibre processing for textiles, paper, and composites. The State of Vermont could expect the potential of adding several hundred new jobs involved in the hemp industry in the next decade (Roulac, 1996). This, however, is not the case in Canada. Only sterilized (non-viable) seeds do not require handling permits in Canada. It is, however, the non-sterilized seeds that the food and cosmetics industries desire for their products due to a higher quality oil from these products (Shamai, 1996). The new Canadian legislation only removes mature stalks from the banned list and not the viable seeds thus providing a bureaucratic hassle to developing a hemp oil industry in Canada.

The cost to import seeds in to Canada is a costly venture (Table 2-A). The price of seeds ranges from Cdn$3.50 to $14.00 per kg. Shipping must be added to this figure, sea freight is the most economical method, and it costs approximately Cdn$4800 to ship a container (18 tonnes of seed) from Europe to Canada (Moravcik, 1996).

Table 2-A Hemp Seed Costs

	minimum	*maximum*
quantity required (kg/ha)	22kg	85kg
price per kg	$3.50	$14.00
Total cost	$77.00	$1190.00

If a farmer had a 25 hectare farm the cost for seed alone would range from Cdn$1925 to $30,000. This is prior to factoring in shipping, resulting in a prohibitively expensive price.

Information on the financial aspects of producing hemp fibre are extremely limited. One detailed report outlines the following costs associated with producing hemp fibre (Meijer *et al*, 1995):

sowing seed, fertilizer, machinery, labour	Cdn $1400 (fixed)
harvest and storage	Cdn $600/ha
primary production (green scutching)	Cdn $700-900/t of pulp
extrusion pulping	Cdn $550/t of pulp

Other information from the UK suggests the potential revenue from hemp fibre could be around Cdn$770/t and the hurds would fetch an additional Cdn$70-85/tonne (Low, 1996). Making comparisons based on this information is difficult as the costs reported are for different stages in the production of hemp. It would appear that because of the high cost of seed and processing there would have to be markets for both the hemp hurds as well as the fibre. The production of hemp seed oil may the highest value product but if plants are not allowed to go to seed then this possibility is eliminated.

In 1916 it was revealed that the hemp growing industry could only increase if a machine brake was developed to prepare the fibre for further processing. It was further noted that a profitable use for the hurds will add an incentive to the use of the machine brake (Dewey, 1916). At that time hurds were used for barnyard litter, stable bedding, a substitute for sawdust in packing ice, and in some cases it was used for fuel. At that time, and currently the marketability of the hurds will greatly influence the gross return on the hemp stalks.

2.5.5 The THC debate

While the THC/legal debate was presented in the introduction some technical aspects of the issue will be presented in this section. It is believed that the medicinal and recreational hemp varieties in North America originated from the West Indies and Mexico. It has been postulated that the Chinese and European varieties of fibre hemp lack the biochemistry to convert a particular cannabinoid into the psychoactive tetrahydrocannabidiol (West, 1996).

THC is but one of many cannabinoids found in *Cannabis sativa.* CBD for instance, while it does not contribute to the psychoactive potential of the plant, its exact role is not known. It is thought that it may contribute to the plant's antibiotic properties, and drought and heat tolerance (deMeijer, 1995; Pate, 1994). THC may be a protective agent from damaging UV radiation that has developed in regions where solar radiation is more intense (West, 1996).

The THC/CBD ratio is useful for differentiating between strains of *Cannabis sativa.* The ratio is sometimes expressed as (THC + CBN)/CBD, where CBN is another minor cannabinoid (cannabinol). If this ratio exceeds 1 then plants are classified as the drug phenotype, and when below 1 then classified as a fibre phenotype (de Meijer *et al*, 1992).

There is still no visual test available for use in the field to discriminate between varieties. It has been postulated that the narcotic potential of drug strains may be suppressed when plants are grown outside in a dense crop (deMeijer *et al*, 1992), thereby reducing the fear of farmers growing fields of recreational hemp instead. Fibre content and the presence of THC are not interrelated, therefore agronomic characteristics cannot be used to discriminate between varieties. One method to avoid the narcotic issue, in countries where hemp is classified as a narcotic, is to grow hemp only for fibre and not for seed. Banning seed production would ensure that only low-THC seed was purchased for each crop. While there are numerous economic advantages to growing hemp for seed it may be necessary to avoid doing so until more acceptance of low THC varieties is generated. This will of course necessitate the continued costly importation of low-THC seed from external markets further hampering the possible expansion of a new industry.

The debate on the legality of growing hemp in Canada still continues though the drug issue has now essentially become irrelevant with the development of low-THC varieties. These new varieties of *Cannabis* have been selected and developed by European and Asian countries wishing to maintain their hemp fibre production in accordance with laws against drug production. In fact the European Union certifies certain seeds as low-THC and these are the only seeds to which the hemp growing subsidy is applied.

At public discussions about hemp, concern is often expressed that farmers will grow recreational hemp instead of industrial hemp (Kentucky IFHC, 1996). The reasons for this fear are unfounded. First of all, with drug penalties becoming increasingly more punitive there is less of a chance that a licensed farmer would take such a risk, regardless of the potential profits. Secondly there are agricultural reasons not to plant recreational and industrial hemp in close proximity. Concern is also expressed that farmers would hide recreational hemp within the industrial hemp crop. If this were to happen, when the seeds cross-pollinate they would go to the lower-THC variety thus effectively ruining the future value of any recreational hemp.

In the United Kingdom, the raiding of the fields was initially the greatest fear associated with revitalizing an industrial hemp industry. Ian Low (1996) reported that while some youths did raid some of the crop the first year, when they realized that it had no recreational value they did not return to visit the crop the next year.

The legal issue is essentially one of education. In Finland, while they had research plots they also had an experimental educational plot in the town centre for the public to see. This was a wonderful opportunity for education on the differences between industrial and recreational hemp (Callaway and Hemmilä, 1996).

2.6 Sustainable Agriculture

2.6.1 Agricultural Aspects

Sustainable agriculture has become one of the many terms affiliated with the all-encompassing term sustainable development. Sustainable agriculture is being promoted by farmers, researchers, and environmentalists who are concerned with degrading soil quality, a dependence on chemical biocides and fertilizers, and the influence of large-scale agri-businesses.

Sustainable agriculture is a concept that can be considered a philosophy, or a practical strategy for agriculture that is ecologically sound, economically viable, socially just and humane (Gips, 1984 in Francis, 1990). Every proponent of sustainable agriculture appears to have his or her own definition of the term. A theoretical definition is provided by Yunlong & Smit (1994) as they state that sustainable agriculture is the:

> ...use of resources to provide food and fibre in such a way that the natural resource base is not damaged, and that the basic needs of producers and consumers can be met over the long term.

This definition incorporates the environmental aspects of sustainable agriculture, the economic aspects, and the temporal dimension. In fact, agricultural sustainability is often discussed in terms of these three dimensions. By not damaging the natural resource base there is the potential for ecological sustainability. Ensuring the basic needs of the producers and consumers can lead to social and economic sustainability. Though the 'long term' is a vague description it does indicate that sustainable agriculture is a process that must overcome specific temporal boundaries.

The previous definition is evidence of the philosophy behind sustainable agriculture. An operationalized definition was created from various definitions and states:

> A sustainable agriculture system is the result of a management strategy which helps the producer to choose hybrids and varieties, soil fertility packages including rotations, pest management approaches, tillage methods, and crop sequences to reduce costs of purchased inputs, minimize the impact of the system on the immediate and the off-farm environment, and provide a sustained level of production and profit from farming (Francis *et al*, 1987 in Francis & Youngberg, 1990).

While the challenges to create a sustainable agriculture may seem difficult, the advantages of doing so are hard to ignore. The need to develop a sustainable agriculture system is motivated by a desire to protect the environment from degradation by agricultural chemicals, soil erosion and other agents (Power, 1990). The call for a more sustainable agriculture has also been a response to the

> ...large-scale, highly specialized, chemical and capital intensive farming systems that have gradually come to dominate temperate zone agricultural production practices over the past 50 years (Francis & Youngberg, 1990).

Sustainable agriculture does not necessarily imply that it is necessary to maintain the current high yields and chemically intense processes now the mainstay of agriculture. While some groups may interpret this concept as a justification for the current agricultural conventions (Francis & Youngberg, 1990), the most prevalent view is that sustainable agriculture will improve the environmental conditions associated with farming. It is suggested that the sustainability in this instance emphasizes optimization at the agroecosystem level rather than maximization of a single crop or component of the system (Andrews *et al*, 1990). Furthermore, there must be a shift toward an acceptance that the ecological productivity of the land is the net sum of the above and below-ground biological growth over an interval of time (Doran & Werner, 1990) and should not simply be measured by crop yields.

While practices that could be considered sustainable are often readily provided, specific methods for implementing them are often lacking in many discussions on this topic. Specific problems that sustainable agricultural practices can address are the loss of soil and soil degradation, the contamination of the environment by pesticides and fertilizers, vulnerability to shortages of non-renewable resources, and low farm income in the face of high production costs. Implementing sustainable agricultural systems may remedy or alleviate some of the above problems. The following are some examples of how a sustainable agriculture system could be achieved.

Using organic nitrogen sources, especially legumes and animal manure are central to a sustainable agricultural system (Andrews *et al*, 1990). Synthetic nitrogen sources are produced by non-renewable petrochemicals and can only be maintained in conjunction with a cheap energy source (King, 1990). In addition, synthetic sources provide only short-term fertility and can have negative effects on the physical and biological properties of the soil (Andrews *et al*, 1990). Manure, on the contrary, is considered an ideal fertilizer; "the organic fraction of manure is not subject to leaching or denitrification losses, it is not toxic to plants, and it mineralizes at a rate dependent on the same climatic conditions as plant growth" (p.284, Beaudoin *et al*, 1984 in Andrews *et al*, 1990). Manure as a whole, however, can be subject to leaching, thus care must be taken when applying it to minimize this risk. (Andrews *et* al, 1990). Using legumes is also considered a component of sustainable agriculture as legumes enhance soil organic matter, reduce runoff, erosion, and groundwater contamination, and can increase yields of subsequent crops.

Reducing the amount of purchased inputs, i.e. herbicides, pesticides, fertilizers, or conducting organic agriculture, are important as this can decrease the chemical contamination of the environment and reduce the production costs of farm operating expenses (Doran & Werner, 1990). Reducing inputs does not simply mean 'going without' but rather changing the system so that these inputs become unnecessary (Lockeretz, 1988).

Herbicide use has expanded with increases in farm size and an accompanying decrease in crop diversity. The practice of continuous cropping has necessitated the use of herbicides in order to maintain yields. The use of herbicides can be reduced by planting crops with weed-suppressing abilities as well as using techniques such as intercropping, allelopathic[5] cover crops, and soil fertility management. Herbicide use can be further reduced by planting crops more densely as there is a more complete capture of water, light, and nutrients thereby providing an advantage over undesirable species. Crop rotations are also effective at weed suppression as there can be a diversity among planting and maturation dates, as well as cool and warm season crops thus creating an unstable and unfavourable environment for the survival and reproduction of annual and perennial weeds (Liebman & Janke, 1990).

Pesticide use can also be reduced without the use of external inputs in the same manner as herbicides. In a sustainable agricultural system the main strategy is not pest eradication but pest avoidance (Bird *et al*, 1990). Pest resistant crops and cultivars as part of rotations is one method to avoid pests. Creating a biological diversity through crop rotations also causes an unstable environment for pests (Doran & Werner, 1990) as the reproductive cycle of pests can be disrupted as well as depriving them of an essential food source (Madden, 1990). Managing soil fertility for sub-optimal growth conditions for pests; avoidance of diseases, transplants and infected seed; and maximizing the use and maintenance of suppressive soils are additional strategies to minimize pests (Bird *et al*, 1990).

Improving crop rotations, in addition to alleviating the stresses from pests, can also diminish soil loss especially when accompanied with appropriate harvesting techniques. This can also lead to improvements for the physical condition of the soil (Francis, 1990). A sustainable rotation has been postulated as the following: a clean cultivated crop (corn, soybeans), followed by densely planted and highly competitive grain crops (barley, oats, wheat), and then mowed and untilled perennial crops (alfalfa, forage grass/ clover mix) (Liebman & Janke, 1990).

Within a sustainable agricultural system the economic and social sustainability are also important parameters. For the economic aspect, according to the Low Input / Sustainable Agriculture guidelines: if a method of farming is not profitable, it cannot be

---

[5] allelopathy=chemicals from cover crop residues inhibit germination and growth of many weeds

sustainable (Madden, 1990). This does not imply that high yields are the goal, for by lowering external inputs, costs can also be lowered thus increasing overall profit.

Social sustainability is another constituent of sustainable agriculture and relates mainly to the sustainability of rural communities. In essence the debate is that by implementing sustainable agriculture, capital can be freed thus freeing people from set patterns of dependence and thus people become more able to contribute to the sustainability of their communities (Flora, 1990).

The concepts presented here will be used to establish criteria in the Methodology section to provide for a subsequent evaluation in the Results chapter.

3. Methodology

Since hemp has not been legally grown in Canada for more than 50 years, a publicly accessible knowledge base, comparable to what exists for other crops, has not been maintained. Nevertheless, a small group of farmers and researchers has been located through various methods. This thesis involves a combination of searches in the published literature, as well as the Internet, conference communications, and finally a small but widely dispersed questionnaire survey of hemp farmers and researchers in Canada and elsewhere. The published literature included reports from the late 1800s and early 1900s which contained valuable information about cultivating hemp. As hemp has become more prevalent, new reports are being released more frequently and several trade journals have been developed. Reports from new Canadian hemp farmers, in addition to ones from other countries, have also become available as they share their experiences. Several hemp conferences have recently been held in various locations around the world. Conferences which were attended to gather information include Winnipeg, Manitoba-February 1996; Toronto, Ontario- April 1996; and Lexington, Kentucky- May 1996.

The conference in Winnipeg, was the first Canadian Industrial Hemp Symposium, and from the conference the Canadian Industrial Hemp Council was formed. The research from the first year of hemp trial plots in Manitoba was presented. Hemp researchers from the Ukraine and Poland provided valuable information about growing industrial hemp and the physical and chemical properties of the hemp plant.

Industrial Hemp: Economic Opportunities for Canada was the name of the Toronto conference. It was held in order to generate interest in establishing a hemp industry in Southern Ontario. Again there were speakers from around the world, this time from England and Germany. There was a large focus on what would be required to develop a hemp industry in Canada, from growing, to harvesting, to marketing.

The third conference attended was held in Kentucky. International speakers at this conference were from England, the Ukraine, the Netherlands, Australia, Ireland, and Canada. Again the focus of the conference was on establishing an industrial hemp industry, this time in Kentucky, where the Kentucky Hemp Growers Co-operative Association is ready to grow hemp once it is legal to do so. There was a large emphasis on different stages and methods of processing and the various products that are presently, and possibly could be, made from hemp.

An important source of information for this thesis has been the Internet. As researchers wait to publish their reports in journals, they are sharing their experiences with the world via the Internet. This medium has been extremely useful as current information on *Cannabis sativa* is difficult to access.

3.1 Questionnaire

Due to the lack of current published information, especially in Canada, a questionnaire was developed and distributed to practising hemp researchers and farmers. This questionnaire was designed to provide a glimpse into what was occurring in the hemp growing sector. A list of recipients was compiled through contacts made at various hemp conferences, hemp organizations, and postings on the Internet. An attempt was made to have representation from all of the current hemp growing areas: China, India, Russia, Ukraine, Romania, Hungary, Poland, France, Spain, Germany, United Kingdom, Australia, Yugoslavia, the Netherlands, and Canada.

In the spring of 1996, 50 surveys were sent out to various hemp farmers and researchers from these countries. Two surveys were included in each package so that recipients could distribute the surveys to other interested parties who may have not received a questionnaire. No attempt was made to distribute the questionnaires on a random basis. The recipients of the questionnaire were regarded as experts.

The questionnaire had 45 questions, divided into 8 sections: background information, rotations, soil characteristics, climate, crop characteristics, use of inputs, incidence of diseases/pests/weeds, yields, and outputs all relating to the cultivation of industrial hemp. The initial set of background questions determined to what extent, for what purposes, and for what length of time industrial hemp had been grown by the farmer/researcher.

A subsequent section contained questions concerning the agricultural, climatic, and agronomic details of growing industrial hemp. Questions specifically asked about the use of fertilizers and various biocides. Respondents were then asked about the hemp yields and the financial returns received from the past five years of their hemp crops. Unfortunately the lack of hemp growing experience severely limited the responses in this section.

By October 1996, there were 20 respondents to the questionnaire. Of this total, 14 had returned the survey and the remainder submitted either their own literature or letters explaining that they did not have enough hemp growing experience to complete the questionnaire. Some of the newly established hemp growers have posted their results on the Internet and these reports have been included to complement the surveys returned.

The results of the surveys have been compiled and explained in the Results chapter. An interpretation of the 14 surveys and additional reports is included in the Analysis chapter. There was insufficient information to perform any statistical tests. Thus the results are for comparative purposes only. In the Results chapter the questionnaire findings will be compared to the information provided in the Literature Review in order to make comparisons between hemp, straw, switchgrass, and wood fibre.

3.2 Sustainability Criteria

Though sustainable agriculture can be considered a philosophy there are also some practical applications and actions that can be derived from this concept. The Literature Review provided a detailed description of sustainable agriculture and the following section outlines some criteria for a sustainable agricultural system,. The criteria in this thesis are based mainly on a set of criteria initially proposed by Lockeretz (1988), and then supplemented with information from other sources (Francis *et al*, 1990). Though in essence each of the following practices may contribute to the sustainability for the 'system', to be truly sustainable all of the criteria must be met. Thus a sustainable agricultural system will incorporate:

1. A diversity of crops through the use of rotations, relay cropping, and intercropping.

2. A selection of crop varieties and livestock that are well suited to the farm's soil and climate.
3. A selection of crop varieties that resist pests and diseases as well as enhancing conditions for controlling or suppressing weeds, insect pests, and diseases. Synthetic biocides to be used only as a last resort, and only when there is a clear threat to the crop.
4. A tightening of nutrient cycles to minimize the loss of nutrients off the farm, and to reduce the need for external inputs, such as by composting of livestock manures and by rotations using legumes to fix nitrogen.
5. An enhancement of the soil's ability to take up applied nutrients for later release as needed by the crop, in contrast to direct uptake by the crop at the time of application.
6. Rotations that include deep-rooted crops to tap nutrient reserves in lower strata.
7. A protective cover on the soil surface throughout the year (leaving crop residues on the surface, cover crops, living mulches).
8. Preferences for farm-generated resources over purchased materials, and locally available off-farm inputs when required, over those from remote regions.
9. A positive impact on the immediate and off-farm environments (physical/ economic/ social).

These criteria will be used in the Results section to compare the sustainability of hemp, switchgrass, straw, and trees as sources of fibre. Trees are included in this comparison as they can be part of an agricultural system, especially in Nova Scotia where farmers often have small woodlots on their properties. In addition, intensively managed forest plantations are more similar to agricultural systems than natural forests.

A scale was developed to rate each fibre source's contribution to a sustainable agricultural system based on the preceding criteria. The scale ranges from 1 to 5, where a rating of 1 indicates that the crop rarely contributes to the sustainability of the system, a rating of 3 indicates that it sometimes contributes, and a rating of 5 indicates that it frequently contributes to the sustainability of the system. The ratings for each criteria are cumulative. A total score will be tallied and used to evaluate each crop's potential to contribute to a sustainable agriculture system.

3.3 GIS and Mapping

Since part of the purpose of this thesis is to determine if hemp could be a crop for Nova Scotia, the capability of the soils in Nova Scotia to grow hemp successfully was evaluated. Agriculture Canada, in Truro, NS, provided data from the Soil Landscapes of Canada Survey, and the Nova Scotia Soil Survey (Patterson, 1996). This data set, based on hundreds of polygons, was interpreted to determine where hemp could be grown in Nova Scotia. A soil suitability matrix was constructed based initially on corn and spring cereal classifications, as these crops share some characteristics with hemp, such as soil type and well drained soils. Some factors, such as stoniness are not related to the crop, but rather to the limits of mechanized farming. The matrix was then modified, based on information from the Literature Review to construct classes suitable for growing hemp. Two matrices were constructed: one for the whole province, and one for a subset of an area in the Annapolis Valley (Aylesford/Berwick, Kings County). The two matrices, and landscape information, were used to produce maps of the province and the study site.

The data for the two sets of maps were from different sources and thus distinct matrices had to be produced for the maps at the provincial level and the study area. For the provincial map, all of the information concerning depth (d), flooding (i), stoniness (p), rockiness (r), slope (t), drainage (w), and texture (m) were provided by the Soil Landscapes of Canada report for the Maritimes. For the smaller study area, all of the soils had to be interpreted manually from soil codes for each polygon provided by the Nova Scotia Soil Survey. Each soil code was reduced into the same components as above with the exception of the texture class. In this data set particle size (s) is used instead. The matrix was then used to rate the polygons for their potential to grow hemp. The following matrices were used in this study:

Table 3-A - Classification Criteria for Provincial Soils

Degree of Suitability	GOOD	FAIR	POOR	UNSUITABLE
Soil Factors				
DEPTH (d)	2-3	1	-	-
FLOODING (i)	None	Occasional	Frequent	V. Frequent
STONINESS (p)	0-1	2	3	4-5
ROCKINESS (r)	0	1	-	2-5
SLOPE (t)	A	B	C	D-F
DRAINAGE (w)	W	I, R	P	E, VP
TEXTURE (m)	CobSL	CoarseS	VGravSL	Peat
	FineSL	FineS	GravLS	VGravLS
	SL	GravSL	GravS	VGravS
	VFineSL	VFineSiCL	C	
	GravL	CobGravL	HeavyC	
	L	GravCL		
	SilL	VFineS		
	GravSiL	LFineS		
	CL	SC, S		
	SiL	CobL, LS		
	SiCL	GravSiC, SCL		

Depth	Stoniness	Rockiness	Slope	Drainage	Texture
1=0-49cm	0=nonstony	0=nonrocky	A=1=3%	E=excessive	Cob = cobbly
2=50-100 cm	1=slight	1=slightly	B=4-9%	R=rapid	S= sand
3=>100cm	2=moderate	2=moderately	C=10-15%	W=well	L= loam
	3=very stony	3=very rocky	D=16-30%	I=imperfect	Grav= gravelly
	4=exceedingly	4= exceedingly	E=31-60%	P=poor	Si= Silt
	5=excessively	5=excessively	F>61%	VP=very poor	C= Clay

Table 3-B Classification Criteria for Study Site Soils

Degree of Suitability	Good	Fair	Poor	Unsuitable
depth of friable soil (d)	>50	20-50	-	<20
particle size (s)	2,3,4	0,1,5	6,7	8,9,P
flooding (i)	None	Occasional	Frequent	Very Frequent
stoniness (p)	0-1	2	3	4-5
rockiness (r)	0	1	-	2-5
slope (t)	B-C	D	E	F,G
drainage (w)	W, MW	I,R	P	VP

Depth Class (cm)
2=20-50
5=50-80
8=>80
X=cemented layer present

Particle Size
0=fine loamy
1=fine loam gravelly
2=coarse loamy
3=coarse loamy-gravel
4=fine sandy
5=sandy
6=sandy gravelly
7=loamy-skeletal
8=sandy skeletal
9=fragmental
P=peat

Stoniness
2=moderately stony

Rockiness
1=slightly rocky

Slope
B 0-2 level to nearly level
C 2-5 very gentle slopes
D 5-9 gentle slopes
E 9-15 moderate slopes
F 15-30 strong slopes
G 30-45 very strong slopes

Drainage
W= well
MW=moderately well
I=Imperfect
P=Poor
VP=Very Poor

The drainage classes remained the same for growing hemp. However, they were upgraded one class under certain circumstances. For all slope classes, other than for 'A' on the NS map and 'B' on the Study Site map, 'fair' rated soils become 'good', and 'poor' rated soils become 'fair'. This upgrade is allowed as tile drains, to improve drainage, can be used successfully on land that is not completely level.

On the Nova Scotia map several of the soils classified as 'fair' for corn were upgraded to 'good' for hemp. This included mainly the clay soils and the silt soils as the literature indicated that these types of soil are extremely suitable for growing hemp (Vessel & Black, 1947). All slope classes remained the same for the Nova Scotia map. However, for the study site map all slope classes were upgraded one rating as there is an additional slope class at this scale.

Each polygon had to be rated according to the matrix as 'good', 'fair', 'poor', or 'unsuitable'. If all conditions were 'good', then the polygon was rated 'good'. The lower class dominates the classification; if there were one or two 'fair' or 'poor' ratings then the polygon was assigned 'fair' or 'poor' along with a letter code to denote the limitations. Three or more 'fair' limitations would result in a 'poor' (Px) rating, and three or more 'poor' ratings would result in an 'unsuitable' (Ux) rating. 'Good' soils are suitable for growing hemp without any changes. 'Fair' soils have at least one limitation that must be overcome before the land is suitable for growing hemp. The poor soils have too many or too severe limitations to allow suitable growing of hemp. It is unlikely that 'unsuitable' soils will ever be suitable for growing hemp.

Once the ratings were established, the data were imported into ArcView (version 2) where they were mapped. The maps are included in the Results chapter. The main objective of the maps was to analyze the soil conditions of Nova Scotia to determine their suitability for growing hemp under a mechanized farming system. With the help of James Boxall, at Dalhousie University, a map was produced of Nova Scotia showing the 'good', 'fair', 'poor', and 'unsuitable' areas to grow hemp (Figure 4-A). A second map of the province was produced showing the 'fair' soils and their limitations (Figure 4-B). Six maps of the study area were produced that allowed for more detailed interpretations than at the provincial level (Figures 4-C/G).

After producing the maps, the data were imported into Microsoft Excel where some analysis was performed. The land area and percentages of soils with 'good', 'fair', 'poor', and 'unsuitable' ratings were determined. In addition, the percentage of the limitations on 'fair' soils were calculated. In the study site map the percentage of land that is presently forested, urban, agricultural, flooded and clearcut was also included. These data will be presented in the Results chapter to determine how much suitable land area in Nova Scotia is available for growing hemp.

4. Results

4.1 Questionnaire Results

By October, 1996, 14 completed surveys were returned. Some organizations and individuals sent their own literature instead of completing the survey. A final response rate of 32% was achieved, a number that is quite high for survey responses. Other information used in this section was gathered from reports that farmers and researchers had posted on the World Wide Web. A summary of the results is located in Appendix B.

4.1.1 Background Information

Of the surveys returned, four were from Canada, three from The Netherlands, two from France, and one each from Australia, England, Yugoslavia, China, and Hungary. The results were extremely varied, as they ranged from small research plots in Canada to full-scale commercial hemp production in Hungary that has not ceased operating since the Middle Ages. Reports from the Canadian test plots in Ontario and Saskatchewan were posted on the Internet and included in this analysis.

The area devoted to hemp production ranged from a 0.12 ha research plot to 8,000 ha in France. The French area, however, is believed to be a total of all hemp crops in France. The survey respondent in this instance was a hemp business which enters contracts with farmers to produce hemp.

The most prevalent purpose for growing hemp was for fibre (12 respondents), followed by four respondents growing oil seed, and 4 growing seed for planting. There was one plot grown exclusively for birdseed (Yugoslavia) and one as a windbreak (Alberta). The dominance of growing hemp for fibre could be influenced by the legal requirements. In Canada, the crops were not allowed to go to seed and were to be grown exclusively for fibre. It is possible that similar requirements existed in other regions as well.

4.1.2 Varieties used

The varieties of hemp grown were dominated by those originating from Hungary and France. Both of these areas have done extensive research into low-THC seeds and have developed government certified low-THC varieties. In the European Union, farmers are only eligible for a subsidy when certified low-THC varieties are used. The French varieties, being the first ones to receive this accreditation have become dominant. In China, a local landrace was used. China reportedly has some of the best hemp varieties, although it is not exporting these seeds.

The Hungarian, dioecious, Kompolti and Uniko varieties were the ones most frequently used, followed by the French, monoecious, Fedrina and Fedora varieties. A complete list of the varieties used is included in the Results summary in Appendix B..

Although the Literature Review suggested that monoecious varieties were easier to harvest, there were only three respondents who reported growing exclusively monoecious varieties. Five respondents grew only dioecious varieties and three grew a combination of both varieties. Dioecious varieties are also believed to produce higher fibre yields (Bócsa, 1994).

4.1.3 Seeding Rates and Row Widths

Table 4-A illustrates the rates of seeding and the row width for both fibre and seed hemp crops. The seeding rate for fibre was quite varied, yet it is not surprising since many of the respondents were researching various factors, seed density being one of them. The seed density is also one factor that is presently subject to a trial and error procedure as farmers experiment with growing hemp in new areas. Seeding rates can influence the final fibre yield and also the degree of competition between plants. From these results it is difficult to establish which factor had the greatest influence on final stem yields.

The density of the hemp crops, as a function of row width, is an important factor for both erosion control and stem yields. There was less variation among row widths responses than for the seeding rates (Table 4-A). Decreasing row widths usually leads to increased plant density at harvest and also promotes a homogeneous distribution of plants (van der Werf, 1994a).

Table 4-A Seeding Rates and Row Width for Hemp Fibre and Seed Production

Seeding Rates (kg/ha)	*minimum*	*maximum*	*average*
fibre	8	85	46.5
seed	4	10	7
Row Width (cm)			
fibre	12	40	19
seed	50	70	65

4.1.4 Use of Manure and Fertilizer

The Literature Review indicated that animal manure was the best single fertilizer for hemp crops. The survey results, in Table 4-B, demonstrate that this advice has not been extended into practical experience. All but 2 respondents used chemical fertilizers to varying degrees. While the use of nitrogen was usually within the rates in the literature, the use of phosphorus and potassium were usually lower.

Table 4-B Reported Annual Commercial Fertilizer Use on Hemp Crops (kg/ha)

	Nitrogen (N) (n=11)	Phosphorus (P_2O_5) (n=10)	Potassium (K_2O) (n=9)	other
Alberta	86	41	14	18 (sulphur)
Netherlands(1)[6]	125	46	173	
Yugoslavia	20	60	40	
Netherlands(2)	120[7]	40	150	
France	60-120	50	120	
Saskatchewan	50	60		
Hungary	100	200	0-200	
Manitoba (1)	0	0	0	sheep manure
Manitoba (2)	100 [8]			
France	80-120	40-60	160-200	
Australia	100	40	40	2000 (lime)
average	81	58	91	

[6] assuming production of 10,000 kg/ha of stem dry matter

[7] when soil N is between 10-50 kg/ha

[8] available +applied

4.1.5 Incidence of Pests, Disease, and Weeds and Biocide Use

The Literature Review indicated that several pests and diseases could affect hemp crops. Experience from respondents indicated very few reports of pest infestations (Table 4-C). *Sclerotinia* was reported on Canadian crops, and was thought to be the result of improperly cleaned seed. Bertha Army Worm (*Mamestra configurata)* was also reported for Manitoba crops; however, 1995 was a peak year for this pest. *Botrytis cinerea* was reported to be a problem in years or regions with excess moisture. In most instances no control measures were taken, except rotations to control pests, as set out in the following section.

4.1.6 Rotations

The rotations used with hemp varied between regions and, as discussed in the Literature Review, rotations in some countries are more a factor of economic needs than maintaining soil quality. The information provided in this section, and displayed in Table 4-D, was limited due to inexperience with hemp crops, or no notice was taken of the rotations used.

The rotations most commonly recommended in the literature were potatoes, sugar beets, cereals, corn, and clover. In practice the following crops are also rotated with hemp: market vegetables, cabbage, root crops, winter wheat, peas, barley, buckwheat, clover, wheat, trefoil, oats, and flax. Canola was also rotated with hemp in Western Canada; however, it could only follow hemp, not the reverse, due to a possible *Sclerotinia* carryover. It was not possible to determine which crops were most commonly used with hemp as each farmer appeared to have a unique rotation presumably arising out of local conditions.

Table 4-C Incidence of Pests, Disease, and Weeds and Biocide Use

Location	Pest	Control	Comments
China	*Psylliodes attenuata* (Flea beetles)	none	
Manitoba (2)	*Sclerotinia sclerotiorum* (Hemp canker)	none	-research parameter, therefore no control measures taken -seed wasn't disease free
	Mamestra configurata (Bertha army worm)	none	-caused severe damage
	Canada thistle, wild mustard	none, hemp worked under	-on a site with reduced-non-uniform emergence
Alberta	*Sclerotinia sclerotiorum*	none	
Manitoba (1)	*Sclerotinia sclerotiorum*	none	
	Mamestra configurata (Bertha army worm)	none	
Netherlands (1)	*Sclerotinia sclerotiorum*	none	-none in practice though experiments with fungicides in research
	Botrytis cinerea	none	-greater incidence in wet years
Yugoslavia	none	none	
Netherlands (2)	*Botrytis cinerea*	none	-can be severe in wet years
	Sclerotinia sclerotiorum	none	
Hungary	*Psylliodes attenuata*	metylparation	
	Sclerotinia sclerotiorum		
	weeds	-benefin	-applied presowing
France	some	no treatment	
France	none	none	

Table 4-D- Reported Rotations used and proposed over a 9 year period.

	Manitoba (1)	Alberta	Yugoslavia	China	Manitoba (2)	Netherlands (1)
4 years prior to hemp		barley				
3 years prior to hemp	flax	barley				
2 years prior to hemp	oats/trefoil	barley			canola	sugar beets or cereals
1 year prior to hemp	trefoil	peas	wheat	market vegetables (spring)	oats	potatoes or cereals
hemp	**hemp**	**hemp**	**hemp**	**hemp**	**hemp**	**hemp**
1 year following hemp	buckwheat/ clover	barley	corn	cabbage and root crops (fall)		
2 years following hemp	clover plowed down	barley	**hemp**			
3 years following hemp	rye	peas	sugar beet			
4 years following hemp	**hemp**	canola				

Crop rotations in Yugoslavia are determined by the acreage of crops rather than contributing to the growth of other crops within the rotation. The rotations are not fixed and are thus able to respond to market demands. Crops are grown in monoculture when the demand is high and not at all when the market demand is lacking.

In most areas hemp was regarded as important for its contribution as a natural herbicide. This was the case for the organic farmer in Manitoba, and the one in Yugoslavia, who were impressed by hemp's weed suppression abilities without the need for chemicals.

In the Netherlands, it is hoped that the introduction of hemp in short rotation with potatoes may improve soil health because hemp is less susceptible to the fungus *Verticuillium dahliae* and to certain root-knot nematodes (*Melaidogyne chitwoody* and *M. hapla*).

In most regions there had not been sufficient experience to determine if hemp had changed the condition of the soil. In China, it was reported that the level of market vegetable production had increased markedly in the past five years. In France, it was observed that the hemp crops had improved the soil structure and improved the wheat yield. In Hungary, although hemp required irrigation and nutrients, and left the soil exhausted, the natural herbicide factor outweighed these negative factors.

There was only one mention of the concern over hemp's high nutrient uptake and this was in Manitoba. There was no elaboration provided to describe how this factor could be alleviated, nor what the net nutrient requirements were in this instance.

In Alberta, due to the *Sclerotinia* infestations, it was noted that hemp should not follow canola or peas due to possible carryover of this fungus. Ensuring that the hemp seed was clean and free of contaminants would also minimize such pest infestations. Improperly cleaned seed was apparently the reason for the low yields, attributable to pests, in some of the Manitoba fields (Moes, 1996). In Hungary, it was recommended that hemp not be sown on the same fields successively as there would be a danger of *Psylliodes attenuata* damage.

The literature also recommended the use of a green manure to supply fertilizing elements. In the 8 surveys where rotations were provided (6 detailed reports, 1 report that hemp followed corn, and 1 report that it followed cereals) there were only 2 sites where a legume was included in the rotation (trefoil, clover, and peas). In both instances, hemp followed a legume in the rotation, thus receiving maximum fertilization benefits.

Due to the limited number of responses it was difficult to determine how often hemp appeared in rotations. In Manitoba, a four year rotation was proposed, compared to Yugoslavia where only a two year rotation was anticipated, and in China hemp was grown every year (though between spring and fall crops).

4.1.7 Climatic Conditions Affecting Hemp

When respondents were asked about unfavourable conditions for growing hemp, it was reported that drought and excess moisture affected hemp more than frost conditions. In the Netherlands, it was found that young plants could tolerate short night frosts of -8°C to -10°C, and older plants could tolerate frosts of -5°C to -6°C. In Hungary, it was reported that hemp was resistant up to a -5°C frost.

Drought stresses on peaty soil were reportedly a major cause for lower yields, causing reductions of 25-35%. Drought was also considered to be an important factor during flowering in Hungary and Yugoslavia. In France, it was remarked that drought would halt the growth of the hemp plant.

Excess moisture was reported to definitely halt the growth of the plants. Though excess moisture is not considered a problem in Hungary, it was noted that this condition could lead to susceptibility to *Botrytis* and *Sclerotinia*. In Manitoba, it was observed that excess moisture seemed to make hemp more susceptible to disease. Rain during harvesting could also pose challenges to effective drying of the hemp on the soil surface, though some moisture is required if retting is to take place on the fields.

4.1.8 Planting and Harvesting Dates

The time required for harvesting hemp crops is dependent on the varieties grown and climate considerations. Examples of planting, harvesting and flowering dates are presented in Table 4-E. The days to harvest ranged from 60 to 155 days, which is quite a large difference. This is most likely attributable to the use of early and late flowering varieties, though this information was not provided in the survey. Several respondents indicated that they planted early and late maturing varieties. Unfortunately specific dates for different varieties were not provided. Harvesting for fibre is undertaken when flowering occurs. Hemp seed is usually harvested about one month after flowering. Late flowering varieties are commonly used to maximize stem yields as they do not mature until early fall. By the time these varieties flower, the weather is no longer suitable to wait the extra month required for seed development.

The establishment of some of the Canadian plots in 1995 was delayed due to problems securing permits, thus seeds were planted significantly later than desired by the farmers. Mechanical limitations were also responsible for some harvesting delays.

4.1.9 Yields

The yields reported in Table 4-F are consistent with those documented in the Literature Review. As discussed in the Literature Review, yields are a function of variety, density, fertilizer and other agronomic and climatic details. A comparison of seeding rates, yields, and fertilizer is illustrated in Table 4-G. From these surveys, it is difficult to determine what the main limiting or beneficial factor was for the yields attained. Information from the Netherlands indicated that the production of dry matter, under favourable growing conditions, is proportional to the amount of light intercepted by the canopy. The information from the surveys indicates that more research into yields is necessary, especially in regard to seeding rate. Two respondents indicated yields of 8-10 t/ha of total dry matter, yet they had quite different seeding rates, 22 kg/ha and 80 kg/ha. Since the cost of the seed is currently one of the highest costs involved in growing hemp, a farmer wants to know about potential yields expected from different seeding rates.

The reported yields are indicative of hemp's potential as a fibre crop, particularly because there were both farmers and researchers among the respondents. The highest yields were reported in Alberta (13t/ha), China (12t/ha), and Australia (11t/ha).

Table 4-E Days to Flowering and Harvest for Hemp

	planting date	*total days to flower*	*harvest date*	*total days to harvest*
Manitoba (1)	June 15		Sep 10	88
Alberta	May 24		Aug 18	87
Yugoslavia	10 April		Aug 20	133
Netherlands (2)	15 April		15 Sept.	155
France (1)	April/May	July	Aug/Oct.	
China (fibre)	April	70-110 (x=90)	July	
China (seed)	May/June		Sept.	
Saskatchewan	June 17	55	Aug 29	73
Hungary	early April	110-115 (x =113)	late August	
Manitoba (2)	June 10	45-70 (x=58)	midAug- late Sept.	
France (2)	April 10-May 30		July 25 - Oct. 10	107-153 (x=130)
Australia		60		60
Ontario	June 13		Aug 15	63
average	May	75	Late August	98

Table 4-F Reported Yields for Hemp (ton/ha)

Location	*total dry matter* n=9	*bast fibre* n=11	*seed* n=2
Manitoba (1)		1	
Alberta	13	3.2*	
Yugoslavia	8-10	2-2.5*	0.6-0.8
Netherlands (2)	8-10	2-2.5	
Netherlands (3)		1	
China	8-12	0.7-1.0**	
Saskatchewan	8	2*	
Manitoba (2)	4.5-7.5	1.1-1.8*	0.1
France (2)	6-10	0.6-1.0	
Australia	11	2.7*	
Ontario	2.9-7.3	0.7-1.8*	
average	8.8	1.7	0.4

**fibre = 35% of stem is bark, 70% of bark is bast fibre*

***hemp ribbon pulled off by hand*

Table 4-G Comparison of Nitrogen Use, Seeding Rates, and Fibre Yields

Location	*Nitrogen Use (kg/ha)*	*Seeding Rate (kg/ha)*	*Fibre Yield t/ha*
Manitoba	Manure	48	1Tfibre
Alberta	86	8-32	13
Netherlands (1)	125	40	13.6
Yugoslavia	20	80-85	8-10
Netherlands (2)	120	22	8-10
France (1)	90	45	n/a
China	n/a	75	8-12
Saskatchewan	50	32-96	8
Manitoba (2)	100	80	4.5-7.5
France (2)	80-120	50-60	6-10
Ontario	200	27.3	2.9-7.3
Australia	100	n/a	11

The Ontario information is relatively low, this was explained by the researcher that the seeding rate was much lower than desired (only 27kg/ha). It was reported that if the seeding rate had been higher then the yields would probably also have been higher. It is difficult to interpret the accuracy of this statement due to the variation in the results between seeding rates and yields. This statement further supports the necessity for further research into the effects of seeding rates. The report from Manitoba also stands out as one of the lowest reported, but notes from the survey suggest that this was due to pest infestations lingering from a canola crop.

While varieties bred for high primary fibre yields can yield up to 35% primary bast fibre, a more reasonable estimate of 24.5% was used to extrapolate from total dry stem content to fibre content (stem contains 35% bark and 70% of this is bast fibre). The report from France, however, suggests a fibre yield of 1/10th of the total dry matter yield. The yield of fibre is also dependent on the extraction method. In comparison to the other yields, the Chinese fibre yield of 0.7-1.0 is also low; however, this fibre is pulled off the stalks by hand (Clarke, 1995).

4.1.10 Height and Width of Hemp Stems

Reports about hemp's lofty heights are widespread and are presented in Table 4-H. The results of the survey indicate that the range of heights was between 1.8m and 3.2m. The average height was 2.5m.

The thickness of the hemp stems was requested in the survey as this can be an indicator of optimum plant density and fertilization. In addition to the information presented in Table 4-I, two respondents indicated that the thickness of the stems was a factor of density, and the respondent from Saskatchewan observed that at a higher density the stem thickness decreased (6mm for 200seeds/ha and 4mm at the 600 seed/ha rate).

4.1.11 Financial Returns

The only financial information that was provided in the surveys was from China where $US600-800/ ha was received for hemp fibre. Information was not available for Canada because one condition of the research permits is that the farmers/researchers are not allowed to sell any portion of the crop. Information from other areas was not provided, in most instances because the plots were only for research. Unfortunately, the respondents from the regions where hemp is produced commercially did not divulge the financial aspects of growing and/or selling hemp.

Table 4-H Reported Heights of Hemp Crops (m)

Location	*Height (m)* *n=13*
Manitoba (1)	2
Alberta	3
Netherlands (1)	3
Yugoslavia	2.5-3
Netherlands (2)	2.5-2.9
Netherlands (3)	3.2
France (1)	1-3
China	2.5-3
Saskatchewan	2
Hungary	2.5
Manitoba (2)	2-3
France (2)	2-2.5
Australia	1.8
average	2.5

Table 4-I Reported Stem Thickness of Hemp (cm)

Location	*Thickness (cm)* *n=8*
Manitoba (1)	1
Alberta	2
Yugoslavia	1-1.5
Netherlands (3)	15
France (1)	0.3-2
China	1
Saskatchewan	0.6-0.4
Hungary	0.8
average	1

4.2 Comparative Analysis

In this section the results of a comparison of the physical properties, growing and harvesting conditions, and fibre yields for hemp, switchgrass, straw (wheat/oats/barley), and trees will be presented. This information will be used to evaluate the environmental and economic sustainability of these sources of fibre for the pulp and paper industry.

4.2.1 Physical and Chemical Properties of Select Fibres

Table 4-J outlines the physical and chemical properties of wood and non-wood fibres. This table provides the basis for the upcoming comparisons of these various fibres. In the Literature Review, it was stated that cellulose content is the main factor in determining whether a fibre is suitable for pulp and paper production. From this table it can be seen that the hemp bast fibres have the highest cellulose content of the ones used in this comparison. Switchgrass and trees have similar levels and the hemp hurds approximate the cellulose content of straw. Given that straw is commanding increased attention as an agri-pulp (IIED, 1996), it is possible that hemp hurds could also fit into this niche while allowing the more valuable bast fibres to be used for textiles or specialty paper.

Fibre length is of great concern to papermakers, as longer fibres can provide more strength. From this table it can be seen why hemp fibre is often considered too long. Its length exceeds all other fibres in the evaluation. This could be of benefit as the hemp fibres can then be cut to uniform lengths, thereby avoiding the problem of variable lengths. Because of wheat straw's shorter lengths, in comparison to hemp, it could be used as a filler pulp and combined with longer fibres that would overcome the strength issue. Hemp hurds could have the same application.

The lignin content is another important factor for pulp production. This chart confirms that hemp bast fibre has one of the lowest amounts of lignin. Even at the high

Table 4-J Physical and Chemical Characteristics of Non-Wood and Wood Fibres

	HEMP bast fibre	HEMP hurds	SWITCH GRASS	TREES softwood	TREES hardwood	STRAW* general cereals	STRAW* wheat
Fibre length (mm)	1°=10-100[1] x=25[11]-45[4] (2°=2)*	0.26-0.44[4] 0.55[1]	1.36[6]	1.5-5.7[9] x=3.5[9]	0.7[8]-0.8[6]	0.6-3.1[9] x=1.5[9]	x=1.5[8]
Fibre width (μm)	13[11]-67[4] x=25[11]-30[4]	14-27[4]	11[6]	24-59[9] x=35[9]	20[11]-30[8]	7-27[9] x=13[8]	x=15[8]
Cellulose content (%)	60-72[4]	34.5[2]-41[4]	43[6]	spruce=43[9]	birch=41[9]	34-40[9]	34[11]-54[3,7]
Lignin content (%)	2.3[4]-8[2]	19-21[4]	21.5[6]	20-34[5,9,8]	20[9]-30[8]	16-20[9]	10-20[5,7]
Ash (%)			1.5[6]	<1[8]	<1[8]	5-8[8]	5[8]-11[6]
Silica (%)	n/a	n/a	n/a	n/a	n/a	3-7[8]	3-7[8]

**(1°=primary bast fibre, 2°=secondary bast fibre)* *n/a=not available*

[1] Heuser ,1927; in van der Werf, 1994
[2] Christie, 1978; in Walker, 1994
[3] Clark, 1994; in Walker, 1994
[4] EP de Meijer, 1994 (in Rosenthal)
[5] Hunsigi, in Rosenthal, 1994
[6] REAP, 1996
[7] Laith *et al*, 1994
[8] US PTF, 1995
[9] UNEP,1996

estimate of 8%, this is still half as much as the average content of the other fibres evaluated. Since lignin is one of the compounds that must be broken down in the pulping process, it can be concluded that it would take less energy and chemicals to process the hemp bast fibres, although this would depend on the particular pulping process used. The lignin content of hemp hurds is within the same range as the other wood and non-wood fibres. Wheat straw had the second lowest amount of lignin.

Another factor that is important to pulp production is the silica content. The presence of silica, a mineral component of the fibre, can affect the quality of the paper. Silica also accumulates in the chemical recovery system, making it difficult to recover the black liquor effluent produced by the pulping process. Straw contains a large amount of silica compared to other fibres thus posing some problems for pulping, however, with new technology it is believed that this problem could be overcome. Silica is one component of the ash, thus the inclusion of the ash content allows interpretation where the silica content is not provided.

4.2.2 Fertilizer Use

It is difficult to make conclusions about the use of fertilizers as it depends on the initial fertility of the soil. From the literature and the surveys it can be concluded that for hemp, high soil fertility and/or the use of fertilizers are required to achieve the high yields of fibre and this is supported by the literature.

In the comparison of fertilizer use (Table 4-K), the amount applied to trees stands out as the lowest. One reason for this result is that this amount has been amortized over the life of a 20 year stand. Switchgrass also has low nutrient requirements. On the other hand, hemp and winter wheat stand out as having relatively high nutrient demands. For hemp this can be attributed to its rapid growth.

4.2.3 Biocide Use/Requirements

In terms of biocide use, it was difficult to make comparisons, as the application of biocides is dependent on the presence, or anticipation, of pests, weeds, or diseases. Biocide is more variable than fertilizer use. Thus for comparative purposes a list of

Table 4-K Fertilizer Requirements (kg/ha) for Non-Wood and Wood Fibres per annum

Crop	*Nitrogen*	*Phosphorus*	*Potassium*
Hemp[9]	81	58	91
Switchgrass[10]	50	10	0
Straw[11]			
Spring Grains	60-90	30-45	30-45
Winter Wheat	95-190	40-100	40-100
Trees[12]	9-30	9-30	-

[9] Surveys

[10] REAP (after establishment year)

[11] NS Provincial Data

[12] US Paper Task Force

biocides available for the different fibre sources is presented in Table 4-L. Hemp has no prescribed herbicides, and no mention of pesticides was found in the literature. As for fungicides, there was only one mention of pre-treating hemp seeds with a fungicide to prevent *Botrytis* and *Sclerotinia* (van der Werf, 1994a). Switchgrass requires some chemicals pre-establishment and during its first year in order to ensure that it remains competitive. The cereal crops had, by far, the largest number of biocides listed for prevention and control of pests, diseases, and other herbaceous plants. Interestingly, some of the target weeds that preparations such as RoundUp eliminate, can be eliminated by a crop of hemp, e.g. Canadian thistle and quackgrass. For trees, the most common pest in Nova Scotia is the Spruce Budworm and this is controlled by the use of Bt *(Bacillus thuringiensis*), a biocontrol that is supposed to target only the budworm. Unfortunately it also kills some moth and butterfly species (Orton, 1991). Herbicides are also widely used for forest site preparation, and these are listed in the table (NSF, 1988).

4.2.4 Fibre Yields

The fibre yields presented in Table 4-M provide a definite argument for the use of non-woods. For switchgrass the literature suggests an average yield of 9 t/ha. For Nova Scotia, based on a yield of 25% more than a hay crop in this region, the yield would be about 7.6t/ha (average yield of hay in Nova Scotia over the past five years was 6.1t/ha). Even at this amount, the yields of switchgrass and hemp stalks far outweigh that of softwoods and hardwoods. The yield of wheat straw is comparable to that of hardwoods, although barley and oats are lower.

The most interesting observation is that softwoods have the lowest fibre yield per hectare. Although the softwood yield is equal to that of hemp hurds reported in the surveys, it is below that of the hemp hurd yields in the literature. One bias in this comparison is that fast-growing trees were not used in the comparison, i.e. trees grown in intensively managed plantations, as this is not the predominant wood fibre source in Nova Scotia. In comparisons undertaken by others (US Paper Task Force, 1995; IIED, 1996) only fast-growing hardwood exceeded non-wood yields, but only by 1 t/ha/annum.

Fast-growing softwoods were higher than straw sources, but lower than hemp (IIED, 1996).

Given these yields, the evaluation of the capability of Nova Scotia to produce hemp fibre will be presented in the following section.

Table 4-L Biocide Requirements

Crop	*Pesticides*	*Herbicides*	*Fungicides*
Hemp	none[13]	none	vinchlozin* 0.5kg/ha iprodion* 0.5kg/ha
Switchgrass		RoundUp[14] (Glyphosphate) Laddock/Basagran[15]	none
Wheat	**Aphids:** Dimethoate Malathion **Armyworms:** Carbaryl Chlorpyrifos Melathion Methoxyclor Trichlorfon	RoundUp Amitrole 2,4 -D MCPA Thifensulfuron Dicamba Bromoxynil Cyanazine Mecoprop	Dithane M-45 Tilt Bayleton
Oats	same as above	same as above	Tilt
Barley	same as above	same as above	Tilt
Trees *(in Nova Scotia)*	*Bacillus thurigiensis*	Vision/Glyphosphate 3.2-4.7L/ha Esteron 600 5.6L/ha Velpar L 8.3L/ha Princep 9-T 7.0kg/ha Simazine 80W 8.2 kg/ha	

[13] based on survey results pests and fungi occurred but control measures rarely taken, precautions can avoid most pests

[14] Fall prior to establishment

[15] during establishment year only

Table 4-M Fibre Yields for Non-Wood and Wood Fibres (ton/ha)

FIBRE TYPE	range (min-max)	average
NON-WOOD FIBRES		
Total Hemp Stalks Literature	6.0[2]-16.0[1]	11.0
Survey	4.5-13.0[7]	8.8[7]
Hemp bast fibre	2.0[1]-3.5[7]	2.8 1.6[7]
Hemp hurds	3.4-10.8[3]	7.1
Switchgrass	6.0[4]-12.0[4]	9.0
STRAW[8]		
Barley	5.2*	3.1**
Oats	4.7-7.5*	2.3**
Wheat	6.8 (winter)* 8.1 (spring)*	3.4**
TREES		
Softwood trees	1.6[6]	1.6
Hardwood trees	3.4[6]	3.4

1-Meijer *et al*, 1995
2-van der Werf in Rosenthal, 1994
3-Birrenbach in Rosenthal, 1994
4 Girouard, 1994
6 US Paper Task Force, 1995
7 Thesis survey results
8-NS Department of Agriculture& Marketing, 1995
*harvest target levels
**based on past 5 year average for NS

4.3 GIS and Mapping Results

The production of maps proved to be a useful part of this thesis. Historical records have indicated that Nova Scotia was one of the best places in Canada to grow hemp (Gehl, 1995). The use of maps and GIS has allowed for interpretation of the present conditions for growing hemp in Nova Scotia and whether it truly is a suitable location. In total, eight maps were produced and are all included at the end of this section.

There are two maps for the entire province of Nova Scotia and six for a study site located within the Annapolis Valley region of the province. Maps showing the 'good', 'fair', 'poor', and 'unsuitable' soils for growing hemp within the province and the study site were produced (Figures A&F respectively). Maps were then produced to show the 'fair' soils and their limitations. 'Good' and 'fair' soils are candidates for hemp growing areas. 'Fair' soils have ongoing slight limitations which without increased inputs would result in lower yields and decreased quality (Figures B&G). 'Poor' soils might be used if they occur in association with good soil, or if the price of hemp were very high. Unsuitable soils would rarely, if ever be used for hemp (Patterson, 1996). To provide more information about the study site, maps were produced showing; generalized present land use (Figure 4-C); settlement patterns (Figure 4-D), and the hydrologic patterns (Figure 4-E). Figure 4-H had soil suitability for hemp overlaid upon the present land use (forest and agriculture).

When the data for the map of Nova Scotia were compiled there were no 'good' soils for growing hemp. The percentages and land areas of each soil suitability class are presented in Table 4-N. The lack of 'good' soils can be attributed to the soil classification schemes used. The data at the provincial level had one less slope class than the data for the study site. The 'fair' slope class in this instance included slopes from 4% to 9%, the smaller study site had an extra class (2-5%) which was considered 'good'. Thus polygons at the lower end of the 'fair' range of the provincial classification could be considered 'good' for hemp. There is no way of determining this slope information as polygons are simply assigned a code and not a value. The limitations for the 'fair' soils at the provincial level are presented in Table 4-O.

While there are small pockets of all classes across the map (Figure 4-A), it is apparent that the 'fair' soils are located mainly in the counties of Annapolis, Kings, Lunenburg, Hants, Pictou, Cumberland, Colchester, and Antigonish. 'Poor' soils dominate the province, and 'unsuitable' soils are concentrated in Cape Breton and a portion of Colchester County.

'Fair' soils have either one or two limitations that result in a 'fair' rating (three would result in a 'poor' rating). The limitations on 'fair' soils can usually be overcome and thus made suitable for cultivation. When the limitations for hemp in Nova Scotia are examined, it becomes apparent that the combination of depth and slope limitations is the most prevalent. Combinations of limitations were common, as 90.8% had two limitations while the remainder (9.2%) had only one limitation.

The Figures and Tables at the provincial level are not indicative of how much land is available to grow hemp, as land uses were not taken into account at this level. This simply indicates the suitable soils in the province where hemp could be grown if the land were available.

This study site has a large proportion of 'good' and 'fair' soils in comparison to the provincial level (Table 4-P). The 'fair' soils' limitations are presented in Table 4-Q. The greatest limitation in the study site was particle size (30%), due to the large presence of sandy soils, this was followed by the combination of particle size and drainage (21%). It is likely that the soils with only one limitation would be improved for agriculture prior to those with two limitations. In contrast to the provincial limitations, 70% of the soils had only one limitation, indicating a high potential for agricultural activity.

In the study site, there are 17 500 hectares of land, however, only 43% (7538ha) of this land is currently in agriculture. The graphic overlay of soil suitability over agriculture and forest land was produced to facilitate a visual interpretation of how much of these lands are either 'good', 'fair', 'poor', or 'unsuitable' for growing hemp (Figure 4-H). The amount of suitable agricultural land could only be estimated visually as this GIS package is not able to perform such a calculation, though a more sophisticated package could perform this topographical overlay.

It is apparent that on Figure 4-H a large portion of the 'good' soil for hemp is presently forested. It is not the purpose of this thesis to advocate the replacement of forests by hemp. However, hemp could be used on the clearcut areas, a practice that has been suggested to regenerate clearcut lands (Conrad, 1993), barring mechanical limitations.

Table 4-N Hemp Suitability Ratings for Nova Scotia Soils

Rating	*# of hectares*	*%*
Good	0	0
Fair	972 722	17.7
Poor	3 758 540	68.1
Unsuitable	733 633	13.3
Total	5464895	100.0

Table 4-O Limitations for Hemp on Provincial 'Fair' Soils

Limitation	*# of hectares*	*% fair*
Depth & slope	666 090	68.5
Texture & slope	141 786	14.6
Slope	59 980	6.2
Depth & drainage	58 601	6.0
Drainage	24 852	2.6
Texture & drainage	16 329	1.7
Depth	3 152	0.3
Flooding	1 153	0.1
Stoniness & slope	781	0.1
Total	972 723	100.0

Table 4-P Soil Suitability Ratings for Study Site

Suitability	*area (ha)*	*%*
Good	5290	30
Fair	6189	35
Poor	2773	16
Unsuitable	3226	18
TOTAL AREA	17478	100

Table 4-Q Limitations for Hemp on Study Site 'Fair' Soils

Limitation	*Area (ha)*	*% fair*
Particle size	1874.2	30.3%
Particle size & Drainage	1280.8	20.7%
Slope	914.8	14.7%
Depth	870.5	14.1%
Drainage	648.5	10.5%
Depth & Drainage	208.0	3.4%
Particle size & Slope	141.6	2.3%
Depth & Particle Size	122.7	1.9%
Depth & Slope	65.4	1.1%
Flooding	63.2	1.0%
Total	6189.6	100.0

Table 4-R Present Land Uses in Study Site

Land Use	*area (ha)*	*%*
Agriculture	7538	43.1
Forest	7412	42.4
Urban	1000	5.7
Hydro	707	4.1
Clearcut	144	0.8
Flood	91	0.5
Total site area	17478	100*

**does not include transportation and unclassified areas*

Figure 4-A
Generalized Soil Suitability Ratings for Hemp in Nova Scotia

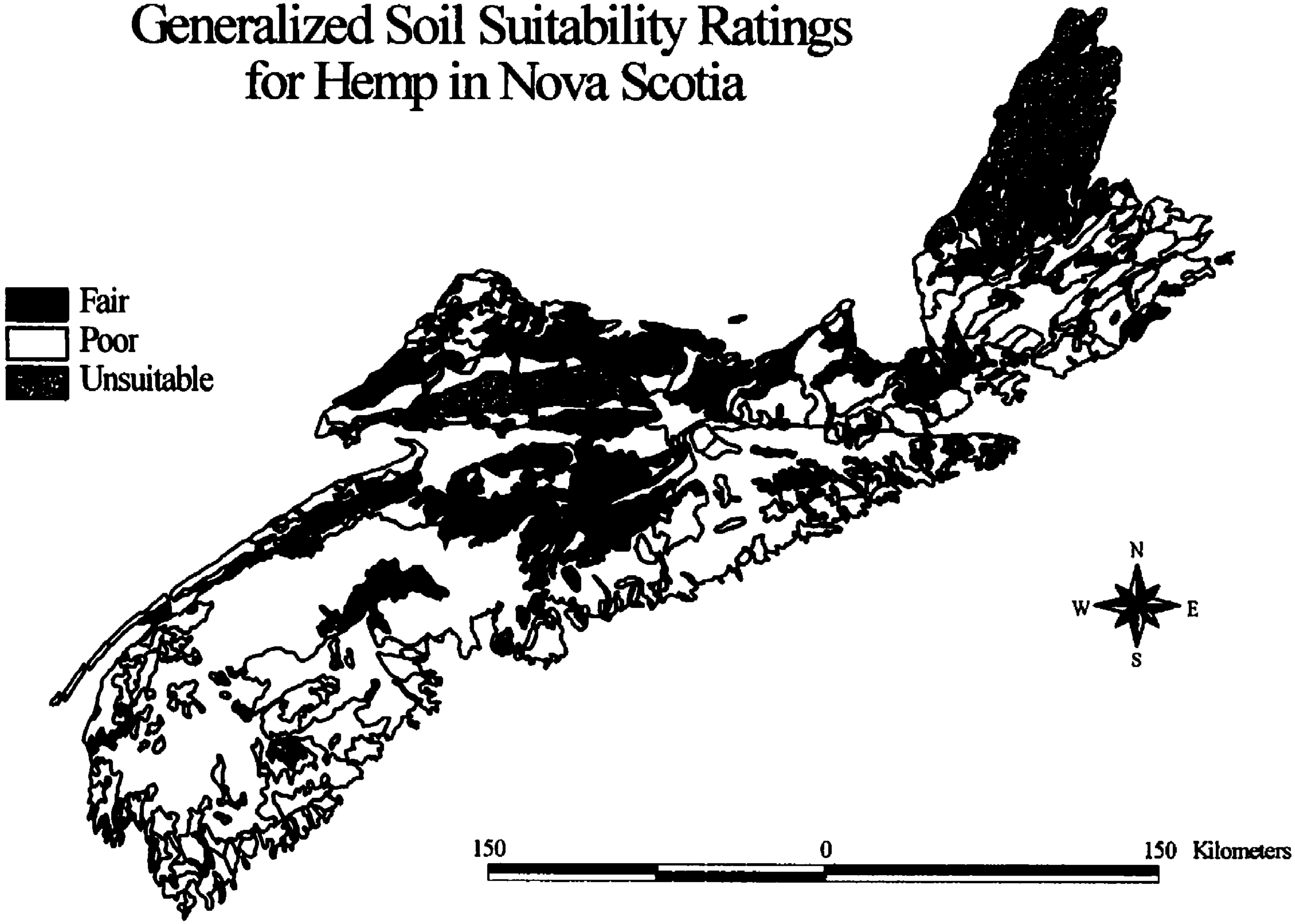


Figure 4-B
Limitations for Hemp on Nova Scotia Fair Soils

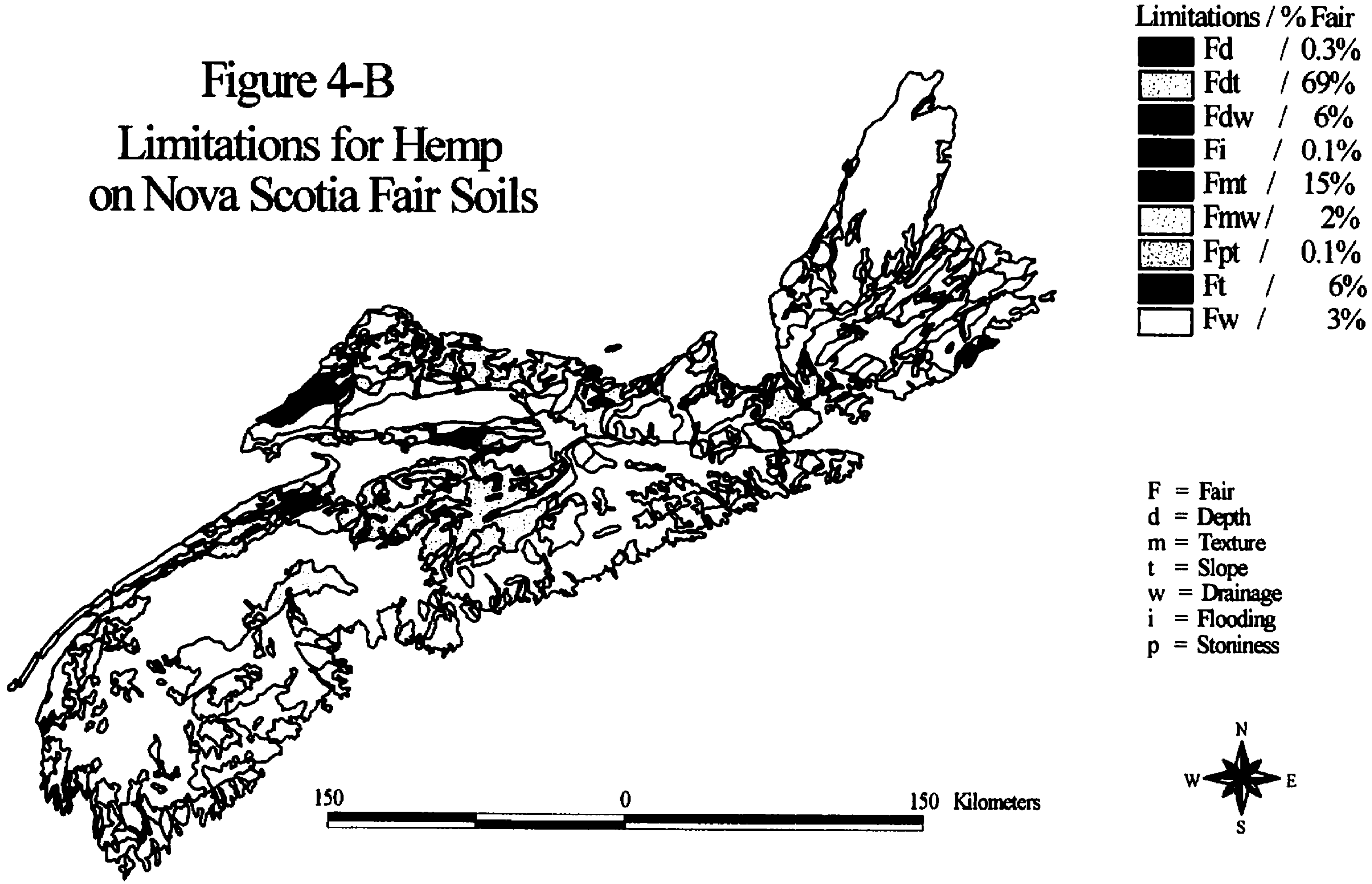


Figure 4-C

Generalized Land Use of the Hemp Study Area

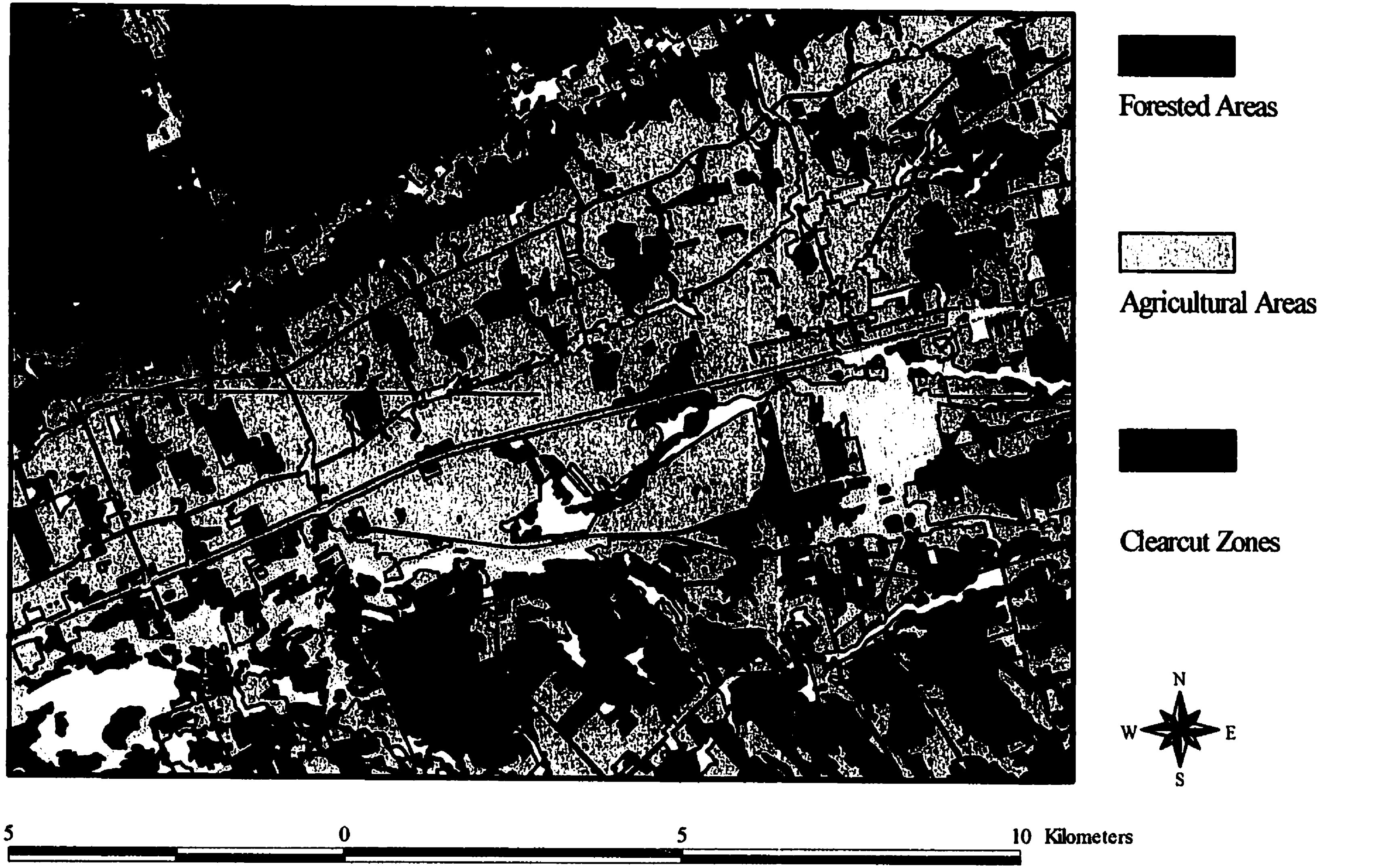


Figure 4-D

Settlement Features of the Hemp Study Area

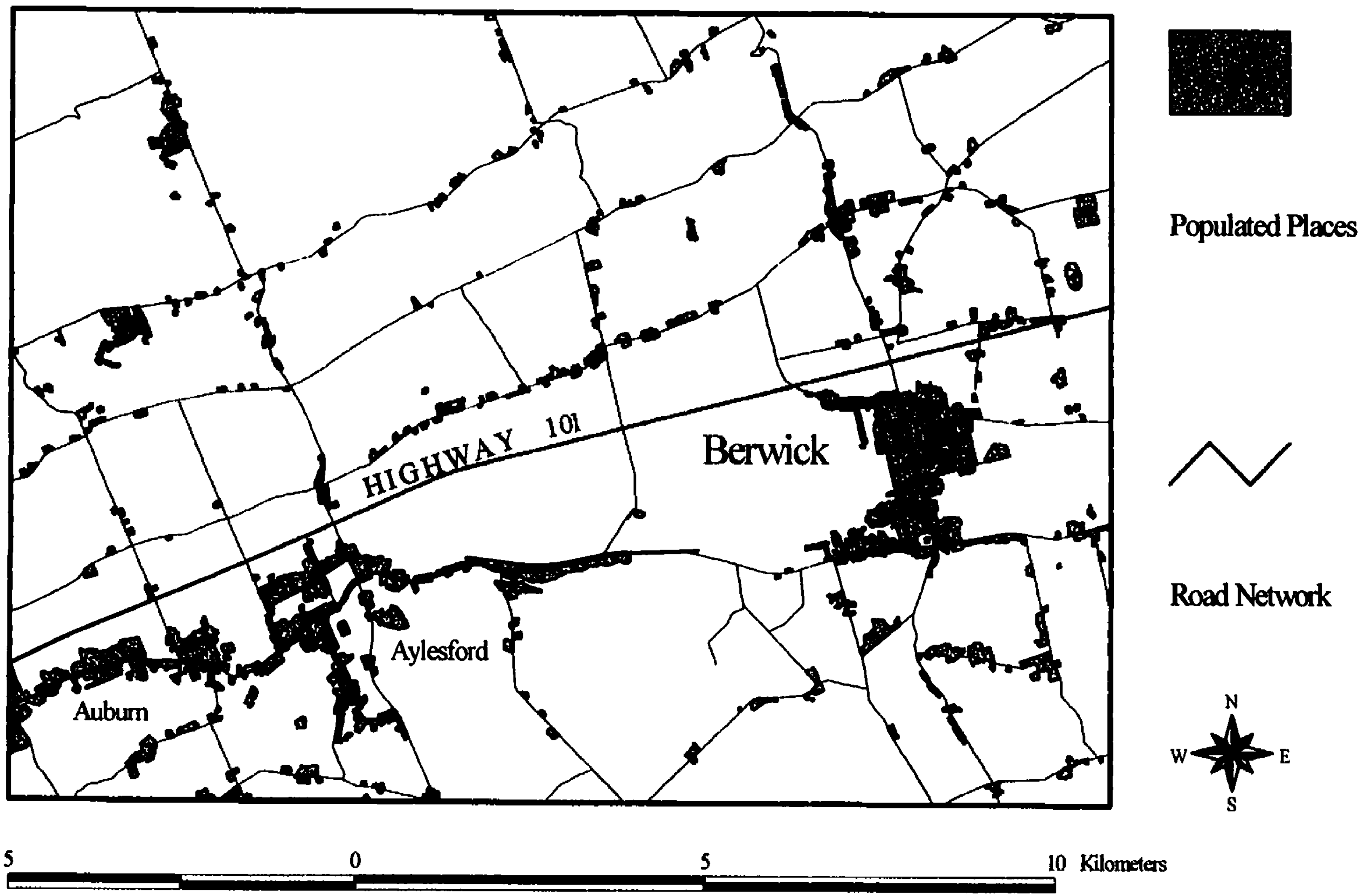


Figure 4-E

Hydrologic Features of the Hemp Study Area

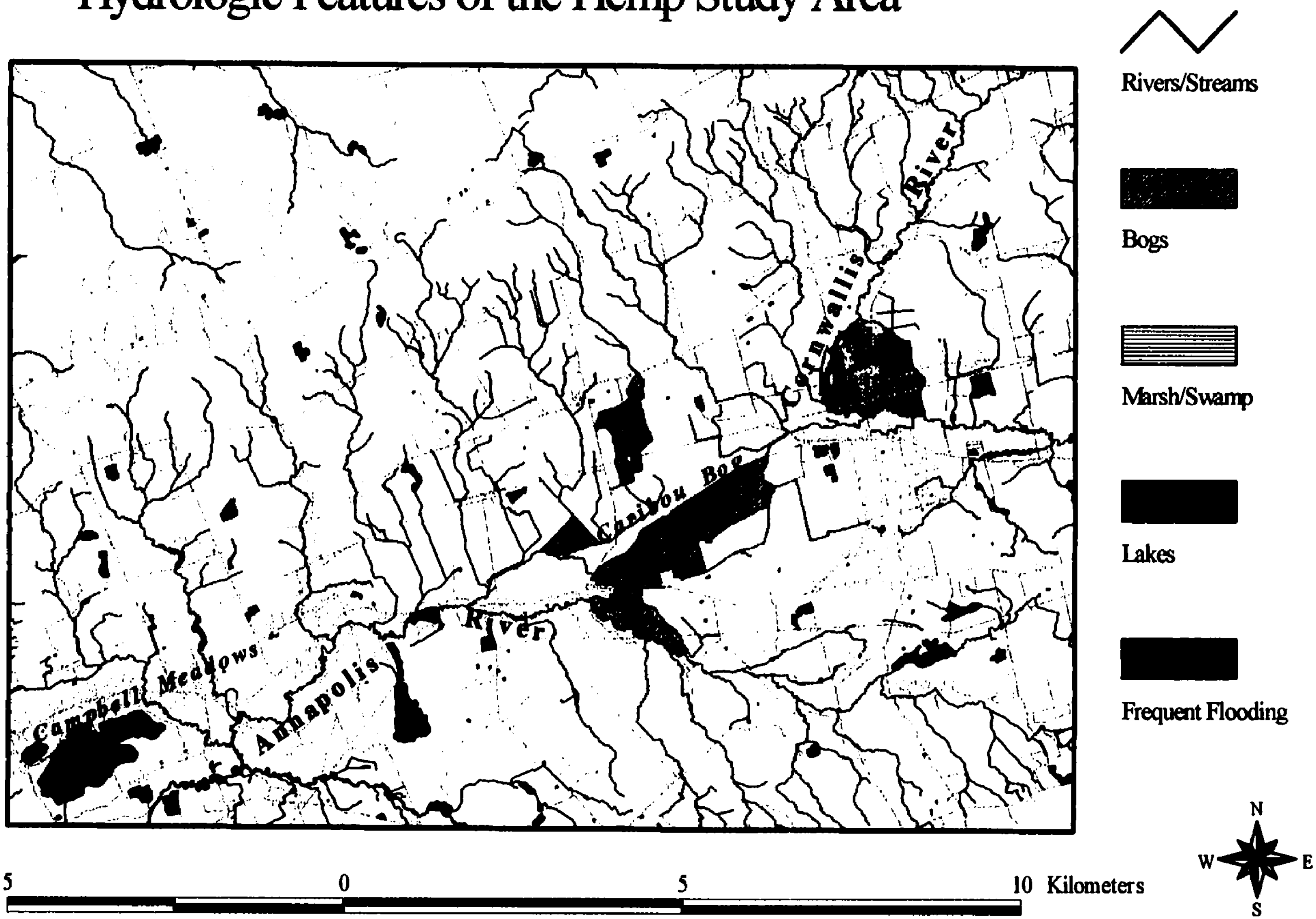


Figure 4-F

Generalized Soil Suitability Ratings for Hemp in Study Area

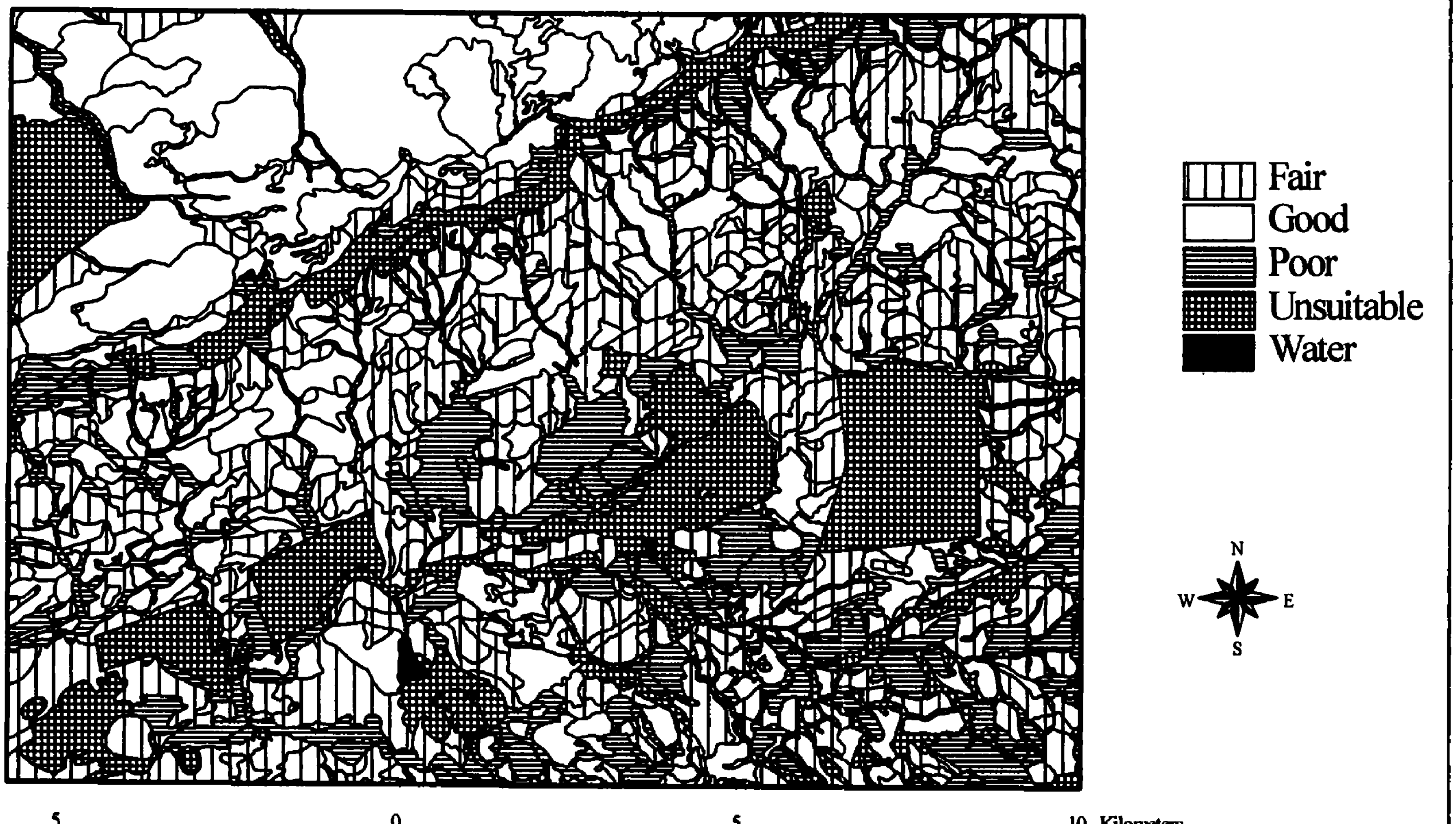
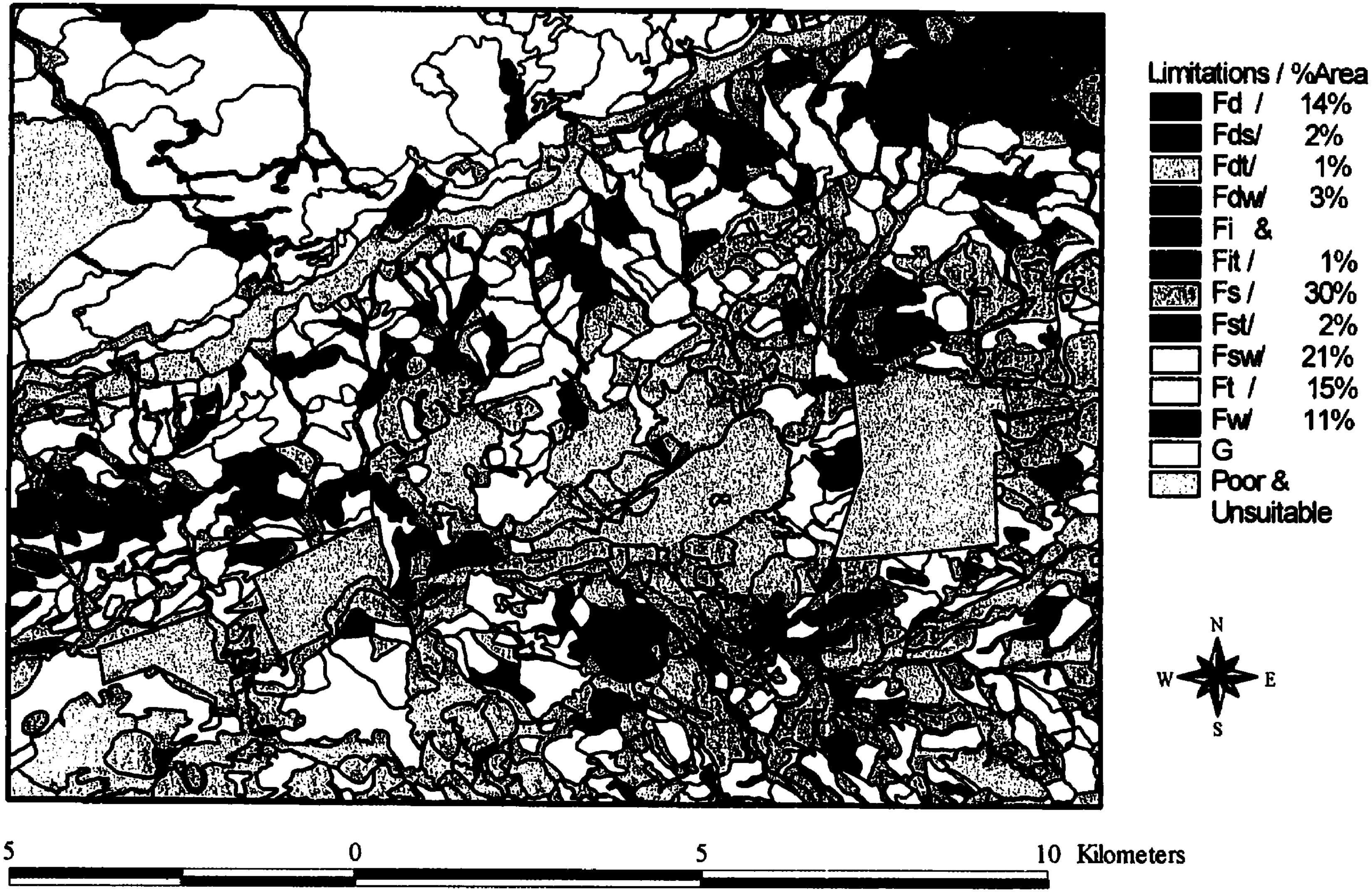


Figure 4-G
Limitations for Hemp on Study Site Fair Soils



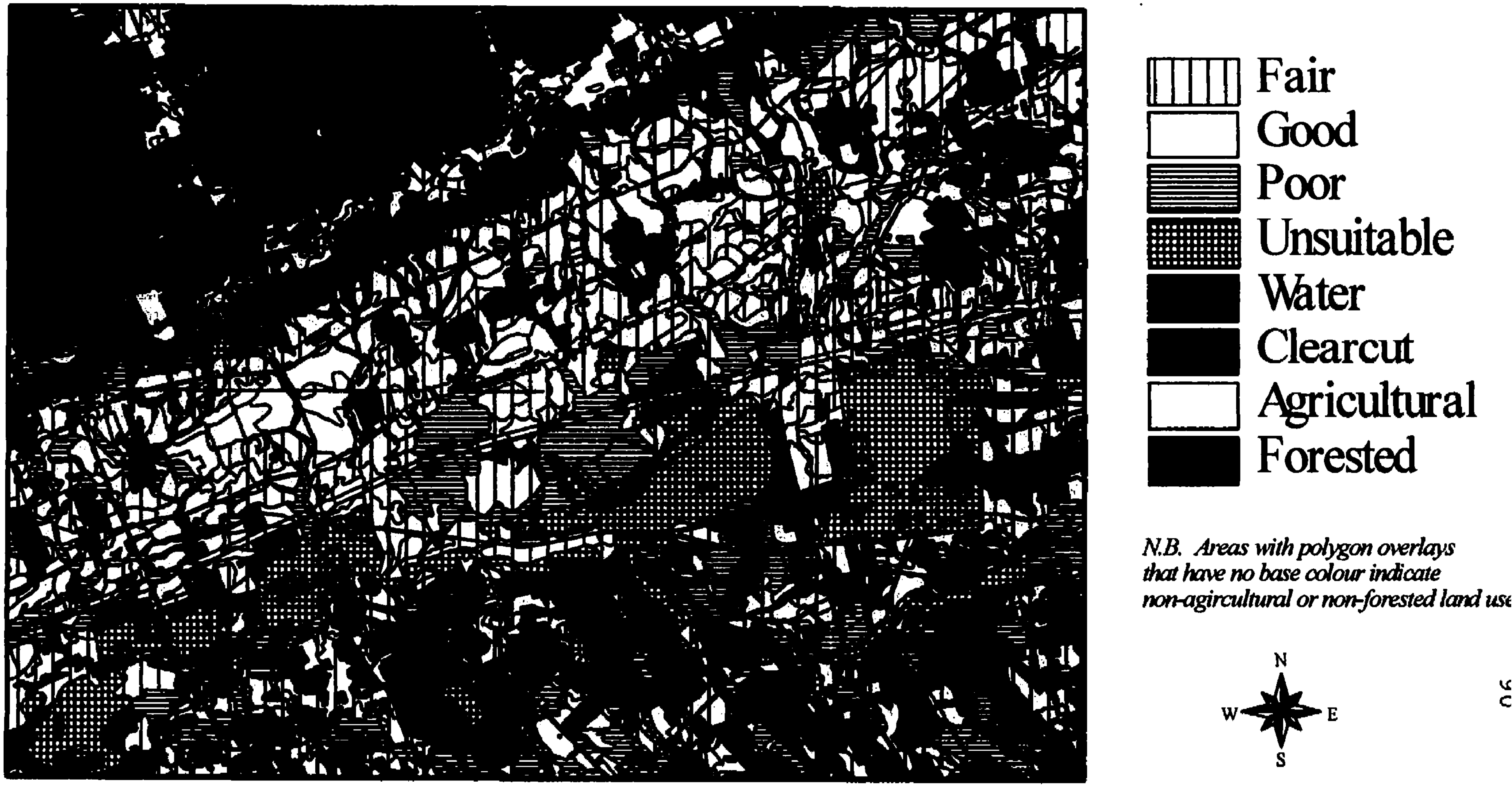
F = Fair Suitability
G = Good Suitability
d = Depth

w = Drainage
i = Flooding

t = Slope
s = Particle Size

Figure 4-H

Overlay of Soil Suitability for Hemp with Agricultural and Forested Land



4.4 Fibre supply

The following section compares the pulp yields and the area required for each fibre to supply a 100,000t/ha pulp mill. The availability of the various fibres, in Nova Scotia, will also be determined. A 100,000 tonne mill was chosen as a possible size for a non-wood processing mill. Due to the bulky nature of non-woods, transportation to mills will have to be minimized and a mill this size is deemed to be about the largest that could accommodate this factor (Byrd, 1996).

The pulp yields were based on information from the literature, as well as personal communication with people in the hemp and pulp and paper industry. The pulp yield is highly dependent on the pulping method used, and thus for illustrative purposes, two values for hemp bast fibre are presented. The 45% yield is based on a chemical process (US Paper Task Force), and the 80% is based on a mechanical process (van der Werf, 1996). It is possible that for other non-woods there could also be such large ranges in pulp yields, however, no values have been found to date to suggest this, or else the information has been considered proprietary and not released. Most chemical pulps, however, are within the 50% yield range, while mechanical pulps are much higher, in the 80% range (IIED,1996)

The most significant observation in Table 4-S is that softwood trees, the most predominant material for papermaking, are the least efficient for achieving this purpose. Not only do they produce the lowest yield of fibre per acre, but they also have the lowest pulp yield. The highest pulp volume is found when hemp's whole stalk is pulped, often the hemp bast and hurds are pulped separately, though there have been some experiments done on processing the whole stalk. If it turns out that whole stalk processing produces an acceptable quality of paper then this source will definitely be able to provide sufficient fibre.

Switchgrass and spring wheat produced comparable amounts of fibre, with the hemp hurds just slightly below these two. Oats and barley also provided quantities of fibre above softwood and hardwood trees. The hemp bast fibre yields falls between softwood and hardwood yields.

Table 4-S Potential Fibre Supply and Requirements for a 100,000 t/annum mill.

	Hemp (whole stalk)	*Hemp bast fibre*		*Hemp hurds*	*Switchgrass*	*Straw*			*Trees*	
						oats	*barley*	*wheat*	*soft*	*hard*
fibre yield (t/ha/annum)	10	2.2		7	8	5.2	6.1	6.8(w) 8.11(s)	1.6	3.4
pulp yield (%)	45	45	80	45	45	44			43	53
pulp volume (t/ha)	4.5	0.99	1.76	3.15	3.6	2.3	2.7	3 -3.6	.67	1.8
area required (ha) for 100,000 tonnes pulp	22,222	101,010	56,818	31,746	27,777	43,478	37, 037	27,777 (s)- 33,333 (w)	149,253	55,555

w=winter wheat

s=spring wheat

The fibre yields used in this evaluation were based on averages found from values in the literature and the hemp values are from the survey. Given that there is a great deal of research focussing on improving the yields of switchgrass and hemp, and the various pulping methods available, these fibres look promising as sources of non-wood fibres. Crop residues from cereal crops also appear to be able to provide large quantities of fibre, providing that their removal from the land is not contributing to soil degradation.

The next table (4-T) ranks the area required for each fibre source to provide 100,000 tonnes of fibre per annum. While this information is provided in Table 4-S, by presenting it in a ranked order in Table 4-T the abilities of the different sources to produce fibre is even more apparent.

Given that softwood is the lowest producer of pulp leads one to ask why it has become the dominant choice of fibre for pulp production. The only obvious explanation can be their widespread accessibility, especially in Canada as illustrated in Table 4-U, and the availability of efficient technology.

Another observation that is central to this debate concerns the time required to produce these quantities of fibre. These fibre yields represent the annual production of fibre. For trees, this 1.6t/ha figure represent the 'mean annual increase' of fibre per hectare on managed forest lands (Ruthman, 1996). Thus this amount is not one that would be harvested every year, but rather after a period of at least 20 years. For hemp and straw fibre, if grown in rotations then the amount of land would have to increase by the same factor as the length of the rotations (*i.e.* a four year hemp rotation would require 88,888 hectares of land to produce 100,000 tonnes of pulp). Switchgrass is the only fibre that has high yields on the same area of land every year, because it is grown in a monoculture and harvested annually.

Another aspect of this comparison is that a paper composed of only one type of fibre (e.g. 100% hemp or 100% straw) is not likely to be produced whether due to undesireable paper characteristics, or the cost. It is more probable that the non-wood fibres would complement each other in non-wood pulp mixes, or they would be added to wood or recycled pulp to add strength or other desired characteristics.

Table 4-T Fibre sources ranked according to area required.

Rank	***Fibre Type***	***Area required to supply 100,000 t of pulp per annum:***
1	Hemp (whole stalk)	22,222
2	Switchgrass	27,777
3	Spring Wheat	27,777
4	Hemp hurds	31,746
5	Winter Wheat	33,333
6	Barley	37,037
7	Oats	43,478
8	Hardwood	55,555
9	Hemp (bast fibre-80%)	56,818
10	Hemp (bast fibre-45%)	101,010
11	Softwood	149,253

Table 4-U Current availability of fibre in Nova Scotia (1996)

Fibre	*Availability (tonnes)*
Hemp	0
Switchgrass	0
Wheat*	16,470
Barley*	29,377
Oats*	19,742
Pulpwood	1 343 320**

**based on average production 1991-1995*

***Ruthman, personal communication; and CCFM, 1996*

When the availability of these fibres is compared in Table 4-U, it is apparent why softwood trees have become the mainstay of the pulp and paper industry. In addition, the continued management of forests for pulpwood encourages this attractiveness. There is enough fibre presently available in Nova Scotia from agricultural residues to provide some non-wood fibre to experiment with non-wood processing.

Hemp and switchgrass are not currently available in Nova Scotia. For hemp, it is due to the unavailability of permits available to grow hemp on a commercial basis. Switchgrass has only just started to receive attention in the past few years as a non-wood fibre source in Canada.

From the GIS data, there are 7500 ha of land presently available for agriculture in the study site. If all of the 'good' and 'fair' land in the study site (11 000 ha), regardless of land use, there would be enough land to produce hemp, or other non-woods, either as a supplementary fibre or to supply a smaller mill. Given that existing land use is a factor the following example is more realistic.

If 5000 hectares of the presently available agricultural land in the study site, were to be planted with hemp in a four year rotation, assuming a total stem yield of 10t/ha, then 12 500 tonnes of stems could be produced annually. Given that this is a small area of the province, it could be extrapolated that there would be sufficient land to supply hemp, at least as a supplementary fibre to a mill to complement wood pulp or recycled pulp production. The question remains "are hemp and other non-wood fibres sustainable sources of fibre?" This will be addressed in the following section.

4.5 Sustainability Evaluation

This section is comprised of two divisions. Initially the abilities of hemp, switchgrass, straw and trees to contribute to a sustainable agricultural system, as a source of fibre, will be evaluated and rated according to the criteria set out in the Methodology. The second section consists of a chart comparing these ratings. It is important to note that it is not the sustainability of the crop that is being evaluated, but rather the potential for the crop as a fibre source to contribute to the overall sustainability of the system. Trees are included in this evaluation as they also have the potential to contribute to a sustainable system, in addition, with the development of fast-growing species, trees are more similar to agricultural crops than natural forest stands.

Each of the following 9 criteria contributes to the sustainability of the whole system, and thus the sources of fibre will be ranked in terms of meeting each criteria and these values will be totalled to determine the sources' contribution to overall sustainability. A scale of 1-5 is being used for the rankings. A rating of 1 indicates that the potential to contribute to sustainability is very low, or would rarely occur; at the other extreme, a rating of 5 indicates that the potential is high and the crop would frequently contribute to sustainability. The ratings are cumulative and totals will be presented in Table 4-V.

4.5.1 Evaluation of Hemp's Potential for Sustainability

According to the previously established criteria a sustainable agricultural system will incorporate:

1. ***A diversity of crops through the use of rotations, relay cropping, and intercropping***

   The use of crop rotations is important to reduce the severity and incidence of weed and insect damage, as well as maintaining soil fertility.

   Like most crops, hemp thrives when in appropriate crop rotations, therefore a diversity of crops can influence hemp's performance. Hemp's diversity is mainly temporal since different crops would be rotated on a yearly basis. If early maturing varieties were used, another type of crop could be planted following hemp further contributing to temporal diversity. Hemp would have minimal spatial diversity as its high density plantings do not lend themselves well to intercropping. Thus, hemp is assigned a rating of 3 in meeting this criterion.

Switchgrass, although it could be grown in short rotations, is more likely to be in stands that are managed for approximately 10 years. After this time they could be rotated with other crops, or new varieties of switchgrass could be planted (REAP, 1996). Thus, there is not as much temporal diversity for switchgrass. There would be some opportunities for spatial diversity, if other grasses were to be intercroppped with switchgrass. Switchgrass would essentially be a monoculture, and while it has existed in this form previously, in the Prairies, this might not be the case in other regions. Thus switchgrass receives a rating of 2.

It is recommended that cereal grasses be rotated annually as this reduces the incidence of pests and diseases. The advent of chemical controls, however, has facilitated the eradication of pests instead of their prevention. Thus rotations are not as long as they could be to provide disease and pest breaks. In Nova Scotia, when soil conservation is of concern, cereals are often rotated with potatoes. Cereals can be underseeded with other crops, thereby providing some spatial diversity. Therefore straw receives a rating of 3.

Trees as a crop do not provide much spatial or temporal diversity, especially when undesireable species are removed from stands. A forest, on the other hand, is extremely diverse both spatially and temporally over the long term. As this evaluation is for trees as a source of fibre, they are assigned a rating of 1 as their diversity is minimized in plantations.

2. ***A selection of crop varieties that are well suited to the farm's soil and climate***

To be sustainable, the input of additional requirements should be minimized, e.g. irrigation, fertilizers, and chemical controls. Attempting to grow crops that are not suitable for a certain soil type or climate may increase inputs that would otherwise be unnecessary if appropriate crops were selected. For example, kenaf is not being evaluated in this thesis as Nova Scotia's climate is not suitable for the production of this tropical plant.

Conversely, hemp and switchgrass are both temperate plants that can grow in Nova Scotia. It is known that hemp grew well in Nova Scotia in the early 1900s, thus it is assumed that industrial varieties could once again be selected to thrive in this area. Nova Scotia's climate also provides sufficient moisture for hemp. There may be some physical limitations, e.g. slope and drainage, to growing hemp here, however, these would be limitations for most agricultural crops (Figures 4-B&D). Nova Scotia's acidic soils require the addition of lime to establish a pH suitable for hemp. Thus in terms of being a suitable crop for Nova Scotia, hemp receives a 3.

Switchgrass, although a plant native to the Prairies, Ontario and Quebec is thought to be a plant that could be grown here commercially. Switchgrass can also be grown on marginal lands that would not be suitable for grain production (Girouard, 1994). Switchgrass is a C4 species, and thus may not be suitable to Nova Scotia's climate due to an unsuitable climate. Thus switchgrass receives a rating of 3.

Cereal production is well suited to Nova Scotia's maritime climate as they perform well under cool and moist growing conditions. Cereals require the addition of lime, and would also have to overcome slope and drainage limitations. Cereals are assigned a rating of 3.

There are many varieties of trees that are native to Nova Scotia, however, the introduction of new fast-growing non-native species may have unwarranted effects. Trees are also assigned a rating of 3, for the pulpwood mandate is encouraging unsuitable practices in terms of species selection.

3. ***A selection of crop varieties that resist pests and diseases as well as enhancing conditions for controlling or suppressing weeds, insect pests, and diseases. Synthetic biocides are to be used only as a last resort, and only when there is a clear threat to the crop.***

Hemp's abilities as a natural herbicide are clearly evident from both the Literature Review and the Questionnaire responses. Hemp does not require herbicides and also clears the field of weeds so that following crops do not require herbicides.

Hemp is also recognized for its natural resistance to pests. Though it does have some pests, they can be managed through effective crop rotations, and ensuring that the seed is free from disease. Overall, hemp has far fewer pests worthy of control than other crops. In addition, the surveys indicated that the losses attributable to pests were so insignificant that it was not worth the cost of purchasing and applying synthetic pesticides. Hemp is also believed to eradicate pests that are of concern for other crops such as *M. chitwoody, M. hapla* and *V. dahliae* that attack potato crops in the Netherlands. Hemp is assigned a rating of 4 as it is renown for its abilities to control and suppress weeds, yet may need some control measures for pests and fungi.

Switchgrass does require the use of herbicides prior to and during the first year of establishment in order to ensure that it gets a competitive edge over other plants. It is also believed to be a plant that will break certain pest and disease cycles that affect other crops. Since the criteria states that synthetic biocides are to be used only as a last resort, switchgrass receives a rating of 2.

Cereal crops are subject to numerous pests and diseases, and as shown in Table 4-L, there are numerous synthetic biocides available for their control. Resistant varieties are available though they may not be resistant to all pests or diseases, and although crop rotations may prevent some infestations, if these are not undertaken then biocides will be necessary. In fact, the use of biocides on cereal crops is recommended in growing guides, thus cereals receive a rating of 1.

The use of synthetic biocides is also highly recommended on trees, though over the life of a stand the amount used would be less than on annual crops. Trees are thus assigned a rating of 2.

4. ***An efficient cycling of nutrients, to minimize losses and reduce the need for external inputs. Nutrient requirements to be met, when possible, by composting livestock manures and by using legumes and green manures in rotations.***

The questionnaire respondents did not indicate a high level of manure use although this fertilizer is recognized as being the best one for hemp. Animal manure could be recommended as a suitable fertilizer to new hemp farmers. Some survey respondents indicated the use of legumes to meet nitrogen requirements. Appropriate rotations for hemp would include a legume or green manure crop since these have been identified as effective methods for meeting nitrogen requirements. Having soil tests performed to determine available soil nutrients is also one way of avoiding the use of excess fertilizers.

Maintaining soil fertility sustainably requires that the nutrients taken up by the plants are returned to the soil so that they can be used again. Hemp does take a large amount of nutrients from the soil; however, they can be returned through falling leaves, decomposition of the roots, and conducting retting on the fields. When hemp is harvested prior to seed development the majority of the nutrients remain in the plant tissue as they have not yet started to concentrate in the seed. Hemp is also known for improving the soil quality for other crops in the rotation. Hemp thus receives a rating of 4, as it may be necessary to supplement the soil if the initial fertility is low, or if retting is not conducted on the fields.

Switchgrass stands will require annual applications of fertilizer, although only nitrogen and phosphorus, as it does not respond to excess potassium (REAP, 1996). Over the life of the stand, switchgrass will return nutrients to the soil as its roots regenerate and leaves fall to the ground. As it is a perennial crop, the removal of the unharvested plant material does not have as large an effect as an annual crop as plenty of plant material remains on the surface. Switchgrass is also renowned for its ability to improve soil quality and consequently receives a rating of 4.

Cereal production also requires the use of fertilizers, since the use of legumes in a rotation is usually not sufficient. In addition, when the straw is returned to the soil after harvesting the grain, nutrients are also recirculated. Thus, if the straw is removed there may be additional nutrient requirements for the following crop, especially for potassium. In addition, at the time of harvest many of the nutrients are concentrated in the grains thus removing more nutrients from the cycle. Thus cereals receive only a rating of 2.

Trees may or may not require fertilizer during establishment depending on the initial soil fertility. Once a stand is established there is very efficient cycling of nutrients within the system, thus trees receive a rating of 4.

5. ***An enhancement of the soil's ability to take up applied nutrients for later release as needed by the crop, in contrast to direct uptake by the crop at the time of application.***

This criterion can be met by the decomposition of the roots of the hemp plant which improve the fertility of the soil for the following crops. In addition the fallen leaves and retting (if undertaken) enhance the soil fertility. For hemp, it is recommended that manure be applied to the soil in the preceding fall so that it is thoroughly mixed prior to planting. Its long tap root reaches nutrients at lower depths thus bringing more nutrients into the cycle. Hemp receives a rating of 5 as the residues left on the field enhance soil fertility.

Switchgrass improves the soil's aggregate stability and also has a long tap root. It receives a rating of 5 as it too leaves the soil in good condition for following crops.

Cereals alone do not improve soil quality. Although some potassium can be returned by incorporating the straw into the soil, if it is removed as a source of fibre this will not occur. Cereals receive only a rating of 2 in this instance.

The size of the forestry operation determines the potential for nutrients to be cycled. Small operators usually leave leaves and branches on-site to decompose and regenerate the soil, while larger operators usually remove all material off-site thus necessitating the input of nutrients prior to subsequent plantings. The potential for trees to meet this criteria is high, however, in actual practice the potential is low therefore, trees receive a rating of 3.

6. ***Rotations that include deep-rooted crops to tap nutrient reserves in lower strata.***

Hemp, which is an excellent example of a deep-rooted crop, is well known for its ability to access deep nutrient resources, and thus receives a rating of 5. Switchgrass is also renown for a deep tap-root, and trees also have an excellent root system and both receive a rating of 5. Cereals generally do not have a deep tap-root and thus receive only a 2.

7. ***A protective cover on the soil surface throughout the year (leaving crop residues on the surface, cover crops, living mulches).***

Early maturing hemp varieties can be harvested as early as the middle of August in the Northern Hemisphere, thereby providing sufficient time for the planting of a fall cover crop. Depending on the date of maturity, it may also be possible to plant a fall cover crop after late flowering varieties. Since hemp can survive light frosts in the spring, it can be planted earlier than other crops thus providing an early protective cover.

Though it is not common practice, the hemp stalks can be left on the surface all winter for retting. The crop residues (leaves, stubble, roots) are left on the field to decompose. Hemp receives a rating of 4 in this instance, for although the decision to plant a fall cover crop is highly dependent on maturity date and individual farm practices the potential to do so exists.

As switchgrass is a perennial crop there will be a cover on the surface for the duration of the stand, therefore it receives a rating of 5.

Cover crops can also be planted after cereals, though it depends on varieties. Cereals can also be underseeded with other crops that mature at a later date. Cereals receive a rating of 4.

Once trees are established there is a sufficient cover on the soil surface for the duration of the stand, however, if clearcutting is used for harvesting (as is the dominant practice in Nova Scotia) then the surface is over-exposed and subject to erosion until a new stand is established. Trees are assigned a rating of 3.

8. Preferences for farm-generated resources over purchased materials, and locally available off-farm inputs, when required, over those from remote regions.

Since hemp does not require many external inputs this criteria can be easily met especially since green manure crops and animal manure can meet its fertilizer needs, if desired by the farmer. Hemp will require the addition of lime on acidic soils.

This criterion is highly dependent on individual farmer choice. Hemp does not have a high need for external inputs in the form of pesticides and fungicides. However, because it is an annual crop, it requires annual cultivation and harvesting thus a higher need for inputs such as fuel. Hemp receives a rating of 3 in this situation.

Switchgrass also receives a rating of 4 as its fertilizer requirements could be met by manure if desired by the farmer. It does, however, require the purchase of some chemicals.

Cereals require chemical inputs, for manure alone, or nitrogen from legumes, is insufficient for optimum yields. Cereals will also require the addition of lime on acidic soils. Since cereals are also annual crops they receive a rating of 2.

Trees require the use of purchased chemicals, yet their use is spread over the life of the stand and is less than that applied to conventional annual crops, thus they receive a rating of 3.

9. A positive impact on the immediate and off-farm environments (physical/ economic & social).

Although this is a lofty criterion to meet, it has already been shown that hemp can contribute positively to the physical environment. The main disadvantage for hemp is that it is an annual plant and thus the soil on which it grows is disrupted on an annual basis. Minimizing this would increase the sustainability of the system.

As for the economic and social environments, hemp can also contribute positively to these areas. Hemp's multi-purpose characteristics lend themselves to more economic markets, whether they be fibre, textiles or oil. There are, therefore, more opportunities for hemp to be a profitable crop and respond to various market demands.

It is also believed, and hoped, that hemp could revitalize local economies. Its bulky nature means that mills and farms will have to be in close proximity, thus providing opportunities for more communities. In Britain, hemp is advocated as a crop that could contribute to regional self-sufficiency. Hemp thus receives a rating of 4 for its potential to contribute to the physical, economic, and social environments.

Switchgrass also receives a rating of 4, though it outweighs hemp due to its perennial characteristic, its marketable products are not quite as diverse. Although they may be as profitable this is hard to compare at this point.

There is a surplus of cereals in Canada, though not necessarily in Nova Scotia as 50% of cereals are imported to the province. This would lead to the conclusion that it is cheaper to import grain than to produce it in this province. Cereals have also come to be a chemical dependent crop. Cereals are given a rating of 3.

Trees are a major source of income for a number of Nova Scotians, especially since 75% of forested land is privately owned. However, the true costs of using trees for pulp are not usually taken into account. Too often trees are seen only as a cheap source of pulp. It is difficult to assign a dollar value to trees' other qualities such as environmental, physical, and recreational though these are often equally if not more important. Thus when considered as a pulp source, trees receive a rating of 3.

4.5.2 Potential for Sustainability

This section includes the chart with the ratings from the previous section and allows some visual comparisons to be made. When the potential for sustainability of different fibre sources is compared there are some interesting observations (Table 4-V). The first is that trees, the dominant source of pulp, are not the most sustainable. In fact, although they ranked higher than straw, trees were lower than both hemp and switchgrass. The results of this chart indicate that less emphasis should be placed on intensively managed tree plantations since they do not have a high potential for sustainability.

The ranking system also demonstrates the relatively low potential of straw to contribute to a sustainable agricultural system. Straw is often promoted as an excellent fibre resource as it is simply left over from the production of cereals. From this chart we can see that the production of cereals is not very sustainable. In fact, removing the straw from the fields may also remove important nutrients such as potassium. The same could be said for removing hemp stalks, however, the root mass and leaves do return a certain degree of nutrients to the soil. It could be argued that the straw may as well be used since it is being produced anyway; however, it would not make sense to promote a crop as a sustainable source of fibre if the production of the grain that results in the fibre availability is not sustainable.

According to this criteria, although switchgrass and hemp do not meet each criterion equally, in the end they have almost the same potential to contribute to sustainability. Though the benefits of switchgrass as a perennial outweighs hemp as an annual; it requires the use of herbicides prior to establishment and there is not as much potential for diversity over time with switchgrass.

In the end, not one of these sources is perfectly sustainable but advantages and disadvantages between them are apparent. It has now been established that hemp can contribute to a sustainable agricultural system, and that there is sufficient land area within Nova Scotia to sustain hemp production. Hemp's ability to be an alternative source of fibre for Nova Scotia is assessed in the following Chapter.

Table 4-V Comparison of Sustainability Characteristics

(1-rarely meets criteria, 3-sometimes meets criteria, 5-frequently meets criteria)

Criteria	*Hemp*	*Switchgrass*	*Straw*	*Trees*
1.Diversity of crop rotations.	3	2	3	1
2 *A selection of crop varieties that are well suited to the farm's soil and climate.*	3	3	3	3
3 *Crop varieties that resist pests and diseases. Synthetic biocides to be used only as a last resort.*	4	2	1	2
4. *A tightening of nutrient cycles*	4	4	2	4
5 *An enhancement of the soil's ability to take up applied nutrients.*	5	5	2	3
6 *Rotations that include deep-rooted crops*	5	5	2	5
7 *A protective cover on the soil surface throughout the year*	4	5	4	3
8. *Preferences for farm-generated resources over purchased materials*	3	4	2	3
9. *A positive impact on the immediate and off-farm environments*	4	4	3	3
TOTAL	35	34	22	27

5. Discussion "The case for Hemp"

In this section, hemp's potential as an alternative source of fibre, and to diversify the fibre production capacity of Nova Scotia will be evaluated, based on the information presented in the Literature Review and the Results section,

The results of the survey indicate that hemp, as a crop, is at the developmental stage. Though places such as Hungary and France have had many years experience growing hemp it remains difficult to come up with concrete recommendations for aspects such as fertilizer application and seeding rates. It would appear that there are several factors that influence final yields and they require more investigation for a wider range of climates and soil types.

This lack of information on seeding rates has a profound influence on the ability to conduct market studies of this crop. In the survey there were two responses of yields of 8-10t/ha, however, upon investigation it was found that one was at an 80kg/ha seeding rate and the other at 22kg/ha. Ranges such as this make it difficult to make predictions on the relationship between seeding rate and yields. Since the price of seed is presently one of the costliest aspects of growing hemp, a grower would want to make sure that the seeding rate is going to be the most economical.

The survey was very useful at confirming results claimed in the literature. Hemp is unquestionably able to compete effectively with weeds and thus not require any herbicides. It must be noted that this is only at high densities, as when sown for fibre, and when hemp has an early and uniform emergence over other crops. It is possible that when growing hemp for seed, due to the lower densities, some broadleaf herbicides may be necessary (Winnipeg, 1996). This requires further investigation as there were few reports that evaluated the differences between growing hemp for seed and for fibre.

In comparison to other crops, hemp does appear to be disease and pest resistant. It was susceptible in some cases, but it is worth repeating that in most instances these diseases were not considered significant enough to be worthy of treatment. In a subsequent discussion with a hemp researcher it was noted that a fungicide program would be a last step after ensuring that the seed was properly cleaned, and effective rotations were minimizing the risk of diseases (Moes, 1996).

In terms of fertilizer use the survey results were not as high as those quoted in the literature. It remains, however, difficult to extrapolate recommendations for fertilizer as this would be highly dependent on initial soil fertility. It has been suggested that fertilizer amounts should be deduced from the final uptake of nutrients by the hemp plants, and adjusted according to soil testing results (van der Werf, 1994).

Although based on a limited sample, the survey also suggested that manure and legumes are effective methods of meeting nitrogen requirements. One of the farmers who responded is a certified organic farmer and it is reassuring to see that hemp can be grown with adequate results without the addition of synthetic fertilizers. In fact, the cultivation of hemp may prove to be one method that farmers can 'get off the chemical train' as they could start by growing a crop such as hemp, that does not require any chemicals, in order to wean themselves off chemical dependency.

When contrasting hemp to trees it is difficult to compare the use of chemicals. The conditions for pests are often optimized when forest stands are managed for one particular product, in this case softwoods for pulping (Hunter, 1990). While trees may not require chemical applications every year, when a pest such as the Spruce Budworm is present, large amounts of biocides (whether biological or chemical) are released into the environment. A large proportion of pesticides never reach the targeted pest, or worse, affect other pests (Pimmental, 1995). Thus there should be attempts made to prevent the conditions that are conducive to the pest instead of eradicating the pest after an outbreak. Unfortunately, Nova Scotia forests are still being managed for pulpwood, despite some attempts to place more emphasis on hardwoods (Eidt, 1996).

Hemp does have a low lignin content, and it was also the lowest of those evaluated in this thesis and it also has a high cellulose content that makes it suitable for pulping. The low amount of lignin in hemp does indicate that a lesser amount of chemicals would be required for pulping, thus less chemicals discharged into the environment. Although there is some concern that there would be more pollution from a non-wood pulping process, this judgement is often made when referring to mills in industrializing countries where environmental regulations are lax (IIED, 1996). In Canada, there is a move toward closed-loop pulping systems that include effluent recovery; and there is no reason why hemp could not fit into such a system.

Hemp does have the ability to contribute to a sustainable agricultural system. While the growing of crops such as cereals can be modified to be sustainable, hemp facilitates a move toward implementing a more sustainable system. Its main contributions are that it requires less chemicals overall than other crops, in the form of both fertilizers and biocides; its "plant and harvest" requirements indicate that less energy has to be expended in maintaining the crop; and it is known for its abilities to improve the soil quality. The reduction of inputs in the end leads to lower costs. Hemp also improves soil quality when retting is conducted on the fields. Nova Scotia's climate has been identified as extremely suitable for conducting retting (Gehl, 1994), and this process, though labour intensive could be encouraged to tighten nutrient cycles.

Hemp may not be considered an ideal fibre for certain types of paper, e.g. its high strength characteristics are not always desired in the production of newsprint (Wells, 1995). Hemp's real potential lies in being combined with recycled paper, as it will add strength to the recycled pulp and thereby allow the paper to have a longer life-cycle (Byrd, 1996). It does not make sustainable sense to replace one renewable product with another (i.e. hemp instead of trees), in achieving true sustainability there must be a reduction in the consumption of raw materials. By adding hemp fibre to a product such as recycled pulp, there is the ability to reduce the consumption of trees for pulp and paper production, as well as reusing the recycled paper more often as its life-cycle is extended.

It is important that we do not develop a dependence on one fibre source, whether it be trees, switchgrass, or hemp. Not only do farmers' lands need to be more diverse but the economic base also has to be more diverse. When the main fibre source is trees then it becomes more justifiable to protect this source whether it be from pest infestations or fire. By diversifying the fibre source, a trend away from maximizing pulpwood could be facilitated, and this could be accompanied by a reduction in chemical use and a return to more diverse forests stands that would be less susceptible to environmental stresses. Forests have many attributes besides those based on the extraction of fibre. By expanding the sources of fibre it may be possible to reduce the tendency towards monocultures and increase the diversity of utilization within the forests.

The potential exists in Nova Scotia for non-woods to be a source of fibre. There are already experiments going on in Alberta and Quebec to pulp straw and switchgrass. The advantage of using straw as a source of pulp is that it would no longer be burned on the fields, a practice that creates a lot of problems in terms of smoke production. In Nova Scotia, however, this practice is being reduced as straw is presently commanding high market prices for its use as animal bedding, which could also be a significant market for hemp hurds. One concern of using straw as an agri-pulp would be the effects of removing the straw residue from the surface. In the case of hemp, the leaves are returned to the ground; however, for straw all of the leaves and stem material are removed. There would have to be some investigation into the amount of residue that could be removed from the surface without creating a need for additional fertilizers. The presence of silica in straw is also believed to cause some challenges to effluent recovery systems but these could be addressed with additional research (IIED, 1996).

The promotion of switchgrass as an alternative source of fibre has been geared toward the Canadian Prairies, Ontario and Quebec, but it is not known what kind of acceptance it would receive in Nova Scotia. Switchgrass is a C4 grass, which may not produce high yields here due to unsuitable climatic conditions, mainly cool temperatures. Switchgrass is also being promoted primarily as an alternative energy crop, and its true success may be in the form of a biomass crop and not as a pulp source (REAP, 1996). This is most likely a function of location and the demands for energy or pulp. Hemp is also promoted as a biomass crop, but it is believed that its potential as a fibre or oil source would exceed that of its potential as biomass (Walker, 1994).

In terms of hemp's abilities to be a profitable crop, it has a high multi-use potential. While traditionally crops were grown exclusively for fibre or seed, now with the development of monoecious varieties crops can be grown for both fibre and seed. Within these new varieties, there are attempts to maximize the bast fibre content and/or the oil content (Bócsa, 1994). This multi-use potential means that hemp could be used for the production of textiles, paper products, or oil products. In addition, a portion of the hurds produced could complement paper production as a filler material, and the remainder could be used for other products such as animal bedding. In terms of an economical comparison between hemp and other fibres, the figures available do not necessarily reflect the potential for Canada. In Europe, due to a subsidy, hemp is a profitable crop to grow. It could be that in Canada hemp would also be profitable but the cost of the seed will definitely be a barrier until Canadian grown seed can be produced. One encouraging observation is that even with numerous legal requirements, and no ability to recoup costs incurred, there is an increasing amount of interest in hemp farming in Canada, especially given the fact that there are subsidies available for the production of other crops.

The bulky nature of non-woods is often claimed to be the main disadvantage to developing a non-wood industry. This assertion needs to be carefully evaluated. It could be that this bulky nature requires the establishment of small mills in several locations. This could lead to increased economic development in some regions, and if it is undertaken with a sustainable crop then this could lead to long-term sustainability within a region. The fact that hemp would be grown on agricultural land that already has an established transportation infrastructure could compensate for its bulkiness. The establishment of logging roads to access remote sites could also be reduced if hemp were to be a significant source of fibre. Using hemp as an additional source of fibre, whether it be for paper or textiles, may lead to a return to smaller self-sufficient cottage industries. This could further promote regional development.

In comparison to other crops that could be sources of fibre, hemp does have some clear advantages. It is a crop that is suitable to Nova Scotia's climate, and it is known that it has been grown here as an industrial crop in the past. Its economic sustainability can never be evaluated or realized if hemp is not allowed to be grown on a commercial basis.

Hemp may not be 'the plant' to save the world but it could alleviate some environmental stress.

According to the Nova Scotia Forest Policy, the industry is striving to double forest production by the year 2025. It is concluded that hemp could be an alternative and additional source of fibre for Nova Scotia. Furthermore, hemp could help facilitate this goal of fibre production, and avoid the intensive management of forests that is certain to accompany the increase in forest production. An issue that needs to be addressed in the promotion of hemp as a fibre crop, is that of using agricultural land for fibre production instead of food production. There needs to be additional analysis performed to address this issue. In the Prairies, there is a surplus of grain production thus it is feasible to introduce a non-food crop to agricultural land. In Nova Scotia, grain must be imported, but it is not clear if this is due to limited land area for producing grains, or if it is simply not cost efficient to do so. If there is limited land area for producing food then perhaps industrial crops would not be suitable, however, if most of the crops are simply being exported then it may be of benefit to grow an industrial crop that could help to sustain the province's economy.

As the need for additional fibre sources approaches, hemp needs to be given an opportunity to compete against other fibres. Some recommendations are proposed, in the following section, that could facilitate the development of a commercial hemp industry in Nova Scotia and Canada.

6. Recommendations and Conclusions

6.1 Recommendations

In order for a commercial hemp industry to be established in Canada the definition of *Cannabis sativa* must be elaborated upon in the Controlled Drugs and Substances Act. Ideally industrial hemp should be removed from the Act as it has been established that it is not a narcotic. If this is not acceptable then there must be a clear delineation within the act between industrial (low-THC), and recreational/medicinal (high-THC) *Cannabis*. As in the European Economic Union, a limit could be established for low-THC varieties and seed could be certified as meeting an acceptable level. In addition, the Minister of Health should develop a framework for the commercial production of industrial hemp, in conjunction with organizations such as the Canadian Industrial Hemp Council and other members of the public. Without these changes, and the accompanying framework, a Canadian hemp industry will never develop. Accompanying this framework a distribution of power should be extended from the Minister of Health to the Minister of Agriculture.

Within this framework, permits could be issued for the cultivation of industrial hemp on a commercial basis. The issuance of permits could be simplified from the present system, but would continue to be in place to alleviate fears of misuse.

Since it appears that Canada is likely to follow the example of European countries and allow commercial hemp production, a significant amount of research needs to be undertaken by both Government and the private sector. This research would have to be undertaken at both the Federal and Provincial levels and within various Government departments. It is believed that all of the Canadian varieties that were grown in the 1920s and 1930s have not been maintained. Thus, research of varieties suitable for Canadian climates is necessary.

A process, such as the one undertaken for the GIS work in this thesis, could be developed to identify suitable regions for growing hemp. This work could be taken one step further, since GIS can also permit one to determine where mills could be situated in relation to the hemp fields.

In order to maximize hemp's potential to contribute to sustainability, investigations to determine crop rotations that would be complementary to different crops could be beneficial for both the farmer and the field. Other agronomic requirements would be an exploration into the seeding rates for different climates, soils, fertility levels, and desired yields and end products. This thesis research indicated that this is often a situation of trial and error, and since the cost of the seed is presently one of the greatest expenses, optimum seeding rates should be established for different conditions. This could be furthered by investigations into optimal planting and harvesting dates.

One of the main problems with the present permit process is that permits are often not approved in time to meet optimal planting dates. A new regulatory framework would have to ensure that permits were approved in sufficient time to produce a satisfactory crop.

In addition to investigating the agronomic requirements of hemp in Canada, the development of harvesting and processing technology will have to be facilitated, along with the associated infrastructure. The changes to the Narcotics Control Act will simplify this aspect, as it will no longer be illegal to be in possession of mature hemp stalks, a condition which has limited development in this area. This will allow more research to be done on processing industrial hemp for various applications, however, it does not contribute to the development of a Canadian based industrial hemp industry. Viable hemp seeds are still regulated under the Act, which hampers the ability to do agronomic research as multiple permits for the different aspects of handling narcotics must be issued.

The issue of the market potential for hemp also needs to be addressed. In conducting this research it was difficult to establish the true costs of hemp production. The costs are presently linked to international markets as there is no domestic supply. Once the barriers to hemp production are removed it is predicted that a market will flourish whether it be in the form of specialty niche markets or as supplements to existing products. One reason that hemp production is profitable in Europe is the availability of a subsidy. This issue will have to be addressed in Canada. If the legal barrier is removed a financial one might still exist if it is perceived that other crops are more profitable to grow.

Another area that needs to be addressed is that of education. There are numerous misconceptions about hemp and its potential as a narcotic. It was a public education campaign that led to hemp's prohibition, it is now time to reverse this and correct the misinformation that has persisted for almost 60 years.

6.2 Conclusions

The purpose of this thesis was to determine if hemp fibre would reduce the impacts of forestry and agriculture on the environment, yet meet the needs of the Nova Scotia pulp and paper industry. From the research undertaken for this thesis it is apparent that there is sufficient suitable land in Nova Scotia to supply hemp at least as a supplemental fibre. Taking this action could reduce the need to use forests as a source of fibre for the pulp and paper industry. Hemp has a high yield/per hectare/per year in comparison to trees, and thus less land is required to produce the same amounts of fibre. Even if hemp were to be grown in a four year rotation, the fibre yields would still be higher than those from the average managed forest. In addition to the high yields, hemp's abilities to improve agricultural conditions were well documented in this thesis.

In conclusion, hemp appears to be a suitable non-wood fibre for Nova Scotia. It was hypothesized that hemp would be more sustainable than annual crops, and this was proven to be true. The research indicates that switchgrass is likely a more environmentally sustainable crop, however, it may not be a suitable crop for Nova Scotia. Hemp's high overall potential to contribute to a sustainable agricultural system was demonstrated. This was mainly due to the suitability of hemp to Nova Scotia's climate and the diverse range of products that can be made from hemp. Furthermore, hemp could easily be incorporated into farmers' rotations, providing a source of fibre as well as improving soil quality.

In terms of economic sustainability, the lack of information in this area made it difficult to evaluate this parameter. Based on the fact that it has proven to be profitable in other countries, it could be inferred that it might also be profitable in Canada, and Nova Scotia. The only accurate way to establish this will be when commercial hemp can be produced domestically.

In 1924, after the first year of research into growing hemp in Nova Scotia, the researchers noted that: "The reports from manufacturers are very favourable as to the quality of the fibre and would indicate a profitable line of undertaking. Further work is contemplated for 1925." (Kentville, 1924). Perhaps the time has finally come to resume this work.

7. Appendices

APPENDIX A

GUIDELINES FOR THOSE APPLYING TO CULTIVATE MARIHUANA

Please note that the Narcotic Control Regulations allow the Minister to issue a licence to cultivate *Cannabis sativa* to a qualified person for scientific purposes only.

Applicants for a licence to cultivate marihuana for research purposes should supply the following information:

-the name, address, and birth date of the applicant;
-qualifications of the applicant in relation to the proposed research;
-name and birth date of all people who will be in contact with the plants;
-the location to be licensed;
-description of the project;
-variety of the marihuana seeds, the supplier of the seeds and, if applicable, the importer;
-the cannabis species to be cultivated, the anticipated percentage of THC in the plants, the methods used to determine the percentage and the conditions under which it will be grown;
-the specific location where the marihuana will be cultivated, and a description of the location in relation to surrounding fields and the surrounding area;
-owner of the field;
-the area to be cultivated;
-the number of plants to be cultivated;
-a list of grants received in regard to this project;
-the name(s) of any laboratories that will be conducting an analysis of the plant;
-the name(s) of the individual or company who will be conducting any scientific studies on, or transforming the plant, or any part of the plant;
-description of the physical security which will be provided to the plants and seeds;
-method of destruction which will be used to destroy the plant, and any part of the plant removed for study;
-description of the record keeping;
-name and address of the police force that normally responds to a call for help, the address of the closest provincial police force as well as a letter from them stating that they have no objection to the cultivation; and
-any other information which the applicant feels will facilitate the issuance of a licence.

(Health Canada-Health Protection Branch, Drugs Directorate, Ottawa, Ontario)

APPENDIX B

QUESTIONNAIRE

Please answer all questions as completely as possible in the space provided, if a question is not applicable to your situation please indicate. Additional comments may be included in the space provided at the end of the questionnaire. Measures have been taken for you to include information if you have more than one field of hemp under cultivation.

BACKGROUND INFORMATION

1. Are you a farmer? A researcher? Both? Other ?

2. A) What legal procedures and permits, if any, are required to grow hemp in your region?

3. A)How many hectares of industrial hemp do you have under cultivation?__________

   B) How many fields of industrial hemp do you have under cultivation ?__________

4. How many years have you had industrial hemp under cultivation ? __________

5. For what purpose are you growing industrial hemp?

   fibre seed for seed/oil products seed for planting

6. A)What varieties of hemp are you growing?

   B) What is the level of THC in the varieties you are growing?

   C) Are these hemp varieties monoecious or dioecious?

ROTATIONS

7. A) What crop rotations are typically used with the industrial hemp crop?
   B) What do these crops contribute to your soil/other crops?
   C)How long have you been using these rotations?
   D)Please describe positive and negative aspects of these rotations?
8. **For the last hemp crop grown:**
   A) What was grown 4 years prior to the last grown hemp crop :

	Field #1	Field #2	Field #3
1 year prior to hemp			
2 years prior to hemp			
3 years prior to hemp			
4 years prior to hemp			

B) What was grown, or do you anticipate growing, for the 4 years following the last grown hemp crop?

	Field #1	Field #2	Field #3
1 year following hemp			
2 years following hemp			
3 years following hemp			
4 years following hemp			

SOIL CHARACTERISTICS

9. What is the texture of the soil on which the hemp is growing?
   Coarse Medium Fine Other
10. What is the percent organic content of the soil on which hemp is growing?
    %
11. What is the pH of the soil that the hemp is growing on ?
12. What is the available rooting depth of the soil ?
13. What is the percent slope that the hemp crop is grown on?
14. What are the drainage conditions of the soil?
    excessive (droughty) well-drained imperfectly-drained poorly drained
15. Has the hemp crop changed the condition of your soil? YES / NO
    If yes, how has it changed?

CLIMATE

Were the daily precipitation, temperatures, and number of frost free days, in your region **during the growing season**: *average, below average, or above average* for the last five years. If you have numerical values please include them.

	1991	1992	1993	1994	1995
precipitation					
temperature					
# of frost free days					

17. When has an industrial hemp crop been susceptible to frost, drought, or excess moisture in your region? How was the crop affected in each case?

CROP CHARACTERISTICS

18. On what dates were the industrial hemp crops planted and harvested in the last five years?

	1991	1992	1993	1994	1995
planted:					
harvested:					

19. What were the days to flower for the hemp crop?

	1991	1992	1993	1994	1995
days to flower					

20. What is the planting density of the hemp crop? seeds/ha **or** kg/ha
21. What is the row spacing of the hemp crop? ____________ (m)

USE OF INPUTS

Was animal manure was used as a fertilizer? YES / NO

If yes, then:

	1991	1992	1993	1994	1995
22. What type of manure was applied					
23. How much manure was applied?					
24. When was it applied during the rotations?					

25. What type and quantity of fertilizers have you used in order to prepare your soil for
    A) industrial hemp
    B) other crops in the rotation?
26. What type and quantity of pesticides/fungicides have you used in order to eliminate pests from your
    A)industrial hemp crop,
    B) other crops?
27. What type and quantity of herbicides have you used in order to eliminate weeds from
    A) industrial hemp crops
    B) other crops in your rotations?
28. Has your industrial hemp crop ever required irrigation, inter-row cultivation, or other inputs not noted elsewhere in this questionnaire? Which ones and when?

INCIDENCE OF DISEASE / PESTS / WEEDS

29. A) Were there any disease outbreaks on the hemp crop? YES / NO
    B) If yes, what were they and how were they treated?
30. A)Were there any pest outbreaks on the hemp crop? YES / NO
    B) If yes, what were they and how were they treated.
31. A) Were there any problems with volunteer crops or residues in the hemp crop?
    YES / NO
    B) If yes, how were they treated?

YIELDS

32. What total yields (kg/ha) have been achieved by industrial hemp in the last 5 crops?

Field #1	*fibre*	*seed*	Field #2	*fibre*	*seed*	Field#3	*fibre*	*seed*
Year:			Year:			Year:		
Year:			Year:			Year:		
Year:			Year:			Year:		
Year:			Year:			Year:		
Year:			Year:			Year:		

33. If there was more than one hemp crop did the yields tend to be consistent across each field? YES / NO

    If no, was there variability related to soil type, drainage, or other factors? Please elaborate.

34. Upon harvesting the hemp crop what is the average:

    height ________(m) thickness________ (cm) of the hemp stalk?

35. What are the tillage, seeding, and harvesting operations required to produce industrial hemp on your farm ?

36. What is the minimum tractor horsepower rating required to produce hemp on your farm?

    ____

37. What farm machinery expenses are incurred to produce hemp on your farm (diesel fuel, gasoline, oil)?

    $ ________ (indicate currency)

38. What are the total production costs per hectare to produce industrial hemp? Include land rental or ownership costs, labour, and the management required to arrange permits etc.

    $ ________ (indicate currency)

OUTPUTS

39. Is the hemp crop retted in the field prior to harvest? YES / No
    If yes, for how long and what type of retting is used?
40. Were the leaves removed from field upon harvesting? YES / NO
41. What are post-harvest requirements of the crop?
42. What are the main industrial applications for your hemp crop?
43. Which companies/ organizations buy your crop?

44. What were the **total** returns for fibre, stalk, hurds, and seed for the last five crops? (Include those that are applicable- please specify currency used)

	fibre	**raw stalk**	**hurds**	**seed**
Year:	$	$	$	$
Year:	$	$	$	$
Year:	$	$	$	$
Year:	$	$	$	$
Year:	$	$	$	$

Please use the remainder and/or back of this page if you have any additional comments, and thank you for participating in this study.

APPENDIX C

Survey Results Summary

survey#	1	2
region	Manitoba 1	Alberta
background	farmer	farmer
legal	Can. permits	Can. permits
hectares	2ha	0.12 ha
fields	1	
years	1	1
purpose	fibre	fibre
	oil seed	oil seed
		windbreak
varieties	Zolotonosha	Kompolti
	<0.3%	
		0.009-0.023%
mon/di	both	dioecious
rotations	buckwheat/clover	not after canola or peas due to Sclerotinia carryove
	plow down clover / wheat	peas-barley-canola
	trefoil/oats/flax	
texture	medium	medium
%organic	6%	7-8%
pH	7.3	6.2
rooting depth	no limit	no limitation
%slope	2%	1-2%
drainage	well	well
changed		
days to harvest	June 15-Sep 10	May24-Aug18
days to flower		70
density	48kg/ha	500,000-2000000 seeds/ha
row spacing	6"	20-40cm
manure	sheep manure previous year	no
fertilizer	plow down green manure	86kg N
		41 kg P
		14kg K
		18 kg S
disease	Sclerotinia	Sclerotinia
pest	army worm	
residue		
yields	1T fibre	13,000 kg/ha dry matter
		fibre= approx 1/3 of dry matter
height	2m	3m
thickness	1cm	2cm

survey#	3	4
region	Cornwall, England	Netherlands
background	researcher	researcher
legal		none as long as grown for fibre, seed, or wind break
hectares	1 acre	4
fields		4
years	1	4
purpose	fibre	fibre
varieties	Uniko	Fedrina 74
	Kompolti	Fedora 19
	Kompolti Hybrid	Vinai unisexualis
		Kompolti Hybrid TC
		Kompolti Sargaszaru
		Kompolti Hyper Elite
		Kozuhra zairai
mon/di		see survey
rotations		
texture		
%organic		
pH		
rooting depth		
%slope		
drainage		
changed		
days to harvest		
days to flower		
density	40kg seed /acre	100-120 seeds/m2
row spacing		12.5cm
manure		
fertilizer		for 10kg/ha of stem dry matter
		125 kg/ha N
		46 kg P2O5
		173 kg K2O
disease		
pest		
residue		
yields		
height		3m
thickness		

survey#	5
region	Yugoslavia
background	researcher
legal	none
hectares	1
fields	
years	50
purpose	fibre
	bird seed
	seed
varieties	local
	Novosadska konoplja
	Uniko B
	Kompolti TC
mon/di	dioecious
rotations	wheat-hemp-corn
	corn-hemp-sugar beet
texture	
%organic	5-6%
pH	7
rooting depth	unlimited
%slope	flat
drainage	well
changed	
days to harvest	10-20 April - 15-20 Aug
days to flower	
density	80-85 kg/ha fibre
	4-5 kg/ha for seed
row spacing	12.5 for fibre, 50-70cm for seed
manure	no
fertilizer	8/24/16
disease	
pest	
residue	
yields	8-10T ha
	seed 600-800 kg/ha
height	2.5-3
thickness	1-1.5cm

survey#	6	7
region	Netherlands1	Netherlands 2
background	researcher	researcher
legal	none	none
hectares		
fields		
years		
purpose		
varieties	Fedrina 74 di	
	Kompolti Hybrid TC mon	
	<0.5%	
mon/di	di/mon	
rotations	potatoes	
	cereals	
	sugar beets	
texture	coarse to medium, 40-50%clay, 0.5% lime	
%organic	2%	
pH	6.5-7.0	
rooting depth	1m	
%slope	0	
drainage	pipes - well	
changed	increase soil health for potatoes	
days to harvest	15 April to 15 Sept	
days to flower	10-Aug	
density	22kg/seed ha	
row spacing		
manure		
fertilizer	if N between 10-50kg/ha then 120kg N applied	
	150kg K20	
	40 kg P2O5	
disease		
pest		
residue		
yields	8-10 ton/ha	10kg/ha stem dry matter
height	2.5-2.9 m	3.2m
thickness	depends on density	1.5 cm

survey#	8	9
region	France	Shandong, China
background	org.	researcher
legal	French regs	none
hectares	4500	5,000
fields		50,000
years	22	1987
purpose	fibre	fibre
	oil seed	
	seed	
varieties	Fedora	Local landrace
	Fibrinon	
	Futura	
	Felina	
	Fedrina	<1.00%
	0-0.12%	
mon/di	monoecious	dioecious
rotations	corn	market vegetables -spring
		cabbage, root crops - fall
		winter wheat
texture	medium-fine	
%organic		<5%
pH		6.8
rooting depth		1m
%slope		flat
drainage		well
changed		market veg production has increased
days to harvest	april-may to aug-oct	fibre -april, seed -may/june = july - sept
days to flower	July	70-110 days
density	45kg/ha	75 kg/ha for fibre
		10kg for seed
row spacing		broadcast
manure		yes
fertilizer	60-120 kg/ha N	
	50-P	
	120 - K	
disease		
pest		
residue		
yields		0.7-1.0t/ha fibre ribbon
height	1-3m	2.5-3.0m
thickness	3mm to 2cm	1cm at base

survey#	10	11
region	Saskatchewan	Kompolt, Hungary
background	researcher	researcher
legal	Can. permits	none
hectares		1000 ha fibre, 400ha seed
fields		
years	1	since Middle Ages
purpose	fibre	fibre
		seed
varieties	Ukranian	Kompolti
		Uniko-B
		KHTC (Kompolti Hybrid TC)
		Fibriko
	<0.003%	<0.3%
mon/di	dioecious	dioecious
rotations	peas	after cereals
	barley	
texture	medium	fine
%organic	3%	humus 2.8%
pH	7.3	5.5
rooting depth	1.6m	60cm
%slope	5%	flat
drainage	well	well
changed		exhausted but weed-free
days to harvest	June 17-aug 29	early April-late August
days to flower	55	110-115 avg
density	200-600 seeds/m2	80kg/ha
row spacing	0.3m	0.12m fibre 70x70cm for seed
manure	no	no
fertilizer	50kgN	100kg N/ha
	60kg P2O5	200kgP2O5
		0-200K2O
disease		Psylliodes attenuata - metylparation
pest		
residue		benefin-presowing
yields	8000kg/ha	
height	2m	2.5m
thickness	6mm for 200seeds rate	0.8cm
	4mm for 600 seeds	

survey#	12	13
region	Manitoba 2	France
background	researcher	researcher
legal	permits	EEC/France permits
hectares	2	8000 in France
fields	5	
years	2	60
purpose	fibre	fibre
	oil seed	seed
varieties	Zolotonosha 11	French varieties
	Zolotonosha 13	<0.2% THC
	Kompolti	
	Unico B	
	Felina 34	
	Fedora 19	
	Futura 77	
mon/di	mon, except Kompolti & Unico B	mon
rotations	oats, canola	hemp, wheat, barley
		improve soil structure
		and wheat yield
texture	medium-fine	
%organic		
pH	7.2-7.7	>5
rooting depth	>1m	
%slope	0-5%	
drainage	well-imperfectly	
changed		yes, imrpove soil structure
days to harvest	June 10- mid Aug, late-Sept	10/4 to 30/5 for sowing
days to flower	45-70	25/8 to 10/10 for harvest
density	1000000seeds/ha for seed	50-60 kg/ha
	5000000 seeds/ha for fibre	
row spacing	0.2-0.3m	0.17m
manure	no	no
fertilizer	100 kg/ha N available + applied	N 80-120
	45 kg/ha avail + applied	P 40-60
	K2O, S enough available	K 160-200
	soils generally high in K	
disease	Sclerotinia sclerotiorum	no
pest	Bertha army worm	no
residue	Canada thistle,	no
	wild mustard in non-uniform emergence field	
yields	4500-7500 kg/ha fibre	6-10T/ha fibre
	100 kg/ha seed	0.6-1.0 T/ha
height	2-3 m	2-2.5m
thickness		

survey#	14
region	Victoria, Australia
background	farmer/researcher
legal	trial permits
hectares	
fields	
years	1
purpose	fibre
varieties	Ferimon 12 Early Beniko
	Fedora 19 Early Bialobrzeskie
	Felina 34 Mid-Late Kompolti TC
	Fedrina 74 Late Secuini
	Futura 77 Late
mon/di	
rotations	
texture	
%organic	
pH	
rooting depth	
%slope	
drainage	
changed	
days to harvest	60
days to flower	60
density	
row spacing	
manure	
fertilizer	2tonne/ha lime
	100kg N
	40kg P
	40kg K
	K=Pivot, DAP, Ammonium Nitrate
disease	muriate of potash
pest	no
residue	
yields	11tonnes/ha
height	1.8m
thickness	

8. Bibliography

Abdul-Karim, L., A. Rab, E. Polyanszky, and I. Rusznak. 1994. Optimization of process variables for production of dissolving pulps from wheat straw and hemp. *Tappi Journal* 77(6):141-150.

Agriculture Canada. 1989. *Soil landscapes of Canada: Maritimes.* Canada Soil Inventory. Agriculture Canada. Contribution Number 87-18.

Andrews et al 1990. Converting to sustainable farming systems. In *Sustainable Agriculture in Temperate Zones* (Eds. C.A. Francis, C.B. Flora and L.D. King.) pp.281-314 John Wiley & Sons, New York.

Apsey, M. And L. Reed. 1995. *World Timber Resources Outlook.* FAO December 1995.

Atlantic Advisory Committee on Cereal & Protein Crops. *1995 Field crop guide to cereal, soybean & pesticide selection.* Atlantic Provinces Agricultural Services Co-ordinating Committee, Kentville.

Atlantic Provinces Agricultural Services Coordinating Comm. (APASCC). 1991. Atlantic Provinces Field Crop Guide. Publication 100, Agedx No. 100.32. pp. 32 - 42.

Baxter, W.J. 1996. *Hemp: Industry Status Report.* Ontario Ministry of Agriculture, Food, and Rural Affairs. Guelph, ON.

Bird, W., T. Edens, F. Drummond, and E. Groden. 1990. Design of pest management systems for sustainable agriculture. In *Sustainable Agriculture in Temperate Zones* (Eds. C.A. Francis, C.B. Flora and L.D. King.) pp.24-110. John Wiley & Sons, New York.

Birrenbach, J. 1994. Hemp paper production. In *Hemp Today.* (Ed. E. Rosenthal) Quick American Archives, Oakland California. pp.149-154.

Boulder Hemp Initiative Project. 1994. *Industrial Hemp as a Cash Crop for Colorado Farmers*. Boulder Hemp Initiative Project, Nederland, CO.

Byrd, M. 1996. Kentucky Industrial Fibre Hemp Conference. May, 31, 1996. Lexington, Kentucky.

Callaway J.C., and A.M. Hemmilä. 1996. Cultivation of *Cannabis* fibre varieties in central Finland. *Journal of the International Hemp Association.* Vol 3(1):29-31.

Canadian Council of Forest Ministers. 1996. Compendium of Canadian Forestry Statistics.

Canadian Forest Service / Natural Resources Canada. 1993. *Canadian Hunger for wastepaper.*

Charest, N. Personal communication. Hemp Symposium - Feb. 18th, 1996, Winnipeg, Manitoba.

Clarke, 1996. Kentucky Industrial Fibre Hemp Conference. May, 31, 1996. Lexington, Kentucky.

Coalition of Nova Scotia Forest Interests. 996 *New forest strategy for Nova Scotia - Discussion Paper.*

Conrad, Chris. 1993. *Hemp: Lifeline to the future.* Los Angeles: Creative Xpressions. 312p.

Crawford, C. 1996. Personal communication. Eco-Design Group. April-Dec. 1996.

Croon, D. 1995. After recycling, what's next? *Papermaker.* December, 1995. p.26.

Davis, James. 1996. *Report on Australian Hemp Trials from James Davis to Joe Hickey.*

Dean, Donald. 1995. *Hempenfolk International plantations report.* Hempenfolk International, Ottawa.

deMeijer, E.P.M. 1993. Hemp variations as pulp source researched in the Netherlands. *Pulp and Paper.* July 1993. 41-42.

deMeijer, E. 1995 Fibre hemp cultivars: A survey of origin, ancestry, availability and brief agronomic characteristics. *Journal of the International Hemp Association* 2(2):66-73.

deMeijer, E.P.M. 1995. Breeding and agriculture. *Bioresource Hemp Conference*, Germany, March 1995.

deMeijer, E.P.M., H.J. van der Kamp, and F.A. van Eeuwijk. 1992. Characterisation of *Cannabis* accessions with regard to cannabinoid content in relation to other plant characters. *Euphytica* 62:187-200.

DeVries, F.P., M.J.F. Hendriks, A.B. Dronkers, and E. Dronkers. 1994. *1000 tonnes of Dutch hemp produced by Hemp Flax B.V.* Hemp Flax B.V. The Netherlands.

Dewey, L.D. 1913. Hemp. Yearbook of the USDA. Reprinted in *Hemp Today.* (Ed. E. Rosenthal) Quick American Archives, Oakland California. pp.339-376.

Dewey, L.H. and J.L. Merrill. 1916. Hemp hurds as paper-making material. *Bulletin No. 404* USDA, Washington, DC.

Dilek, F.B. and Celal F. Gokcay. 1994. Treatment of effluents from hemp-based pulp and paper industry. I. Waste characterization and physio-chemical treatability. *Water Science Technology.* 29(9):161-163.

Dilek, F.B. and Celal F. Gokcay. 1994. Treatment of effluents from hemp-based pulp and paper industry. Biological treatability of pulping effluents. *Water Science Technology.* 29(9):165-168.

Doering, O. 1992. Federal policies as incentives or disincentives to ecologically sustainable agricultural systems. *Journal of Sustainable Agriculture.* 21-35.

Domier, K. 1995. *Opportunities for Diversification: Crop Fibres.* University of Alberta, October 1995.

Doran. J.W. 1990. Management and soil biology. In *Sustainable Agriculture in Temperate Zones* (Eds. C.A. Francis, C.B. Flora and L.D. King.) pp.205-230. John Wiley & Sons, Inc., New York.

Dronkers, Ben. 1995. History & status of hemp cultivation. *Bioresource Hemp Conference*, Germany, March 1995.

Eaton. P.B., A.G. Gray, P.W. Johnson, and E. Hundert. 1994. *State of the Environment in the Atlantic Region.* Environment Canada-Atlantic Region. Minister of Supply and Services. pp.455

Eidt, D. Nova Scotia Dept of Natural Resources. Personal communication. November 29, 1996.

Flora, C.B. 1990. Sustainability of agriculture and rural communities. In *Sustainable Agriculture in Temperate Zones* (Eds. C.A. Francis, C.B. Flora and L.D. King.) pp.343-360. John Wiley & Sons, Inc., New York.

Francis, C. And G. Youngberg. 1990. Sustainable agriculture-an overview. In *Sustainable Agriculture in Temperate Zones* (Eds. C.A. Francis, C.B. Flora and L.D. King.) pp.1-23. John Wiley & Sons, New York.

Francis, C.A., C.B. Flora and L.D. King (Eds.) 1990. *Sustainable Agriculture in Temperate Zones.* John Wiley & Sons, New York. pp.487.

Gehl, D. 1995. *A summary of hemp research in Canada conducted by the Fibre Division of Agriculture Canada 1923-1942.* AAFC Research Farm, Indian Head SK.

Genovali, C. 1995. Stora rejects sustainable forestry project *Taiga News* no. 15. (http:www.sll.fi/TRN/TaigaNews/News15/StorainNovaScotia.htm)

Girouard, P. 1994. Fibre from the farm. *Sustainable Farming.* 4(3):9-12.

Guilford, R. 1996. Hemp farmer. Personal communication. Feb.-Dec. 1996.

Guthrie, Ann. 1994. The amazing history of hemp. Earthkeeper. Vol. 4(3):21-23.

Hackleman, J.C. and W.E. Domingo. 1943. *Hemp. An Illinois war crop.* Circular 547. University of Illinois, College of Agriculture. pp8.

Herer, Jack. 1993 *Hemp and the Marijuana Conspiracy.* (1993/94 Edition) HEMP/Queen of Clubs Publishing, California.

Hockey, J.F. 1967. *Agricultural Research in the Annapolis Valley Area 1909-1960.* Canada Department of Agriculture.

Holmstrom, D.A., B.L. Thompson. 1989. *Soils of the Annapolis Valley area of Nova Scotia.* Report No. 22. Nova Scotia Soil Survey. Agriculture Development Branch. Agriculture Canada, Truro, NS. pp. 184 40 maps.

Howe, Jonas. 1892. *Early attempts to introduce the cultivation of hemp into Eastern British North America.* New Brunswick Historical Society.

Hunter, M.L. Jr. 1990. *Wildlife, Forests, and Forestry. Principles of Managing Forests for Biological Diversity.* Regents/Prentice Hall. Englewood Cliffs, New Jersey. pp.370.

International Institute for Environment and Development (IIED). 1996. *Towards a Sustainable Paper Cycle.*

Judt, M. 1994. Hemp: papermakers should take it with a pinch of salt. *PPI* October 1994:32-35.

Kearns. G. 1996. Canadian Hemp. *Canadian Textile Journal.* June 1996.

Kentucky Agricultural Experiment Station. 1889. *Hemp Experiments.* Bulletin No. 18.

Kentucky Agricultural Experiment Station. 1895. *Field Experiments with fertilizers. Corn, potatoes, tobacco, hemp.* State College of Kentucky.

Kentucky Industrial Fibre Hemp Conference. May 31, 1996. Lexington, Kentucky.

Kentville Agricultural Research Station. Annual Reports 1924-1929.

Kinzer, S. 1995. Germany lifting ban on hemp growing, but not for marijuana. *New York Times International*. Sunday, Nov. 12, 1995.

Krotov, V.S. Hemp or wood: potential substitutes. In *Hemp Today*. (Ed. E. Rosenthal) Quick American Archives, Oakland California. pp.145-148.

Langille, D.R., K.T. Webb, T.J. Soley. 1993. *Supplement to: Soils of the Annapolis Valley area of Nova Scotia*. Report No. 26. Nova Scotia Soil Survey. Agri-Food Development Branch, Agriculture Canada, Truro, NS. pp.67. 14 maps.

Langtry, M. 1995 Internet Communication. http://www.escape.ca/~langtry.htm

Larsen. D. 1995. Canada's Cannabis farmers. *Cannabis Canada.*

Le Dain, G. 1972. *Cannabis. A report of the commission of inquiry into the non-medical use of drugs.* Information Canada, Ottawa.

Lewis, E.B., D.G. Card, and J.S. McHargue. 1945. Tobacco stalks, hemp hurds, and sorghum bagasse as sources of cellulose for making high-quality paper. *Bulletin 515.* Kentucky Agricultural Experiment Station, Lexington. pp.3-14.

Liebman, M. And R. Janke. 1990. Sustainable weed management practices. In *Sustainable Agriculture in Temperate Zones* (Eds. C.A. Francis, C.B. Flora and L.D. King.) pp.111-143. John Wiley & Sons, Inc., New York.

Lockeretz, W. 1988. Open questions in sustainable agriculture. *American Journal of Alternative Agriculture*. Vol. 3(4):174-181.

Lockeretz, W. 1990. Major issues confronting sustainable agriculture. In *Sustainable Agriculture in Temperate Zones* (Eds. C.A. Francis, C.B. Flora and L.D. King.) pp.423-438. John Wiley & Sons, Inc., New York.

Low, Ian. 1995. Three long years of hemp. *Bioresource Hemp Conference*, Germany, March 1995.

Low, Ian. 1996. Kentucky Industrial Fibre Hemp Conference. May 31, 1996. Lexington. Kentucky.

Mackie International. 1996. Kentucky Industrial Fibre Hemp Conference. May 31, 1996. Lexington. Kentucky.

Madden, J.P. 1990. The economics of sustainable low-input farming systems. In *Sustainable Agriculture in Temperate Zones* (Eds. C.A. Francis, C.B. Flora and L.D. King.) pp.315-342. John Wiley & Sons, Inc., New York.

Manitoba Hemp Symposium. 1996. February 16th, 1996. Winnipeg, Manitoba.

Maxwell, B.W. 1918. *Hemp. Its Culture and Possibilities in Ontario*. Ontario Agricultural College, Guelph. pp.27.

McMillan, D. 1994. Putting pulp mill on the rails. *Sustainable Farming*. Vol. 4. No.3 Winter 1994.

McPartland, J.M. 1996. A review of *Cannabis* diseases. *Journal of the International Hemp Association* 3(1):19-23.

Meijer, W.J.M., H.M.G. van der Werf, G.J. van Roekel, E.P.M. de Meijer, and W. Huisman. 1995. Fibre hemp: potentials and constraints. *Opportunities and Profits: Special Crops Conference Proceedings* July 25-27, 1995. Calgary. Alberta Agriculture, Food and Rural Development.

Moes, J. 1996a. Manitoba Hemp Symposium. February 16th, 1996. Winnipeg, Manitoba.

Moes, J. 1996b. New Crops Agronomist. Manitoba Agriculture. Personal communication. Feb-Dec. 1996.

Moravcik, M. 1996. Hemp retailer/researcher-Manitoba. Personal communication. Feb-Dec. 1996.

Morazain, J. G. 1942. *Survey of Hemp Cultivation and Processing in the USA and of the Possibilities in Canada.* Beauchamois, Quebec.

More, James F. Esq. 1873. *The History of Queens County Nova Scotia.* Halifax, Nova Scotia Printing Co.

Murphy, E. 1922. *The Black Candle. 1973 Edition* Coles Publishing Company, Toronto.

Nova Scotia Department of Agriculture and Marketing. 1993. *Soils of the Annapolis Valley area of Nova Scotia.* Report No. 26: Nova Scotia Soil Survey.

Nova Scotia Departmentt of Agriculture and Marketing/Atlantic Office of Statistics Canada. 1995. *Nova Scotia Agricultural Statistics.*

Nova Scotia Department of Lands and Forests (Natural Resources). *Forest/Wildlife Guidelines and Standards for Nova Scotia.*

Nova Scotia Department of Lands and Forests. 1988. *Forestry Field Handbook.* Forest Research Section, Truro, NS.

Orton, D. 1983. *Pulpwood forestry in Nova Scotia.* Presentation to the Royal Commission of Forestry, Halifax, April 19, 1983.

Orton, D. 1991. Pulp and paper primer: Nova Scotia. *GreenWeb Bulletin #26.* Saltsprings, Nova Scotia.

Pate, David. 1995. Function of cannabinoids. *Bioresource Hemp Conference*, Germany, March 1995.

Patterson, Gary. 1996. Agriculture Canada. Personal communication. Feb-Dec. 1996.

Pimmental, D. 1995. Most pesticides miss the target pest. *Sustainable Farming*. Summer 1995. p.4.

Power, 1990. Legumes and crop rotations. In *Sustainable Agriculture in Temperate Zones* (Eds. C.A. Francis, C.B. Flora and L.D. King.) pp.178-204. John Wiley & Sons, Inc., New York.

REAP, 1995. *Le Panic Érigé et l'industrie des pâtes et papiers.* Centre spécialisé en pâtes et papiers, Trois Rivières.

REAP, 1996. Personal communication. Nov. 1996.

Reichert, G. 1994. Hemp. *Bi-weekly Bulletin.* Vol.7 No.23. Agriculture Canada.

Reichert, G. 1995. Industrial hemp in Canada. *Bioresource Hemp Conference*, Germany, March 1995.

Reichert, G. 1996. Report on Straw. *Bi-weekly bulletin.* Vol9. No.2. Agriculture Canada.

Riddlestone, S. 1996 *Hemp textiles in Britain-Opportunities for bioregional development.* Bioregional Development Group. Surrey, England.

Riddlestone, S. 1994. Back to the future for a profitable new industry. *PPI* November 1994. pp.50-53.

Robinson, B. 1943. Hemp. *USDA Bulletin #1935.*

Rodden. G. 1996. Prairie grasses may be a Canadian fibre of the future. *Sustainable Farming* 6(4):1.

Rosenthal, E. 1994. Hemp realities. In *Hemp Today*. (Ed. E. Rosenthal) Quick American Archives, Oakland California. pp.67-82.

Rosenthal, Ed. (Ed.) 1994. *Hemp Today.* Quick American Archives. San Francisco. pp.444.

Roulac, J. 1996. Hemptech. http://www.hemptech.com

Ruthman, T. 1996. Retired pulp and paper superintendent. Personal communication. Jan-Dec. 1996.

Samson, R. 1991. Switchgrass: a living solar battery for the prairies. *Sustainable Farming* 1(3):3-8.

Schabas, B. 1982. Canadian-grown hemp may soon be ready for fine paper producers. *Pulp and Paper Canada.*

Scheifele, G and C. Pinsonneault. 1995. *Report on Research as a result of issuance of cultivation license of Cannabis sativa.* Ridgetown College of Agricultural Technology.

Seale, C.C., J.F. Joyner, J.B. Pate. 1957. Agronomic studies of fiber plants. *Bulletin 590* University of Florida, Agricultural Experiment Stations.

Shamai, Ruth. 1996. Hemp importer/researcher. Personal communication. May-Dec. 1996.

Slinkard, A.E. 1995. *Agronomic studies on fibre hemp at the University of Saskatchewan-1995.* University of Saskatchewan.

Small, E. 1972. The hemp problem in Canada. *Greenhouse-Garden-Grass.* 11(3):47-52.

Small, E. 1979. *The Species Problem in Cannabis, Science and Semantics. Vol. I & II.* Agriculture Canada.

Small, E., P. Jui and L.P. Lefkovitch. 1976. A numerical taxonomic analysis of *Cannabis* with special reference to species delimitation. *Systematic Botany* 1(1):67-84.

Strickland, David. 1995. England's ecological farmers. *Bioresource Hemp Conference,* Germany, March 1995.

Sumach, A. 1995. Joe Strobel grows hemp. *Cannabis Canada.*

Temanex.1993. *The Role of Wastepaper in the Canadian Pulp and Paper Industry.* Prepared for Forestry Canada.

Travers, S. 1996. President Minas Basin Pulp & Power. Personal communication, April 1996.

UNEP. *Environmental management in the pulp and paper industry.*

US Paper Task Force. 1995. *Non-wood plant fibers as alternative fiber sources for papermaking.* White Paper No.13. DRAFT.

Van der Werf, H.M.G. 1994(a). *Crop Physiology of Fibre Hemp (Cannabis sativa L.).* Doctoral Thesis, Wageningen Agricultural University, Wageningen, the Netherlands. pp152.

Van der Werf, H.M.G. 1994(b). Literature review. In *Hemp Today*. (Ed. E. Rosenthal) Quick American Archives, Oakland California. Pp.123-138.

Van der Werf, H.M.G. 1994(c). Hemp facts and fiction. *Journal of the International Hemp Association.* 1(2):58.

Van der Werf, H.M.G. 1994(d). Paper from Dutch hemp? *Journal of the International Hemp Association.* 1(1):18-19.

Van der Werf, H.M.G. 1995. Breeding and agriculture. *Bioresource Hemp Conference*, Germany, March 1995.

Van der Werf, H.M.G. 1996. Personal communication. Oct-Dec. 1996.

Van der Werf, H.M.G., W.C.A. van Geel, and M. Wijlhuizen. 1995(a). Agronomic research on hemp (*Cannabis sativa* L.) in the Netherlands, 1987-1993. *Bioresource Hemp Proceedings.* March 2-5, 1995, Frankfurt, Germany.

Van der Werf, H.M.G. and K. Brouwer, M. Wijlhuizen and JCM Withagen. 1995(b). The effect of temperature on leaf appearance and canopy establishment in fibre hemp (*Cannabis sativa* L.) *Ann. Appl. Biology*. 126:551-561.

Van der Werf, H.M.G. and W. Van den Berg. 1995 (c). Nitrogen fertilization and sex expression affect size variability of fibre hemp (*Cannabis sativa* L.) *Oecologia* 103:462-470.

Van Roekel, G. 1994. Hemp pulp and paper production. *Journal of the International Hemp Association*. 1(1):12-14.

Vessel, A.J., and C.A. Black. 1947. Soil type and soil management factors in hemp production. *Research Bulletin 352*. Agricultural Experiment Station. Ames, Iowa. pp. 384-424.

Virovets, V.G. 1996. Selection for non-psychoactive hemp varieties (*Cannabis sativa* L.) in the CIS (former USSR). *Journal of the International Hemp Association*. 3(1):13-15.

Walker, D. 1994. Can hemp save our planet? In *Hemp Today*. (Ed. E. Rosenthal) Quick American Archives, Oakland California. Pp.83-108.

Warwick, L. 1995. Paper Profits. *Montreal Gazette*. January 30th, 1995. p.9-11.

WCED (World Commission on Environment and Development), 1987. *Our Common Future*. Oxford University Press, Oxford.

West, Dave. 1996. *Industrial hemp farming: history and practice*. Unpublished manuscript.

West, Dave. 1996. Hemp researcher. Personal communication. Jan. 1995-Dec.1996.

Williamson, P. 1996. Customer needs are driving Canada's industry as never before. *Tappi Journal* 79(1):55-61.

Wirschafter, D. 1996. Industrial hemp: Economic opportunities for Canada. Conference. Toronto, April, 1996.

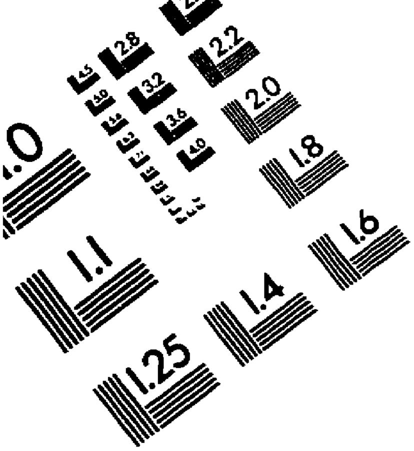
Young, Jim. 1991. It's time to reconsider hemp. *Pulp and Paper*. June 1991, p.7.

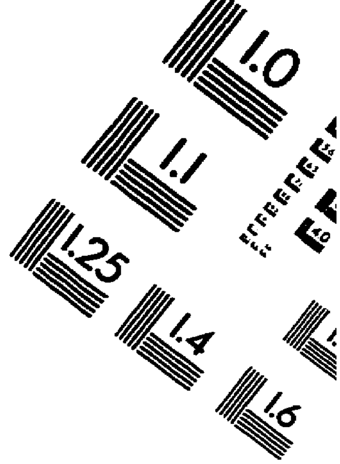
Youngs, G.A., G.A. Goreham, and D.L. Watt. 1991. Classifying conventional and sustainable farmers: does it matter how you measure? *Journal of Sustainable Agriculture* Vol.2(2):91-115.

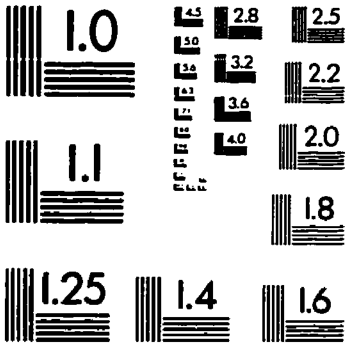
Yunlong, C. And B. Smit. 1994. Sustainability in agriculture: a general review. In *Agriculture, Ecosystems & Environment*. 49:299-307.

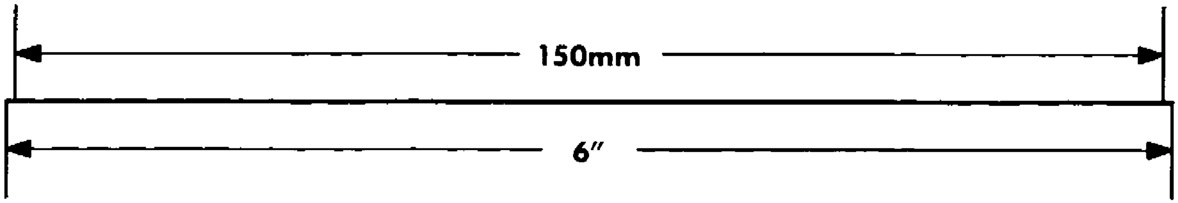
Zomers, F.H.A., R. Gosselink, J. van Dam, and Boke Tjeerdsma. 1995. Organosolv pulping and test paper characterization of fiber hemp. *Tappi Journal*. 78(5):149-155.

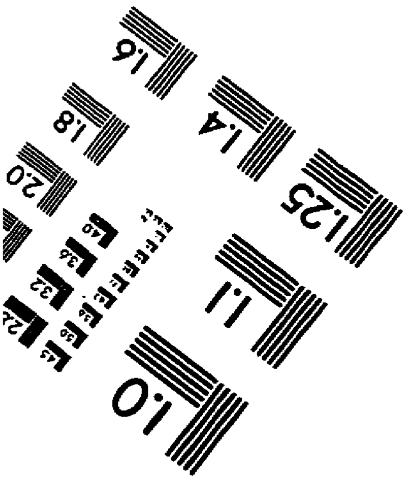
TEST TARGET (QA-3)

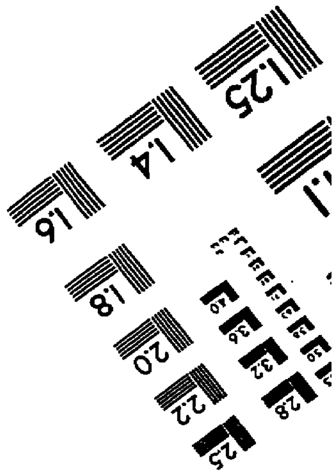












APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989