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The future of industrial hemp in the Netherlands

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Abstract

Allocation of the Common Agricultural Policy (CAP) subsidies from fiber crops including industrial hemp to biofuel and bio-energy crops, induces competition for cropland and jeopardizes the Dutch hemp cultivation. By means of scientific and professional literature and questionnaires, future prospects were drawn for industrial hemp in the Netherlands. In addition, the role of the Dutch hemp industry in the European and global market was investigated. Future prospects were drawn based on the expectations expressed by HempFlax and Dun Agro, the only Dutch hemp processors, and dr. ir. Trindade, hemp breeding expert at Wageningen University. It was assessed that although hemp is receiving more attention, especially in the automotive industry, hemp processors will have difficulty with finding sufficient cropland to grow raw material. It is expected that with ongoing competition for cropland, industrial hemp will disappear from the Netherlands. However, contradicting this, the industrial hemp acreage is expected to grow as a result of the many applications and beneficial properties of hemp. Hemp is well adapted to Dutch climate, grows well on poor Dutch soils without chemical additives, provides a sustainable alternative for cotton and synthetic fibers and may be used as bioremediation, making hemp a very interesting crop for the Netherlands. However, under the current circumstances, the Dutch hemp industry has difficulty to overcome the startup phase and therefore it is recommended that the Dutch and European policies are adapted to create a more supporting environment for industrial hemp.

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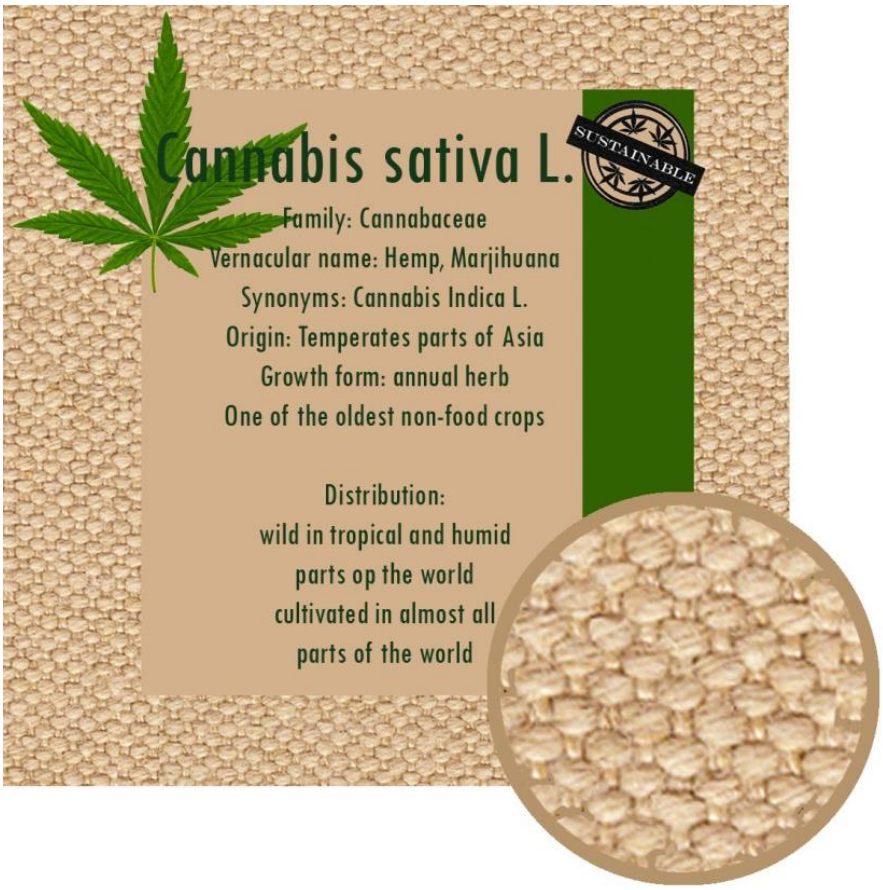
Abbreviations

CAP	Common Agricultural Policy
DA	Dun Agro, Dutch processing company
EC	European Commission
EFA	Ecological Focus Area, measurement of the CAP
EIHA	European Industrial Hemp Association
EU	European Union
HF	HempFlax, Dutch processing company
THC	Delta-9-tetrahydrocannabinol
US	United States of America

Introduction

Industrial hemp is easily grown, requires little water and no fertilizer [66] and is well-adapted to temperate climates such as in the Netherlands [71,78]. All parts of the hemp plant can be used [RW.ERROR - Unable to find reference:197] for myriad applications in among others the automotive, furniture and textile industry [*]. This makes industrial hemp an excellent alternative for the non-sustainable cultivation of cotton [22] and the depleting resources of synthetic fibers [53]. However, hemp is still grown on a small scale in the Netherlands and since 2012 no longer supported by subsidies from the European Union as a part of the Common Agricultural Policy (CAP) [66]. Allocation of subsidies from fiber crops such as hemp to biofuel and bio-energy crops, creates unfair competition for available cropland [9]. This research builds upon previous research by Ronde (2013) that investigated the consequences of the changing subsidies for industrial hemp. Due to small size of the Dutch hemp market, Dutch hemp processors look for supply and demand abroad and are subjected to legislation established by the European Union. Therefore the present study extends the earlier acquired knowledge on this subject by investigating the role of Dutch industrial hemp in the global and European hemp market. In addition, it was examined why hemp is valuable for the Netherlands and perspectives were outlined for the future of industrial hemp in the Netherlands. Firstly, eight factors were identified to have an influence on the global, European and Dutch hemp markets. Secondly, the expectations from the two Dutch hemp processing companies were captured by means of questionnaires answered by K. Dun (Dun Agro) and M. Reinders (HempFlax). Finally, dr. ir. Trindade, hemp breeding expert from Wageningen University, expressed her expectations for industrial hemp in the Netherlands. By these means, a perspective was drawn for the future of the Dutch hemp market. This thesis concludes that industrial hemp is likely to remain in the Netherlands due to the many benefits during cultivation, the sustainable character, the many possible applications and new opportunities to find cropland. Industrial hemp stills suffers from unfair competition by biofuel and bio-energy crops [9] and the European Union and Dutch government are recommended to change policy to give hemp the opportunity to develop a strong base for an healthy market competition.



Firstly, an introduction on industrial hemp and an overview of the cultivation and processing technics are provided (chapter 1.). Then the global, European and Dutch markets are described (chapter 2.), followed by eight factors that influence the market (chapter 3.). Subsequently, future prospects for industrial hemp in the Netherlands are outlined (chapter 4). Finally, bottlenecks and opportunities for the growth of industrial hemp are identified and recommendations are made (conclusion).

[*] Personal communication with M. Reinders, June 12, 2014

Chapter 1. Introduction into hemp

Industrial hemp is often incorrectly associated with hemp for narcotics. Box 1. emphasizes the difference between Cannabis species used as a narcotic (marijuana) and for industrial purposes. Furthermore, this chapter elucidates the nature of industrial hemp by describing the characteristics and a selection of the broad range of possible applications. Finally, a short overview is provided on the harvesting and processing methods. This research is restricted to hemp for industrial purposes thus in all cases hemp refers to industrial hemp.

1.1 Hemp (Cannabis sativa L.)

Hemp originated from Asia and was already cultivated 4,500 years ago in China. Hemp fibers were used for textile manufacturing and the seeds as nutrition. It is estimated that hemp was imported to Europe by nomads in the sixteenth century [78]. In that same century, hemp became a valuable crop in Europe [32]. In Dutch history hemp is often mentioned as a fiber used for the fabrication of ropes, sandals and sailcloth during the Middle Ages and the Golden Age. Famous Dutch painters such as Rembrandt drew sketches on hemp made paper [78]. During the second world war, hemp cultivation was stimulated by the authorities as fibers could be used for soldier uniforms and tents. Alternative fibers such as cotton, sisal and jute could not be imported during this time, therefore hemp had little competition. After the war, due to the reoccurred import of other fibers and the Opium act*, hemp was oppressed from the market. When synthetic fibers were introduced, hemp had almost disappeared from Europe [78].

Box 1. Elucidating the difference between hemp and marijuana

Hemp is often associated with narcotics. However hemp for industrial purposes and marijuana differ significantly. Both types of hemp belong to the same species (Cannabis sativa L.) but are different cultivars [42]. Hemp for marijuana contains high levels of tetrahydrocannabinol (THC) that provoke several psychological effects known for drugs. THC levels are usually defined in a percentages of the psychoactive substance Tetrahydrocannabinol per weight of the leaves and flowering part [35]. The levels of THC in marijuana fluctuate between the 3-15% whereas THC levels in industrial hemp have to be lower than 0,2-0,3%. Therefore industrial hemp is absolutely useless as a narcotic. The production of marijuana requires unfertilized female flowers [10]. Therefore, hemp for narcotics cannot be grown in a field with industrial hemp because that requires the presence of male flowers.

Different from the Netherlands, Spain and France never prohibited the cultivation and processing of hemp for paper. During the 90s several European countries** legalized the production of hemp [66]. The European Union established laws for regulating *delta-9-tetrahydrocannabinol* (THC) levels in hemp and composed a list with cultivars that were allowed to be used for cultivation [79].

1.2 Hemp applications

Hemp fibers

Every part of a mature hemp plant can be used [78], but in Western and Northern Europe hemp fiber is usually the main reason for cultivation [66]. In 2010, 55% of the hemp fibers produced in Europe were processed in pulp and paper, that was almost completely (90%) further processed in combination with flax in the cigarette industry. Insulation material (25.9%) and biocomposites (14,4%) make up the bigger part of the remaining hemp fibers [9]. Biocomposites are made of biopolymer matrices, consisting of e.g. cellulose esters, reinforced with natural fibers such as hemp [84]. Hemp biocomposites are biodegradable, lightweight and low cost [51] and form a sustainable alternative for glass fiber [84]. Almost all hemp biocomposites (96%) are used for moulding in

* The Opium Act was introduced in the Netherlands at the 12th of May 1928 [54]

** The United Kingdom (1993), The Netherlands (1994) and Germany (1996) [66]

automotive applications [9]. Next to pressing fibers for biocomposites, other techniques have been developed to manufacture objects with a higher quality, such as Resin-Transfer-Moulding (RTM) and injection moulding. RTM is used to produce products for furniture and yachts. Moulding is a process used to manufacture objects by shaping plastic on a rigid frame[12] and is employed in the production of urns, trays for grinding discs and applications for the automotive industry [9]. Hemp fibers are robust, have a high absorbance capacity and contain high amounts of hemicellulose [22]. The latter increases breathability and thermal regulation [22], making hemp an interesting crop for the textile industry. For now, only a small amount of hemp fibers is used for textiles [9] and is produced with the same techniques as for linen [78]. Because of its light weight, hemp is an interesting fiber for the fabrication of particle boards [9,78] and parts for the automotive industry [56].

Hemp shives

Shives are the woody core part of hemp stems [4]. One kilogram of hemp fibers is accompanied by 1,7 kilograms of hemp shives [9]. Although about half the value of fibers, hemp shives are a nice by-product with many applications. Shives are particularly suitable for animal related bedding material because of the high absorbance ability of four times their own dry weight. In addition, after usage, the material can be degraded to excellent compost by rotting [9]. Hemp shives are also used in construction work in combination with lime. This mixture has already been applied in private houses in the United Kingdom, France and Ireland. Other applications of shives are generating heat and electricity by incineration [9].

Hemp seeds

In Southern Europe, hemp can be grown for seeds because the growth season is longer and warmer than in the temperate areas, including the Netherlands [66]. However, in most cases hemp seeds are a by-product of hemp grown for fibers. Hemp seeds are mostly used as a whole in stock feed and to a lesser extent for oil. Hemp oil can be processed into paint, ink, lubricating oil and sealant. Hemp oil has the advantageous quality of drying quick due to linolenic acid and helps penetrate surfaces [2]. In addition, hemp oil can be processed into cosmetics such as shampoo [9] and is a popular food because of the high level of omega-3 fatty acids [78]. When dehulled, the seed is mainly sold as human food [9].

Hemp wood

The woody parts of the stem can be used in sheds as ground covering to prevent weed growth, soil dehydration and mud forming. Hemp wood can also be pressed in grains, which can be put in cavity walls for isolation [41].

Previous paragraphs only presented a selection of hemp applications. Image 1 shows a more comprehensive overview of the possible applications of hemp.

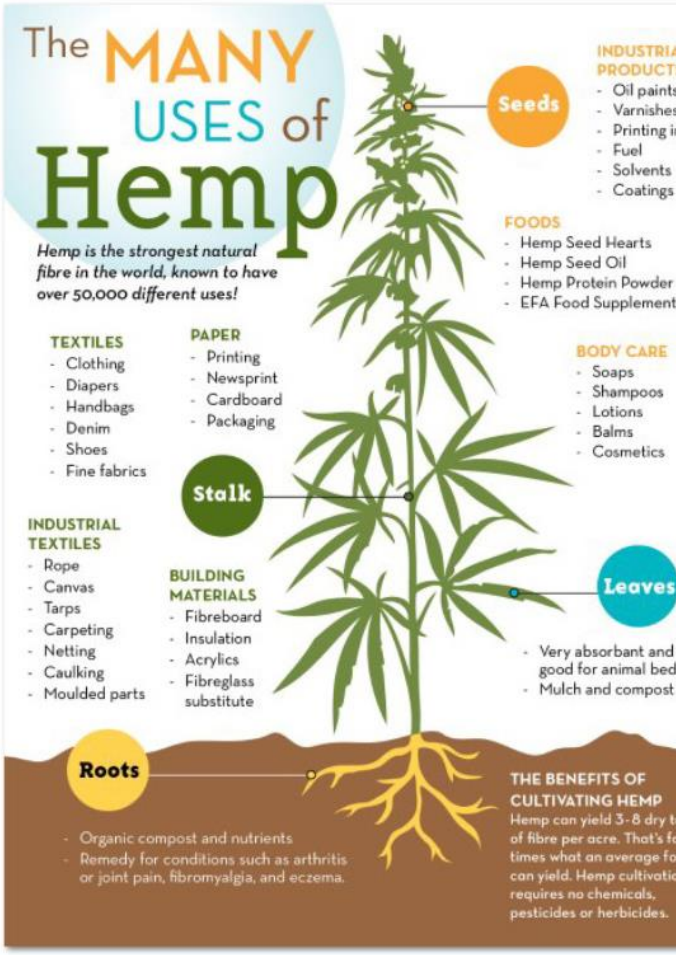


Figure 1. Hemp applications. Spears, M. (2014) What can industrial hemp be used for? Retrieved July 16, 2014 from http://www.hempinformer.com/can-

1.3 Hemp cultivation and harvesting

In terms of cultivation, hemp has a relatively high number of advantages in comparison to other crops. Hemp grows best in temperate climates [71,78], whereas cotton, one of the biggest competitors of hemp, does not endure most European climates. In addition, because of the deep and fine root system, hemp requires little water. No chemical fertilizers and no chemical products for pest control or plant protection are needed for the cultivation of hemp [78]. Some pathogens are known to infect industrial hemp [*], however significant yield loss due to infection is not common [23]. Because of the fast growth rate and density, weeds stand little chance of growing in a hemp field [66,71]. Rotating after hemp cultivation is not needed but is useful because hemp roots improve the soil structure and replenish carbon levels [71]. Due to this list of benefits, hemp is an excellent crop for sustainable agriculture[71,78].

Natural hemp is dioecious. For fiber production, female plants are preferred over male ones because of their prolonged lifespan and significantly higher fiber quality. Nonetheless, male plants are needed for breeding. For agricultural purposes several hemp cultivars have been developed, both monoecious and dioecious. The advantage of monoecious cultivars is a smaller diversity in quality of the fiber [66] because no male plants are required [82].

Selection of a hemp cultivar and the manner of sowing depend on the purpose of the fiber (clothing, construction material or animal related purposes) or the seed (breeding, oil or food). When cultivated for fibers, the plants should be sown at high density, maximizing stem length [66] and discouraging branching and flowering [42]. When the purpose of the plants entails both fibers and seeds, they need to be planted further apart [66]. Hemp is a fast growing crop taking 70 to 140 days from sowing to harvest [42]. Hemp grows poorly on acidic soils. Soil pH above 6.0 is favored and the best result is obtained at a soil pH between 7.0 -7.5 [2]. Applying fertilizer (nitrogen, phosphorus and potassium) enhances leaf and stem development. Organic fertilizer is very well suitable for industrial hemp [14] and optimal compositions of fertilizer are being investigated [69]. Only a few diseases (*Sclerotinia sclerotium, Botrytis cinerea*) and pests (Bertha armyworm, grasshoppers) are known to infect industrial hemp. Diseases can be coped with by sowing non-infected seeds, rotating with non-susceptible crops or applying hosts [2].

Hemp can be cultivated as a dual-purpose crop, that implies that both fiber and seeds can be processed. First the seeds are harvested by cutting the top of the plants. After that the stems are harvested [14]. Harvesting hemp brings along several difficulties. The tough fibers complicate the cutting of the stems and the height of the stems make harvesting a challenge [14]. Furthermore, when fibers are grown for textile related purposes, the long fibers cannot be broken during harvest [2]. Lastly, the moment of harvesting needs to be determined accurately. The moment to harvest hemp for fibers is between flowering and seed formation, immediately after the last pollen is released [14].

1.4 Hemp processing

The hemp plants are often left on the field after harvesting to undergo the process of retting [39]. Retting is a microbiological process that puts into effect the degradation of pectin in the stem [14], therefore separating bast from stem [66]. After a short drying period of 4-6 days, the stalks are sometimes put into water, snow or dew for water retting. This second period takes 10-15 days, optimally with temperature conditions of 15-20°C. Hereafter the plants are dried again and subjected to breaking by machinery [5].

After retting, the hemp fibers need to be further refined in order to improve the separation of woody parts from the fibers. The better the parts are separated, the higher the quality [39]. In the next processing step, the larger fiber bundles are opened and smaller fibers are detached. Modern technics allow processors to produce four different quality fibers. From low to high quality these are: fibers for paper and pulp, fibers for isolation,

[*] Personal communication with dr. ir. L.M. Trindade, July 3, 2014

technical fibers e.g. for automotive applications and textile fibers. HempFlax, one of the two hemp growing and processing companies in the Netherlands, states that the best fiber is obtained when the woody core of the stem is fully removed from the bast fiber. HempFlax has developed their own machinery for this process. The technical fibers from HempFlax are processed into non-woven materials in weaving machines in Germany. Woody parts of the stem are made dust free and packaged [39]. Another result of the optimization of this process is that HempFlax, for now is the only company in world producing hemp fibers for textile production [39].

Here, three processing technics for separating fibers and bast are discussed: alkali treatments, steam explosion and enzymatic separation. Raw hemp bast layers contain cellulose (67.0%-78.3%), hemicellulose (5.5%-16.1%), pectin (0.8%-2.5%), lignin (2.9%-3.3%), fats and waxes (Batre, 2007 as reviewed in [83]). Lignin acts as an adhesive for cellulose. Fiber quality is enhanced when the level of lignin is lowered because of possible degradation due to instability of this component after processing into biocomposites [57]. During enzymatic separation of bast and fibers, enzymes are deployed to dissolve pectin [28]. In alkali treatments, both pectin levels as lignin and hemicellulose levels are decreased. Lowering these components ameliorates the separation process of woody parts and fibers [57]. Removal of lignin and hemicellulose, creates space for cellulosic chains to rearrange, creating stronger and less rigid fibers that have a better load distribution (Sarkar, Mazumdar, & Pal (1948) and Mukherjee, Ganguly & Sur (1993) as reviewed by [34]. Alkali treatments also improve fiber strength by impacting crystallinity and the degree of polymerization [34].

Only the long high quality fibers are suitable for the textile industry (Baudoin, 2004 as referred to by [71]). Obtaining these fibers from raw material requires additional technics such as steam explosion (STEX) [71]. In this technic, raw fibers undergo the process of alkalization and are then treated with saturated steam under high pressure [45] (10-12 bar) and a temperature of 180°C [74]. Pectins are hydrolyzed during this process [78]. After ten minutes, the pressure is abruptly decreased and the steam explodes when the fibers are blown into a cyclone [71]. Within this step fiber bundles are divided into finer fibers with a length of 50mm [74]. These short fibers can be further processed on spinning machines used for cotton. The STEX technic is not new but has been improved several years ago by the 'Institut für Angewandte Forschung' in Reutlingen. Steam explosion is not yet implemented as commercial hemp processing technic [74,78], mainly due to the price [13].

Two technics focussed on obtaining high quality fibers are the Crailar Process developed in Canada, used to prepare fibers for the textile industry, and the ultrasonic processing technique that fabricates high-grade technical fibers, developed by the ecco Group Company in Germany [27]. Both processes have recently been commercialized.

1.5 Spinning and fabrics

In the current textile industry, hemp is combined with cotton (50%) when spun. The combination makes the yarns suitable for the cotton spinning machines. A lower spinning velocity is needed for the production, resulting in a production process slightly lower as known for cotton. However the woven fabric that is produced provides high quality denim and furnishing fabric. Hemp fabric is highly abrasion resistant and quick in taking up moisture. In clothing this is an interesting quality concerning perspiration discharge [74]. Scientists aim to produce 100% hemp fabric [74,78].

1.6 Hemp as a substitute for plastic

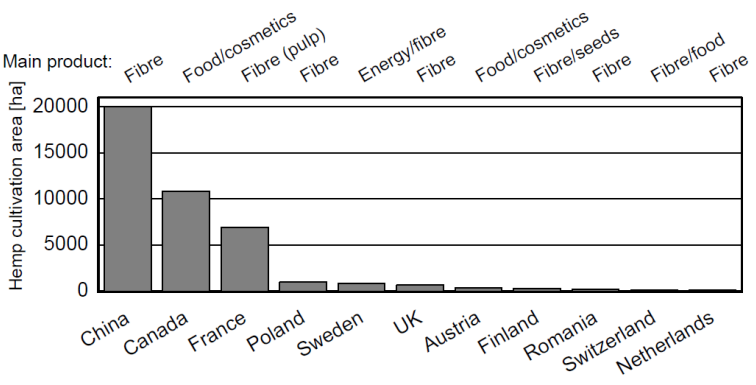
Natural fibers can be embedded in biodegradable polymers from renewable resources. Several bio-polymers derived from natural products such as soy, cellulose, starch and bacterial polyesters, have been developed into plastics. Hemp is one of the bio-fibers suitable for the combination with polymer matrices to form bio-composites. Bio-composites are mostly used as a substitute for glass fiber and in automotive and building industry [52].

Chapter 2. The hemp market

Because the Dutch hemp market is small [*RW.ERROR - Unable to find reference:216], *the European and worldwide hemp production is discussed by means of import and export numbers and legislation in different countries. Statistical data is mostly obtained from FAOSTAT and the EIHA.*[**]

2.1 The global hemp market

Hemp cultivation is currently permitted in more or less 30 countries worldwide. In 2011, around 200,000 acres of hemp were cultivated worldwide. The global production of hemp fibers and seeds raised from 250 million pounds (€308.825.000) in 1999 to 380 million pounds (€469.414.000) in 2011 [42]. This raise in market value can be ascribed to increased seed production [42]. In graph 1. an overview is presented for the largest hemp producers worldwide. As can be seen, the Netherlands represent only a small proportion of the world hemp production. In the following paragraphs the largest producers of hemp (China) [32], the largest importer of hemp (the United States) [37] and the largest exporter of hemp seeds and oilcake to the US (Canada) [35] are illustrated.



Graph 1. Overview of the largest hemp producers globally. Prade, T. (2011) Industrial Hemp (*Cannabis sativa* L.) – a High-Yielding Energy Crop. Retrieved July 16, 2014 from

China

China is the largest supplier of industrial hemp in the world [32]. In 2012, China produced 50.000 tons of hempseed, accounting for nearly 38% of the world production [85]. Hemp in China is widely used as a component for medicine and food and the major part (80%) is used in the textile industry [85]. Towards the end of 2013, China had already exported 591 tons of hemp yarn ($11.9 million) and 840.000 meters of woven fabrics ($5.16 million) [85]. The main export countries for hemp yarn and fabric are East and South East Asian countries. At the moment, there are no statistics on the export of food and medicine [85].

U.S.

Because cultivating hemp is not possible due to strict legislation, the U.S. mainly depends on import [35]. Both unprocessed hemp as finished hemp products are imported. The former shows a significant increase: compared to 2007 ($4.987.000), the import value of unprocessed hemp was more than doubled in 2011 ($11.494.000) [42]. Unfortunately, no data is available on finished hemp products. The value of the total U.S. retail is estimated to be at least $581 million by the Hemp Industries Association (HIA) [38]. Retails sales include food, body products, construction, automotive and textile applications [29,42]. China is the main source of both

[*] Personal communication with K. Dun, June 26, 2014

[**] FAOSTAT (Food and Agriculture Organization of the United Nations) has the largest database, containing information on agricultural production and trade. A large amount of data is available for hemp and other natural fibers. However because non-cannabis fibers with misleading names such as manila hemp and sisal hemp could influence cannabis production and trade numbers (Schnegelsberg, 1996 as referred to by [59]). Therefore when referring to producers and trade within the European Union, when available, data from the EIHA (European Industrial Hemp Association) is used. Data from the EIHA is expected to be more reliable due to their close connections to farmers and processors.

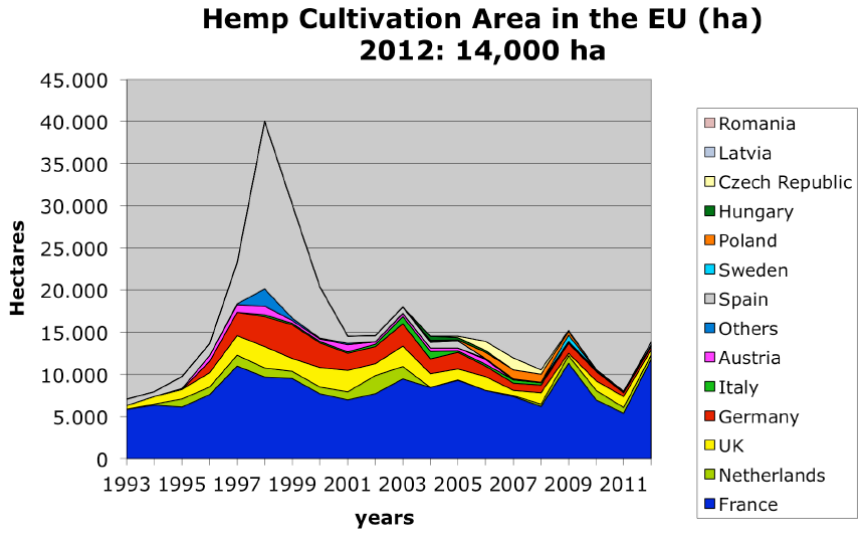
processed and unprocessed hemp products for the U.S. India and European countries including Hungary and Romania also provide the U.S. with hemp products. Canada is the largest supplier of oilcake to the U.S and since 2004 also exports hemp seeds. Switzerland and United Kingdom also export oilcake and hemp seeds to the U.S., but to a lesser extent [42].

Canada

In Canada, laws that permitted the cultivation of industrial hemp were not lifted until 1998. At present, farmers have to deal with strict legislation and control and need extensive documentation to obtain a license [35,42]. Industrial hemp may contain a maximal THC level of 0.3%. Furthermore, Canadian food products may not contain more THC residues than 10 parts per million [35]. Despite of the strict policy, the government supports growers in facilitating regulations and funding to establish market development [2]. In 2011 almost 40,000 acres [42] were cultivated with hemp, primarily in center and the West of Canada [35]. Nowadays, hemp is grown by more than 100 farmers in Canada. Because of the advantageous climate in Canada, the export (876 tons, $3.183.812) was more than double the import (363 tons, $488.669) in 2007. Most of the Canadian hemp products (59%) is exported to the U.S [35].

2.2 European market

In the European Union (EU), France has the highest hemp production [60]. Previously, Germany had a large hemp production, however due to land competition for biofuel crops, a great part of the production was moved to France [9]. Countries within the European Union annually cultivate between 10.000 to 15.000 ha hemp cropland [9,42]. Consumption in Europe was 17.900 tons, including the import from China [7].



Graph 2. Acreage of hemp cultivation in the European Union. Source: Ronde (2013)

Since 1970 the European Union has supported the hemp and flax industry with subsidies which were part of the Common Agricultural Policy (CAP)[66]. This financial support had been established to enable hemp farmers and processors to compete other natural fibers [15]. As can been seen in graph 2., the cultivated area in the European Union peaks in 1998. In Spain this peak in hemp production was a result of subsidy swindle [43]. This case caused negative publicity for the fiber industry and the subsidies were adjusted to prevent further misuse (HempFlax, 2005 in [66]). From 2012 hemp processors within the EU are nog longer supported and farmers now receive support for cultivation regardless of the crop they cultivate [66]. The current situation concerning the European agricultural subsidies is further elaborated in chapter 3.

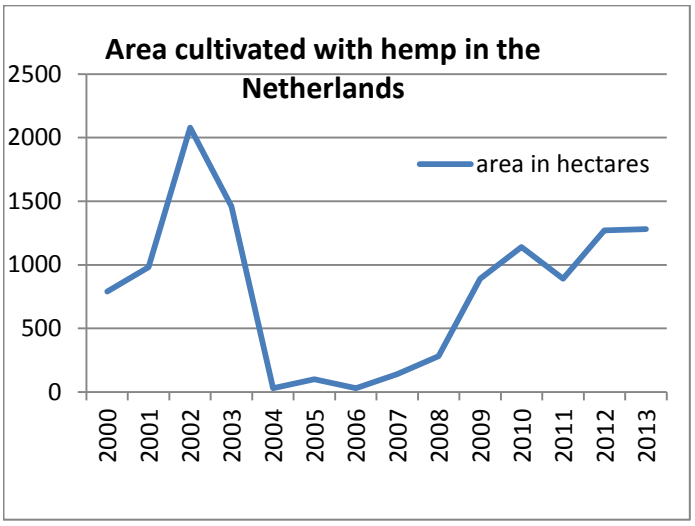
2.3 Dutch market

In 1993, HempFlax was founded and reintroduced hemp in the Netherlands with the cultivation and processing of 140 hectares. Because the crop had not been cultivated for 50 years, technical devices had to be customized to meet the industrial demands at the time [39]. As can been seen in graph 3., in 2004 a dramatic drop in hectares occurred because HempFlax was compelled to end contracts with farmers [15,40]. In the same year

another processing company, Dun Agro, was founded. After some years the processing and cultivation market grew again. In 2013, an area of 1284 hectares was cultivated with hemp [66]. Nowadays, the Netherlands hold only these two commercial hemp processing companies [66]. It was estimated that HempFlax and Dun Agro had the capacity to process around 4000 hectares. However, only half of this potential is reached (Berg, 2003 in [66]). Table 1. shows this year's processing data provided by both hemp processors.

Currently most Dutch hemp fibers are used for paper and interior car parts, while hurds are made into animal related bedding material [66].

In 2012, a new machine was brought into use by Dun Agro. With this machine hemp leaves can be separately harvested from the stems. Harvesting leaves separate from the stems has some advantages. Energy costs decrease, harvested straw is cleaner without the leave material and less residual waste is produced. The leaves can be used for example for livestock feed. With the new harvest technique Dun Agro hopes to overcome the loss of income from European Agricultural subsidies [43].



Graph 3. Number of hectares cropland cultivated with hemp in the Netherlands. Data obtained May 26, 2014 via CBS.nl: http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=81302ned&D1=67,126&D2=a&HDR=G1&STB=T&VW=T, based on Ronde (2013)

Table 1. Processing data from HempFlax and Dun Agro, provided by means of questionnaires. This information applies to the year 2014.

	HempFlax	Dun Agro
Number of hemp growers associated with HempFlax and Dun Agro	+/- 40	42
Site of cultivation	The Netherlands, Germany Romania	The Netherlands, Denmark
Plant parts processed	Fibers, flowers, leaves, seeds	Fibers, leaves

Chapter 3. Factors influencing the hemp industry

Eight factors have been identified that have a stimulating or deteriorating effect on the development of the hemp industry. The factors are connected to one another. (1) ***Subsidies*** *provided by the European Union, allow low-cost production and processing of hemp and therefore lowering the (2)* ***price*** *on the market. Low prices provide hemp an opportunity for (3)* ***competition*** *with other natural fibers and for available cropland, which has an influence on the steady (4)* ***supply*** *of raw hemp by farmers. The* ***demand*** *for hemp can be raised by creating new niche markets and (5)* ***managing*** *applications of hemp, for example by (6)* ***breeding*** *new cultivars of Cannabis or increasing fiber quality by altering* ***treatments****. With breeding technics, lower THC levels can be obtained that may result in eliminating the ban on hemp cultivation in countries such as the U.S. and a subsequent rise in the hemp market. In addition, lower (7)* ***THC levels*** *improve the* ***image*** *of hemp, as will the (8)* ***sustainability*** *aspect of hemp. In order to make Europe more green, sustainability subsidies for crops, including hemp are offered.*

3.1 Subsidies

With support from the European Union farmers and processors of hemp fibers were able to compete with cotton and synthetic fibers at the European industrial market and with flax from the USSR [15]. In the beginning subsidies up to 450 euros were provided per hectare of sown hemp, regardless of the yield. Farmers received 50% of the premium directly while the other 50% was channeled to the processors. As mentioned above, Spanish farmers misused the subsidies by planting seeds without harvesting or even by burning down the fields with hemp [66]. Hereafter regulations changed and to receive a subsidy, farmers had to contract a processor. Since 2001-2002, processors were provided with an extra 90 euros per ton of processed fibers and subsidies were now linked to local grain yield [66]. Hemp subsidy and grain yield were decoupled again in 2006 [15,66]. In 2012 the processing support ceased resulting in a significant loss of income for processors including the Dutch companies HempFlax (€72.305) and Dun Agro (€52.993) (Dienst regelingen in [66]). The subsidy for farmers changed in that the premium is no longer pegged to hemp production but is a fixed premium irrespective of the crop that farmers grow (a single payment system [11]. This development does not encourage farmers to cultivate hemp [66]. As a consequence farmers will consider alternative crops like grain because of the high sales price. This hinders the startup of a successful hemp market [15,66]. In order to make a smooth transition towards a single payment system, the European Union made €930.000 available for Dutch fiber crop growers. Hemp and flax farmers divided the financial support and received a maximum of €300 per hectare in 2013 and €270 per hectare in 2014 [64].

The EU financially supports green agricultural initiatives in order to create a more sustainable European Union. The hemp industry can benefit from this support but it also brings along competitors. Biofuel and bio-energy crops receive a higher amount of support from the EU [9] and therefore competition for cultivation area is increasing [27]. This problem is discussed in more detail in the paragraphs 3.3 and 3.8.

3.2 Price

The hemp price has been stable for a long time. Over seven years, hemp and flax short fibers showed an increase of only 10% in price [27]. In spite of the many applications hemp can be used for, effective application will depend on the price of cultivation and processing [55].

The price of hemp is determined by more factors than harvesting and processing. The following components for the most part constitute hemp sales prices:
(1) Cultivation: The costs for cropland, land preparation, sowing, fertilizing, irrigating, storage building and machinery for harvesting (cutting, retting, baling [32]), supplying fertilizer and the seed drying process. (2) Processing: breaking bast, spinning, seed dehulling, packaging, storing. In addition licenses and taxes are part

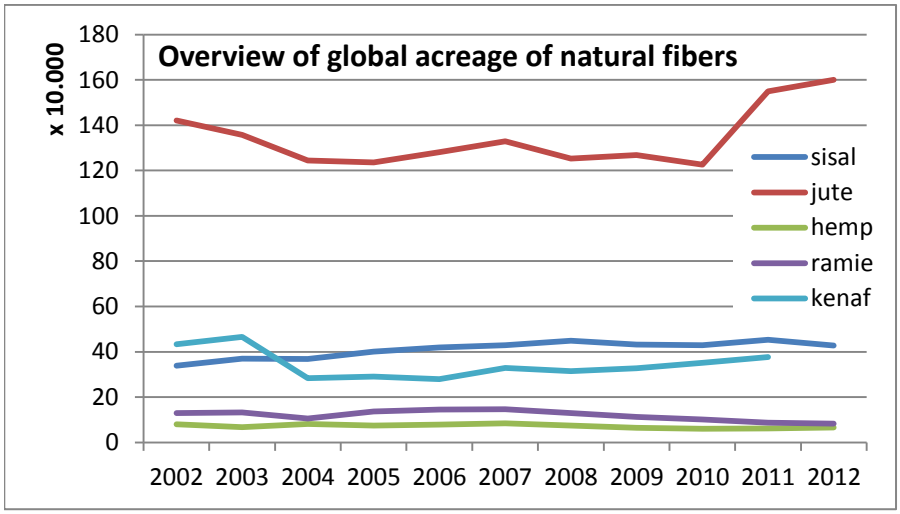
of the investment [1]. Transportation costs are also a main part of the production process because raw hemp is very incompact [66]. Transport costs are kept low by placing the processing process close to the fields. In the Netherlands, HempFlax has fields within a radius of 80 kilometers of the factory that provide them with raw material. HempFlax saves on harvesting costs by having their own machinery that can be maximally employed during busy harvesting months [*].

The hemp production can disappear from the Netherlands because of heavy subsidized crops for biofuel and energy [*]. The lack of hemp producers in th Netherlands, would result in higher prices, because raw material has to be imported from China and Eastern Europe. With more local suppliers, hemp will become more accepted and will accelerate the development of technologies to process and produce hemp (products) [67]. Therefore in order to retain low hemp prices, cultivation should not disappear from the Netherlands.

Finally costs for labor are still high. In contrast with the low maintenance during cultivation, labor requirements for processing are relatively high partly due to a lack of technical devices that can simulate the process of retting. Although, new technics are being developed such as steam explosion and ultrasound, it is still difficult to compete with low labor cost countries such as Romania, Poland, Hungary and China [23,32,76]. Steam explosion is not yet commercially implemented but could, when used on large scale, lower the price of hemp fibers by reducing labor costs [76]. Therefore, current research into improving the hemp industry focus predominantly on developing machinery for fiber separation [19] and processing [55].

3.3 Competition

Hemp is subjected to competition by several natural fibers. Here, competition is divided in two types: competition for available cropland and competition by alternative crops on the market.



Graph 4. Overview of hectares cultivated with natural fibers worldwide. Kenaf also includes allied fibers. No data was available for kenaf and allied fibers in 2012. Data source: FAOSTAT (n.d.), International jute study group (n.d.)

Graph 4. presents an overview of natural fiber acreage. It can be seen that within this comparison jute is the most cultivated natural fiber and hemp the crops with the least acres. This distribution is not a result of cropland competition. Table 2. shows that most natural fibers are not cultivated in Europe, except for flax. In Europe, instead of competing for land with natural fiber crops, hemp has to face competition by flax and crops for biofuel and bio-energy. Because the latter are heavily subsidized, farmers are encouraged to abandon their regular cultivation routine. It is expected that competition between biofuel and energy crops on the one hand and food and natural fibers crops on the other hand, will intensify [68]. This may result in the loss of hemp cultivation in the Netherlands [*].

Hemp is not the only crop struggling with land competition. Jute and kenaf also have to compete with crops for other purposes. Sisal on the other hand can be cultivated in very dry regions in Africa and South America which are often unsuitable for other crops and therefore experiences less competition [31].

[*] Personal communication with M. Reinders, June 12, 2014

Marketwise, natural fibers certainly are competitors because of their overlapping applications. Especially jute's qualities are very similar to hemp (low heat conductivity and good insulation) as are the applications (textile, particle boards, pulp and paper) [31]. In comparison in terms of fiber quality, hemp has an advantage over most natural fibers. Hemp contains high levels of cellulose and low levels of lignin. Removing of lignin is high energy demanding, so the low lignin levels of hemp are beneficial. The high cellulose levels makes hemp very useful for pulp and paper fabrication [67]. Furthermore, hemp, flax and ramie (bast fibers) have the strongest and stiffest fibers among natural fibers [70], resulting in high quality fibers. Thus, in terms of strength, bast fibers surpass leaves and seed fibers.

Table 2. Inventory of the cultivation areas of the most competitive natural fibers for hemp. Adjusted from: FAOSTAT (2012)

Natural fiber	Area cultivated
Sisal	Brazil, East Africa, Haiti, Venezuela, Antiqua, Kenya, Tanzania, India
Flax	Poland, Belgium, France, Spain
Hemp	Poland, China, Hungary, France, Romania
Ramie	Honduras, Mauritius Islands, China
Jute	India, Egypt, Guyana, Jamaica, Ghana, Malawi, Sudan, Tanzania, Brazil
Kenaf	Iraq, Tanzania, Jamaica, South Africa, Cuba, Togo, USA, Thailand

Marketwise, hemp's largest competitor is cotton. Cotton is characterized by very high cellulose levels [30] and therefore very suitable for some applications such as membranes for medical uses that require (almost) 100% cellulose. Hemp cannot match this high level of cellulose and will therefore not be a competitor for cotton on this field. In addition, cotton is the most used fiber for the textile industry, nonwithstanding several non-practical qualities: cotton can only be cultivated in sub-tropical regions and requires vast amounts of water and chemical treatment [22]. Therefore, alternatives are searched for on a large scale. According to Ebskamp hemp and flax are promising alternatives for cotton textiles [22]. Next to natural fibers, hemp has to compete with synthetic fibers. Synthetic fibers have been applied for almost every application which was previously employed by natural fibers. The main reason for this is the cost effectiveness of these fibers. Despite the success, people are becoming more skeptical on synthetic fibers, because of their lower physiological and hygienic properties and absent ability to be naturally degraded [65] and predominantly their non-sustainable nature. Additionally, hemp must compete with natural fiber import into Europe. As Carus *et al.* (2013) mention, Europe has no protection for the import of alternative fibers, from low-cost production countries predominantly from Asia. These countries have lower environment and social standards, which do not suffice the European regulations [9].

Finally, hemp does not only suffer from competition for fibers, but also on oil seeds. Two of hemp's comeptitors are soy bean and linseed [2]. Industrials mainly constitute from linseed oil because it dries rapidly. Hemp oil has similar properties and therefore can only compete with linseed oil in terms of price [2].

3.4 Supply and demand

Many aspects need to be taken into account before statements can be made about hemp supply. Because the hemp market is small scale, hemp is mostly sold on niche markets and supply has a major influence on the price of hemp. Therefore, to maintain profitable prices, supply should never exceed demand [2]. The hemp market should be conscientiously increased in order keep supply and demand in balance[35]. Furthermore, steady supply depends on contracts and mutual trust between growers and processors. When growers prove to be able to grow high quality plants and deliver on time [2], processors need to purchase the agreed amount of raw material and search the market for sales potential. According to the ministry of Agriculture and rural development of Alberta, Canada, reaching the market is best be done by offering a steady supply of high quality hemp products. As mentioned in the previous paragraph, in Europe providing a steady supply is

hampered by cropland competition with heavily subsidized biofuel crops. Hemp supply could expand when more customers are willing to spend extra on hemp textiles. This would motivate processors to invest in additional technology to produce textiles on a larger scale for a lower price [2].

Next to biofuel and bioenergy crops, hemp has to compete with the more traditional crops in the Netherlands. Maize and wheat were mentioned as important competitors in the research by Ronde [66] that investigated what factors farmers include in considering which crop to grow on their land. It was mentioned that the farmers crop choice depends on sales price and marginal costs. Therefore, based on the article by de Wolf, van den Brink and Spruijt (2012), Ronde [66] elaborated investments such as harvest labor, fertilizer and farm sizes. For now, hemp farmers can profit from low organic fertilizer prices but sales price remains a major part of the growers income. Because supply is unstable, processors cannot afford to lower hemp straw prices and the supply of hemp stays unstable [66]. This makes it difficult for processors to find farmers that are willing to grow industrial hemp.

The demand for hemp is increasing because of hemp interesting properties. It is reported that in China the demand for hemp increases because of hemp's odor neutralizing and antibacterial effect, fast-drying and moisture absorbing properties (Xiaoyan, Yingting, & Guiqing, 2001 as referred to by [87]).

In the Netherlands, hemp products are available on small scale in minor retail stores and web shops. These products are mainly sold as clothing made with respect for the environment.

3.5 Management and development

By introducing new possible applications, hemp can become more interesting. During the 11th annual International Conference of the European Industrial Hemp Association (EIHA) new applications were presented [7]. One of the new applications was the following: Next to THC, hemp contains another interesting byproduct, Cannabidiol (CBD). This cannabinoid does not, in any dose, induce psychotropic or other side effects. Concentrations range from 0,5 to 2% and can be extracted from the upper part of the plant in the flowers, leaves and stem. CBD can be obtained from industrially cultivated hemp plants. Per hectare of industrial hemp, 3 kg CBD can be collected. CBD is a promising component of hemp in the treatment of numerous diseases, including epilepsy, diabetes, cancer, skin diseases, some anxiety disorders and more. The price for CBD as a pharmaceutical, ranges from €20.000 to €30.000 per kg. In the U.S. a large number of products with CBD are already available, which include dyes, oils and chewing gum [7].

Additionally, hemp can be used to produce energy. The article by Prade, Svensson and Mattsson (2012) sums up the many functions hemp has in generating energy: heat, electricity, fuel and ethanol. Prade *et al.* (2012) highlight that hemp has a high or even higher potential energy yield in comparison to energy crops that are also cultivated in northern Europe e.g. maize and sugar beet for biogas and reed canary grass for biofuel production [61,62]. Regarding to energy gain, it was found that hemp had the highest net yield and output-to-input ratios when compared to similar crops. In the production of biogas, hemp has less convincing results, but provides a high quality. However, according to Prade *et al.* (2012) improvement can be made with upgraded pretreatments of the fibers using steam explosion [44] and possibly enzyme treatments [62].

A trend in customers demand for green building can be clearly observed. However most buildings are still build in the old fashion way while these buildings are the largest emitters of greenhouse gasses in the world. Traditional buildings account of 30% of the emission of carbon dioxide and are responsible for the use of 40% of the world's energy [21]. Therefore building with hemp is another application. Hemp is made into "hempcrete"; concrete made of hemp shives and lime [4]. Building with hemp is a bit different than with concrete. A wooden or stale frame is needed to support the hempcrete, while concrete is its own building material. However this has the advantage that hemp walls can be easily constructed in a factory and then transported to the building site. One saves on both building time and costs because the time the hempcrete needs to dry does not

interfere with other building activities [46]. Hempcrete holds interesting properties for building material. Next to thermal insulation, as mentioned in chapter 1, hemp as concrete also has excellent acoustic insulation (Arnaud L. as reviewed by [24] and fire resistance [20]. An ecological interesting property is that the lime binder can reabsorb much of the emitted CO_2 during its life time, converting it to limestone. Compared to a typical brick house, hempcrete emits 30-40% less CO_2 [24]. Furthermore, hemp also has the capacity to regulate humidity within a building according to local air conditions [24]. However some problems have occurred during the development of hemp concrete. Because of hemp's high absorption potential, excess water is needed for the fabrication of hemp. As a result, the drying process took a few months, more time than acceptable in the building industry. A new projection process has been developed to overcome this and more problems [24]. Hempcrete is already available in the U.S (e.g. American Lime Technology) and in the Netherlands (Dun Agro). Many hempcrete houses are now build with prefab components [4,20], which speeds the building process and reduces the price of a hemp house [20].

3.6 Research and development

Yield, fiber quality and efficiency of processing can be enhanced by respectively research into breeding specific cultivars, adjusting chemical treatments and developing new machinery. In the following paragraphs a short overview is provided on hemp research and development in the hemp sector.
Breeding programs have already brought the hemp industry two major developments, namely monoecious hemp cultivars and hemp cultivars with a low THC level [72]. As shortly discussed in chapter 1., monoecious cultivars produce a more steady quality yield when compared to dioecious plants. Yield from monoecious plants can be processed into material with a higher quality. With THC level regulations becoming stricter, new cultivars should keep the low THC levels [22] or eliminate THC at all. Wageningen University has developed several hemp cultivars with THC levels below the recommended level of 0,3%. Although THC is a secondary compound involved in plant protection, the plant still seems to be adequately protected by other cannabinoid compounds [*RW.ERROR - Unable to find reference:212]. With absence of THC, is not unlikely that more countries will allow the cultivation of industrial hemp.

Breeding programs now focus on enhancing hemp yield, fiber quality and cellulose composition [22,63,72]. Until 2001, the European Union regulated the moment of harvesting (Ienica, 2002 as referred to by [6]). After removing these regulation, there was a lack of knowledge on the optimal growth period and harvesting time. Current research investigates the importance of growth schedule of hemp. The time of harvesting seems to have major influence on fiber quality for example in cellulose level [75]. Next to planning the growth season, hemp cultivars need to be chosen carefully with respect to the region. The corresponding photoperiod of a cultivar needs to suit the hours of daylight to guarantee the highest yield. Bast fibers have a higher quality than core fibers, therefore cultivars with a high bast:core ratio are preferred [75]. With more research into the photoperiod response and maturation time, even better performing cultivars can be bred [75].

Fiber quality can be defined in fiber length (for textiles) and strength (for building material and bio-composites). Alkali treatments are investigated to further enhance fiber quality and adjust the treatment for fibers meant for new applications. Because over-alkalization can negatively affect fibers, research is done to identify an optimal alkali solution [57]. Higher yield and fiber quality can also investigated at molecular level [22]. Genes can be identified that are responsible for certain cellular processes of gene expression. Next to fiber quality, levels of compounds such as Cannabidiol [7] or plant weight ratios, can be lowered or raised by breeding [7], chemical treatments and research into optimal growth period [57].

* Personal communication with dr. ir. L.M. Trindade, July 3, 2014

New machinery for hemp sowing, harvesting and processing is developed constantly to achieve higher velocity or capacity. An example of improved machinery is separately harvesting flowers and stems [*].

3. 7 THC level and the image

Unfortunately, hemp is still associated with psychoactive components in narcotics. However, as mentioned before, THC levels in industrial hemp differ enormously from those in marijuana. In the U.S. hemp cultivation has been prohibited since 1938 because of the potential threat to society. During a Single Convention on Narcotic Drugs by the United Nations in 1961, the North American Free Trade Agreement and the General Agreement on Tariffs and Trade made the distinction between marijuana and industrial hemp [48]. However, although hemp materials are imported in the U.S., the U.S. law does not allow the cultivation because in law the distinction between the plant species is not made [66]. The U.S. law is an example of the difficulties THC levels in hemp create. Although the EU is more tolerant towards industrial hemp, it still regulates the production of hemp materials with strict legislation. In 2001 the EU lowered the maximum allowed level of THC to 0,2% (European Union (EC 2860/2000)) [25,58], as a result well-established cultivars from Eastern Europe caused problems within the EU. Therefore new breeding programs focus on lowering the THC level while maximizing yield and quality would be a better way to sustain the crop [73].

One unfortunate attribute of industrial hemp is that it is morphologically indistinguishable from hemp grown for drugs [58]. However even without strict control, there is little probability that the illegal variant of Cannabis is grown among industrial hemp because cross pollination between the cultivars will severely decrease THC level making the plants useless as a drug (Roulac, 1997 in [86]). Furthermore, illegal or not illegal, cultivated hemp attracts enough attention by itself [86]. Permitting and supporting the growth of industrial hemp by the European Union may contribute to a more positive image of hemp [66]. Furthermore, processors and investors advocate hemp with frequent media reports on new, innovative applications of industrial hemp. The public's understanding is enhanced by constantly emphasizing the difference between low and high Cannabis cultivars [*]. Hemp's beneficial characteristics in terms of sustainability also contributes to a more positive perspective.

In 1998, paper with a small percentage of hemp fiber was sold in Europe and the U.S. In a bulletin from the Oregon State University it was mentioned that because of the ecologically aspect of the fibers (no trees were needed for the production), market acceptance was gained [23].

3.8 Sustainability

Although the European Union abolished the subsidies for conservation of fiber crops, there seem to be possibilities for other subsidies as a result of new priorities. The EU now prioritizes greening of the European environment and stimulates farmers and processors to produce more environmental friendly crops. Hemp would be very suitable for this because of the carbon storage in building material, no requirements for chemicals and the ability to use hemp as a rotation crops for multiple years reducing parasites [8]. However, crops for biofuels and bio energy will still receive more support [66]. The Netherlands are quickly shifting towards a more sustainable philosophy. Both the government sees the point in reducing carbon emissions and the use of fossil fuels as the Dutch citizens. In the Netherlands, many citizen initiatives have been elaborated. Two examples are several construction and real-estate companies that created a network organization that aims to build more sustainable buildings (Dutch Green Building Council) and a website that has an overview of plenty of sustainability projects in the Netherlands (Urgenda.nl). Furthermore, organic food is becoming more popular, including hemp seeds and oil. In 2011 the turnover of sustainable food in the Netherlands was 1.7 billion, an increase of 30,5% when compared to the year before [65].

[*] Personal communication with M. Reinders, June 12, 2014

It is often mentioned that hemp is a very sustainable crop and an interesting alternative for cotton and fibers from non-renewable resources in the textile industry. However, for now chemical substances such as NaOH are used to separate fibers and this process requires large amounts of water. With this in mind, here it is wondered to what extent hemp is and can be produced ecologically. According to [28] hemp fibers for textile purposes can be separated in an organic manner with steam explosion or enzymes. Enzymatic separation of fibers requires less energy than steam explosion and therefore preferred by [28]. The technic does not require much equipment and the separation process can be carried out close to the fields, minimizing transportation costs. Further research into this technic includes optimizing the composition of the enzyme mixture and researching the retting process by specific microorganisms. The technic has been commercially tested [19].

Hemp can lower pressure on natural resources and restore natural environments. Both Dutch hemp processing companies produce hemp wood. HempFlax indicates that this wood is further processed into paper, bedding and building material and thereby prevents unnecessary deforestation [39]. Furthermore, hemp can grow on soils polluted with heavy metals without lowering the fiber quality[47] and is therefore an interesting crop for bioremediation [71]. In the Netherlands, bioremediation is one of the most expensive components of the Dutch environmental policy, perhaps this is the reason it is only applied in several cases. Between 1997 and 2023, €19 billon is available for bioremediation [49]. Other crops have received more attention in recent research for bioremediation: *Brassica Juncea* L., *B. Napus* L., *Helianthus annuus* L. and *Zea mays* L. were most often included in research for bioremediation[77]. Hemp does accumulate heavy metals but not at a high pace. The bioremediation process is enhanced by cultivating hemp in a crop rotation model with hemp grown in the summer and e.g. Lupin in winter [33]. To conclude, hemp could be an interesting crop for bioremediation in the Netherlands [*] for the long term because growth and fiber quality are not negatively affected[36].

[*] Personal communication with dr. ir. L.M. Trindade, July 3, 2014

Chapter 4. The future of hemp in the Netherlands

In this chapter, perspectives are drawn for the future of industrial hemp in the Netherlands. Firstly, based upon the eight factors discussed in the previous chapter, it is discussed what development is in prospect for the global, European and Dutch markets. Secondly, it is questioned how Dutch farmers and processors will handle an increase or decrease of the market. Finally, by means of questionnaires, I captured the views of the Dutch hemp processors and dr. ir. L.M. Trindade, scientist from Wageningen University. The hemp processors HempFlax and Dun Agro clarified their point of view for the future and the development of the market. Trindade was contacted to elaborate the progress of hemp technics and breeding programs in the Netherlands.

4. 1 Overall market prospects

Due to the abolishment of hemp subsidies in the European Union, the price of hemp will rise and competition for land with biofuel and bioenergy crops will expand [66]. The price may further increase as a result of higher transportation costs and complicate competition with natural fibers sold for similar applications.

Hemp becomes increasingly known for its sustainable character and multiplicity of possible applications [*]. Hemp´s improving image may be the result of the EU encouragement and a U.S. farm bill [81] adopted recently that brought hemp growing closer to legalization. Constant research for improving technics [39], breeding better adapted cultivars and developing new applications helps improve quality [*] and obtain access to new markets, such as prefab units for the green building market [RW.ERROR - Unable to find reference:216**]. Due to ongoing research, hemp is expected to someday be a fierce competitor for cotton [22].

The global hemp market

Globally, the hemp market is expected to expand [7]. The sales market for technical fibers increases [27]. For the world leader in hemp production, China, future expectations are not that optimistic since some areas in China still associate hemp with drugs. Therefore, hemp marketing in those areas is difficult. Fortunately, China exports many hemp products to the U.S., Canada, Australia and Europe. Chinese hemp farmers and processors have to deal with the rising strength of the Yuan, institutional restrictions and stagnating national hemp prices. For now, Chinese hemp is not following the success of cotton. Possible, China's accession to the World Trade Organization in 2011, will soon cause improving results [85]. In addition to China, Canada has been steadily expanding the production as well for several years [3]. Whereas in in 2011, 80% of the hemp licensed acres was still used for seed production [3], the fiber producton is upcoming in Canada [7]. It was estimated that one third of the hemp seeds currently produced in Canada could be certified as organically produced [3]. During the annual EIHA international conference, experts foresee a sustainability certification for hemp. Which would made hemp the first natural fiber with such a certification [7] resulting in more positive attention and more sustainable image.

This year, the U.S. Farm Bill was passed allowing higher education institutions and state agricultural departments to grow industrial hemp for research [81]. This bill is or will soon be applied to thirteen states. According to Eric Steenstra, president of the Vote Hemp organization, this move allows the U.S. to regain the knowledge that was lost due to a 50-year ban on hemp cultivation. By now, thirty-two states in the U.S. have laws in favor of industrial hemp, including ten states allowing the cultivation of industrial hemp [81]. With the passing of the Farm Bill, the largest obstacle for hemp production in the U.S. [42] is overcome; however, the start-up phase will not be simple considering the competition by China and Canada. Fortunately, from import data can be concluded that the U.S. demand for hemp product increases [42].

[*] Personal communication with dr. ir. L.M. Trindade, July 3, 2014

[**] Personal communication with K. Dun, June 26, 2014

In the article by Johnson [42] it is stated that Canadian researchers still expect farmers to profit from the cultivation when hemp is legalized in the U.S. This is thought because of the multitude of applications possible for hemp and a rising demand in Canada [42]. According to the Agriculture and Agri-Food organization in Canada, the sustainable benefits that characterize hemp, meet the preferences of the North American customer. This positive view is further supported by the high interest by farmers and processors and an excellent climate for growing hemp [35].

With U.S. also gradually legalizing industrial hemp producion, it is expected that hemp seeds and fibres will reach higher levels than ever. With growing worldwide attention, hemp will be more attractive to globally active business' inlcuding the automotive industry [7]. In 1996 only 400 tons of industrial hemp was used in the automotive industry. In 2000 this number increased to 17.140 tons (Plackett as reviewed in [57]). Between the year 2000 and 2005 the automotive applications of natural fibers including hemp increased significantly. However, after a four year period of little growth, the demand for natural fiber reinforcement for interior parts by the automotive industry increased again. This was possibly the result of enhanced material quality, the rising interest for bio-based and lightweight materials and decreased costs for compression moulding [27]. Car manufactures became interested in developing 100% bio-based cars totally made of hemp, as can be seen in image 2. Displaying the applied bio-based materials in cars, became into fashion [27]. Nowadays, hemp fibers are especially interesting for the automotive industry because of its light weight [56].

Figure 2. The Krestel, car from Canada totally made from hemp. Source: Walia, A. (2013) retrieved June 12, 2014 via: http://www.collective-evolution.com/2013/11/01/the-worlds-most-eco-friendly-car-its-made-entirely-from-hemp/comment-page-1/

Inevitably, there are also some negative prospects for the future of industrial hemp. Regarding insulation material, hemp has a two to four times higher cost price than the materials now dominating the market (glass and mineral wool) [9]. Although, hemp has the beneficial quality of not being irritant which makes it easier to handle and has a better capacity to cope with moisture and heat flows, hemp can only compete these materials in terms of quality. For now, hemp insulation business depends on sustainable oriented customers [9]. However, Carus *et al.* (2013) expect hemp fiber production for non-woven materials to be able to grow considerably.

The European hemp market

To explore the European hemp processors view on the future, a survey was carried out in EU by the EIHA in 2012. Processors mentioned hemp seeds for the food market, hemp building material and hemp shives and lime as products with high growth probability. Hemp reinforced bio composites, i.e. matrices of biopolymers reinforced with natural fibers such as hemp [84], were also named promising. Processors expected a lower growth for pulp and paper and bedding material [9]. From the processing data made available by European processors associated with the EIHA, it was concluded that without an additional investment, hemp cultivation in Europe can be increased with at least 20.000 ha. Due to this result, in terms of capacity the EIHA does not expect any problems in meeting a rising demand [9]. However, a problem is expected with finding sufficient cropland. With the newly updated Common Agricultural Policy (CAP), subsidies are allocated from fiber crops including hemp to biofuel and bio-energy crops, making cropland nowadays only payable for the latter. This

competition will attribute to an ever decreasing area available for hemp cultivation [9]. Furthermore, this competition is unfair because biofuel and bio-energy crops are as well supported in commercial production in terms of fiscal incentives, regulations with regard to green electricity and biofuel and renewable energy quotas [9]. The EU is moving towards a greening policy, which hemp can profit from. Nevertheless, this is not enough to level biofuel and bioenergy crops. The EIHA highly supports leveling of bio-based material including hemp with biofuel and bio-energy crops [9].

Competition for cropland will be a major topic within the European Union. Surely because the hemp market is still in an early stage and certainly not fully developed [85]. The price of hemp will rise due to this development and because additional hemp fibers now need to be imported from China and Eastern European countries [*]. New equipment and developments in technics could lower the price of hemp within the EU because of economizing labor costs [76] and transportation costs [19]. Furthermore, although the European market is not protected from this import, the EU maintains strict regulations concerning the THC levels and strict requirements for organic farming [9].

According to [9] the biofuel and bioenergy subsidy is already gradually decreasing and the updated CAP contains many components focusing on sustainability and greening of the EU. In spite of the elimination of direct support, hemp can still profit from indirect support. An example of a potential profit area in the new CAP is provided below.

As mentioned before, due to the elimination of EU financial support, cropland is difficult to find. Processors have to be trustworthy and offer farmers an equal amount of money as they would receive by cultivating another crop such as wheat, maize or potatoes. Another option is to offer hemp as a crop for the Ecological Focus Area (EFA). Farmers with more than 15 ha of cropland that want to receive support from the CAP, are obliged to turn at least 5% of the land into the EFA. This percentage may rise to 7% when the measure is revised in 2017 [18]. It was estimated by rvo.nl (as referred to by [50]) that approximately 12.500 companies with more of less 670.000 ha, need to establish an EFA, this means a total area of 33.500 ha EFA. There are several options to fill the EFA. Wageningen University investigated potential crops within the CAP policy. Although hemp was not highly rated, mainly due to the lack of contribution to the enhancement of biodiversity [17], the Dutch ministry of Economic Affairs has determined to allow the cultivation of hemp and flax for occupying the EFA. Farmers are obliged to first grow hemp or flax before sowing 'vanggewassen', crops that are grown after the principal crop to prevent leaching of nutrients [50]. With this measure, in response to the elimination of hemp subsidies, the ministry supports hemp as a sustainable commodity [50].

Next to the EFAs, there are more possibilities to obtain support from the EU. Hemp is eligible for sustainability support, like for example the Eco-innovation initiative made available by the European Commission:

"Any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development. This can be achieved either by reducing the environmental impact or achieving a more efficient and responsible use of resources". [26]

It has to be noted that projects already eligible by the CAP such as the cultivation of hemp are usually not supported by this fund, except products with significant environmental benefits. However, interesting is the funding for quality products that lower greenhouse gas emission. Already commercially available products are not supported [26]. This fund could be an interesting source of support for developments in the hemp building industry. Carus *et al.* (2013) expect the European hemp production to expand based on the increasing demand in the automotive and building industry and possibly the employment of hemp certifications. However, as Carus *et al.* also mention, the future growth of European industrial hemp also depends on both the political and the economic EU framework.

[*] Personal communication with M. Reinders, June 12, 2014

The Dutch hemp market

Based on questionnaires answered by the two Dutch hemp processors, HempFlax (HF) and Dun Agro (DA), this paragraph examines the Dutch hemp market. Both companies agree that the Dutch hemp market is still small. As pointed out by Ronde (2013) this brings along the disadvantage that they can only share the costs for production and technic related investments with one other company. Dutch hemp products do not necessarily stay in the Netherlands, both processors export their products for a large part. HempFlax exports 80% of their products, making itself practically independent of the Dutch market. The global hemp market has a considerable size and there are sufficient entry points for Dutch products (DA). Both companies expect the market to increase and the demand to rise, not only in fibers, but also leaves and wood (DA). In terms of applications, it is thought that the use of hemp fibers will increase in the automotive, textile, furniture and the building industry (HF, DA). Products that are expected to come more in demand are insulation and bedding material (DA). Process capacity of raw hemp in the Netherlands can be doubled (HF) or tripled (DA). However, as mentioned by Dun Agro, they should be careful with growing too fast to prevent overgrow of the organizational capacity. It is thought that hemp is becoming more known and trustworthy in the Netherlands (DA).

For Dutch processors the elimination of subsidies means an increase in cost price and a decrease in turnover. Both processors have anticipated on the elimination of the subsidies. Both leaves (DA, HF) and flowers (HF) are now harvested in addition to fibers. New machines have been developed in order to separately harvest leaves and stems. Furthermore, Dun Agro will start this year with the fabrication of pre fab hemp houses made of hemp wood. Both companies put high effort in upholding high quality management by, among others, implementing ISO9001. Another strategy is vertical chain integration, employed by HempFlax. The use of this strategy implies that the company itself holds the supply chain whereas in horizontal chain integration various products in the supply chain would have been produced by different companies. In the HempFlax factory, semi/finished products are made into end products such as non-woven fiber mats and bedding material [**].

Dutch hemp processors do not have to fear competition as a result of the hemp legalization in the U.S. For now, only research related hemp breeding is allowed and it is estimated to take at least five years to build a functional hemp market [**]. HempFlax exports the lion's share of their products to Germany, Switzerland, United Kingdom, U.S. and Scandinavian countries. In spite of the changing subsidies that are accompanied by competition with biofuel crops, potential funding and beneficial legislation for hemp receive more attention. Furthermore, in several parts of the European market, growth is expected. HempFlax can profit from the growing European hemp market and for at least the upcoming five years, export to the U.S. will be able to continue.

In 2006, Suijkerbuijk & Janszen investigated the potential for industrial hemp in the Netherlands (referred to in [66]). It was concluded that hemp needed to be accepted by the market and technics needed to be updated. According to Trindade [*], hemp machinery is improved, especially harvesting gear. Different research groups have been working on improvement of hemp cultivation and harvesting systems. Particularly Italy is strong herein. With regard to market acceptance, hemp processors and scientists have been busy developing new applications and acquiring awareness. Hemp seems to be more and more accepted in the market nowadays [66]. The research by Ronde (2013) concluded that without market failures, hemp production would shrink (raw: 6% and processed: 12%) and the hemp price would fall (raw: 9% and processed: 4%). Furthermore, it was concluded that the survival of industrial hemp in the Netherlands depends on the innovativeness of processors and the Dutch and European policies. It is too early to conclude whether the percentages are correct.

[*] Personal communication with dr. ir. L.M. Trindade, July 3, 2014

[**] Personal communication with M. Reinders, June 12, 2014

However, as mentioned before, processors have developed several new applications and processing strategies to create a more stable position in the market.

De Bont *et al.* (2008 in [66]) concluded that changing subsidies would bring the hemp sector to a halt or even worse, would eliminate the hemp sector in the Netherlands. De Bont *et al.* suggested that the latter could be avoided when processors imported raw hemp from other countries. Interestingly, opposed to this view, Trindade [*], expects an expansion of the hemp acreage in Europe and possibly in the Netherlands given the increasing demands of hemp biomass in the Netherlands for new high added value applications of hemp. Furthermore, Trindade indicates the down-side that accompanies the import of seeds from e.g. China or India, where wild hemp accessions containing high levels of THC can contaminate the seed production fields and consequently increase the THC content to levels non-acceptable for European regulations. The EIHA wishes to employ certification for imported goods and raw material to secure quality and acceptable labor conditions meeting the European standards. In addition, a certification system would ameliorate the competition position of hemp produced in the EU, inducing level playing competition. However, such a certification also complicates the import of raw material from European countries not associated with the EU which does not seem beneficial in times of raw hemp shortage. Trindade mentions that importing hemp from African countries could be a future possibility, provided that scientists will be able to develop cultivars adapted to these climates.

4. 2 Can hemp be produced organically in the Netherlands?

Strict regulations regarding organic agriculture are defined in European legislation ((EEG) nr. 2092/91). For example, hemp can only be qualified as organically produced, when it is cultivated on soil that has been handled organically for a minimum of three years [80]. Practically, this means that the soil has not been treated with products for crop protection and chemical or inorganic fertilizer, neither are these products allowed during cultivation[**]. For now, HempFlax produces hemp in an organically certified manner, however, their products are not certified as organic because 95% of the field are not certified as organic [**]. Both HempFlax and Dun Agro agreed that a doubling in sales volume would not affect the organically manner of cultivation. The same high standards would be maintained. However, a substantial expansion of the hemp acreage in the Netherlands could lead to an increase in the disease development [16]. Currently, only a few pathogens have been observed to infect industrial hemp in the Netherlands. With regard to increased hemp growing, organic cultivation may not be the best manner. For example, hemp could benefit from herbicides [*].

4. 3 What would happen if hemp processors would be disappear from the Netherlands?

Both HempFlax as Dun Agro are located in the north of the Netherlands, in Oude Pekela. This area is known as the Veenkoloniën or Peat districts. The arrival of both factories boosted the area, that was dominated by the cultivation of potatoes and beets and gave a major economic impulse to the area. When the companies would have to leave the area, this would be a great loss, not only economically but also as an example of organic agriculture. With regard to hemp products, especially bedding material would be less available. However, many alternatives for hemp bedding are available in the Netherlands.

[*] Personal communication with dr. ir. L.M. Trindade, July 3, 2014

[**] Personal communication with M. Reinders, June 12, 2014

Conclusion

In this research the future of industrial hemp in the Netherlands was investigated. Hemp can provide high quality fibers as an sustainable alternative for cotton and synthetic fibers and is well adapted to the Dutch climate [71,78] and poor soils [66]. Due to the allocation of the Common Agricultural Policy (CAP) subsidies from fiber crops including hemp to biofuel and bio-energy crops, competition for cropland is jeopardizing the Dutch hemp culture. Previous research investigated the effect of subsidy elimination on the Dutch hemp market [66] but did not focus on factors making hemp valuable for the Netherlands. Furthermore, this research presents an up-to-date overview of the future perspectives on the industrial hemp market by means of professional and scientific literature and interviews with experts.

Hemp is receiving more and more attention, especially in the automotive industry [7], because of light weight hemp fiber applications [56]. Hemp is becoming more known [*] and better accepted [RW.ERROR - Unable to find reference:212] possibly due to the processors' efforts to familiarize people with hemp, the support previously provided by the European Union and hemp's sustainable character. The demand for organic products is increasing [65] and organic farming is heavily encouraged in the new EU Greening policy [18]. Although hemp can be organically grown relatively easy, this may not be the best way. Industrial hemp can benefit from the addition of herbicides [*]. It may be wondered, whether predominantly supporting organic farming of industrial hemp is the most effective way to support hemp.

The findings of this research are partly in line with the research carried out by Ronde (2013). Ronde concluded that a steady supply of raw hemp is difficult to obtain as a result of fierce competition with alternative crops and the elimination of EU support. It was also concluded by Ronde that the future of hemp cultivation in the Netherlands depended on the creative minds of processors and the Dutch and European policy frameworks. The Dutch processors have anticipated on the abolishment of the subsidies and started developing processing lines for leaves and flowers. The creative minds of processors have discovered new entries to (niche) markets like the green building market. Furthermore, HempFlax is almost totally independent of the Dutch market, however unfortunately depends for a large part on Dutch farmland for their supply of raw hemp. The hemp farmers associated with Dun Agro are almost all located in the Netherlands. Due to the competition with biofuel and bio-energy crops both hemp processors will have difficulty finding available cropland in the Netherlands. Both companies already purchase raw hemp from other countries within the EU (Germany, Denmark, Romania) and this could be extended. Furthermore, processors can find cropland by offering farmers hemp as an option to fill their Ecological Focus Area (EFA), that farmers with more than 15 ha have to fill with a specified crop to satisfy the demands for receiving a CAP subsidy [18]. Furthermore, hemp processors can probably profit from the greening policy of the European Commission [9].

Although, Reinders, vice president of HempFlax, foresees the possible disappearance of industrial hemp from the Netherlands due to the imbalanced subsidy policy[**], dr. ir. Trindade, hemp breeding expert at Wageningen University, is more positive and sees the possibilities for hemp cultivation in Europe and possibly in the Netherlands, provided that additional multipurpose hemp varieties are developed [*]. Trindade points out the valuable characteristics of hemp for the Netherlands such as the multiple and specific applications, dual crop growth, barely susceptible for pathogens, sustainable character and the fact that hemp is grown easy and efficient. Furthermore, Dutch scientists and companies contribute greatly to the global and European markets in terms of new cultivars and advanced hemp products. Finally, hemp can be grown on the poor soils of the Dutch Peat districts (Veenkoloniën) without a high level of fertilizer [5] and can possibly be employed for the expensive process of bioremediation [*]. Although hemp does not accumulate heavy metals at a high pace, it

[*] Personal communication with dr. ir. L.M. Trindade, July 3, 2014

[**] Personal communication with M. Reinders, June 12, 2014

remains an interesting crop because growth and fiber quality are not negatively affected when grown on polluted soils[36].

Completely in line with the research Ronde (2013) and Carus *et al.* 2013, this thesis concludes that hemp suffers from unfair competition by subsidies for biofuel and bio-energy crops. Adjustment of the current EU policy could restore healthy competition between these crops and provide hemp with the opportunity to overcome its infancy phase. Interestingly, hemp receives heaps of support in other countries like Canada [3], while it is heavily undervalued by the EU. It can be questioned why hemp is deprived of subsides to such a large extent.

To conclude, based on the information gathered within this research, expectations for the future of hemp in the Netherlands can be outlined. Firstly, although the supply of products from the Netherlands to the European and global market is relatively small, the Netherlands contribute largely in terms of knowledge, new high quality applications and improved cultivars. Secondly, it is expected that hemp processors will stay in the Netherlands. Processors depend on the flourishing global and European sales market rather than the small sales market in the Netherlands. Furthermore, they have anticipated on the abolishment of the subsidies and designed additional value added products that create access to new niche markets. HempFlax already imports about one third of their raw material from Romania. It is a possible that hemp processors purchase raw hemp from low labor costs countries such as Eastern European countries, including Romania [76] that produces hemp that meets the high European standards. Import from China, the largest producer of industrial hemp, will not be a valid option because of the interbred with wild hemp cultivars. Thirdly, The cultivation of hemp is expected to remain in the Netherlands as well. Industrial hemp is an interesting crop for the Netherlands because of the benefits during cultivation, e.g. the ability to grow on poor soils in the Peat Districts, and the potential employability for bioremediation. Industrial hemp can possibly profit from the EU greening policy, the authorization to grow hemp in EFA's and potential new subsidies for organic farming. In addition, the European and Dutch policies should be adjusted to realize fair competition for cropland between hemp and biofuel crops. Finally, it can be concluded that industrial hemp is a very interesting crop for the Netherlands and should receive further support to give processors a chance to establish a well-functioning market.

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