HEMP AS RAW MATERIAL FOR THE FASHION INDUSTRY – A study on determining major factors hampering hemp to be integrated in the textile apparel supply chain

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Bachelor Thesis I Summer 2017

A study on determining major factors hampering hemp to be integrated in the textile apparel value chain

Laura Sophie Kramer

SAXION UNIVERSITY OF APPLIED SCIENCES | ENSCHEDE, THE NETHERLANDS

TEXTILE ENGINEERING & MANAGEMENT PROGRAMME

HEMP AS RAW MATERIAL FOR THE FASHION INDUSTRY

Bachelor Thesis I Summer 2017

SUBTITLE
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Bachelor Programme
Textile Engineering
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SECOND EXAMINER
Dyo van Opstall

DATE
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List of Abbreviations and Definitions

Abbreviations

GOTS	Global Organic Textile Standard
Mg/min	Milligram per minute
mm	Millimetre
NGO	Non governmental Organization
THC	Tetrahydrocannabinol
tex	Mass in grams per 1000 metres

Definitions

Agrochemicals	Chemical used in agriculture, such as a pesticide or a fertilizer
Bio-composites	Natural materials, such as wood fibres or wheat straw, moulded and bonded together with a natural or synthetic resin
Biomass	Organic matter, especially plant matter, that can be converted to fuel and is therefore regarded as a potential energy source.
Cannabidiol	A non-psychoactive constituent of Cannabis Sativa
Cannabis Sativa	A botanical name of one major type of the hemp family
Carbon footprint	The total amount of greenhouse gases produced directly and indirectly related to the production of e.g. a product
Cotton gin	A machine for separating the fibres of cotton from the seeds
Cottonization	Generic term for improving fibre properties by different treatments to approach cotton characteristics
Cross-pollination	Pollination of a flower or plant with pollen from another flower or plant
Decortication	Separation of bast fibres from woody core with a decorticator
Dioecious plant	Having the male and female organs in separate and distinct individual plants
Heckling	Combing fibres with a heckle to split, straighten and clean them
Hemicellulose	Any of a group of plant polysaccharides that occur chiefly in the cell wall
Hempcrete	A mixture of hemp shivs and lime used as material for construction and insulation
Lignin	A complex polymer occurring in certain plant cell walls making the plant rigid
Micro fibres/plastics	Small chemical fibre/ plastic particles in a size of 50 µm - 5 mm, broadly found in marine environments
Monoecious plant	Having the male and female reproductive organs in separate flowers on the same plant
Pectin	Any of a group of carbohydrate substances found in the cell walls of plants and in the tissue between certain plant cells
Primary hemp fibres	Primary fibres are long-staple length fibbers, averaging 20 cm in length positioned around the hollow woody core of the plant
Pull strategy	Introduction of a product driven by market demand
Push strategy	Introduction of a product which is unknown to the market convincing consumers of its benefits
Retting	to moisten or soak (flax, hemp, jute, etc.) to promote bacterial action in order to facilitate separation of the fibres from the woody tissue
Scutching	to separate the fibres from the woody part of (flax) by pounding
Secondary hemp fibres	Short fibres in the plant that are impossible to be spun into yarns
Hemp shivs	A particular woody by-product of processing flax or hemp
Sowing density	Spacing between the seeds being sown
Spinning jenny	an early spinning machine having more than one spindle, enabling a person to spin a number of yarns simultaneously
Vegetative growth	The period of growth between germination and flowering, accumulating resources needed for flowering and reproduction

Preface

This research is performed in the frame of a Bachelor Programme at Saxion University of Applied Sciences Enschede, The Netherlands. I am a 4th year student in Textile Engineering and Management and this report is compiled to serve as Final Thesis submission. A variety of people contributed to the outcome of this thesis. Especially, I want to thank Mrs. Natascha van Hattum-Janssen for her support. I am grateful for her given advises and supervision during my whole graduation time. Moreover, I want to thank all people from the industry that were willing to talk to me and patiently answered my questions.

Enschede, June 15, 2017. Laura Sophie Kramer

Summary

The reason for this research is the minor prominence and application of hemp in the fashion industry. Focus is particularly put on the European market, but also has reference to global developments in the fashion as well as in the hemp industry. The main objective is to determine the major factors hampering hemp to be integrated in the textile apparel value chain, and to further give advice on how these bottlenecks could be solved in the long run. With the aid of a widely designed literature review and the collection of perceptions of experts working in the hemp industry, the goal of the research is approached. The literature review displays information about historical, industrial, agricultural and legal factors that affect the state of the art. Hemp fibre properties are presented and compared with those of cotton, to find out if modification is needed for greater success. Moreover, cultivation, processing and sustainability aspects are elaborated for both raw materials. Furthermore, the limited hemp fibre demand is pointed out from the fashion industry's viewpoint to get a better understanding and create an overall picture about the main obstacles. The hemp industry's opinions serve to gain insight in this branch, to find perceived threats and opportunities of the crop, and to further support the findings from the literature review. By that, the ecological as well as economical perspectives are taken to figure out the future potential for the European production of hemp for the fashion industry.

Throughout this research, it becomes clear that the major barriers are of processing nature. No efficient or optimized production line for hemp primary fibres exists. In all steps, from cultivation to yarn spinning, the existing technology is not adjusted in a way that high quality fibres could be achieved. This partly labour-intensive and inefficient production leads to high costs, which are reflected in the end price. In addition, the given technology is not capable of delivering consistent fibre properties. Too many factors still negatively affect the fibres, whereby quality variations occur. Due to these issues, demand on hemp fibres from the fashion industry cannot be generated. The prohibition to cultivate hemp in Europe, which lasted for around 30 years, created a loss of knowledge in the cultivation and production of fibre hemp and led to a gap of research and development in that area. Nevertheless, the plant profits from the more sustainable approach from a variety of industries. In hemp cultivation only small amounts of water are needed, no agrochemicals need to be applied and the crops can grow under almost all climatic conditions. Growing hemp is environmental friendly and generates high yields on small crop areas. As a result of that, the cultivation of hemp in Europe is steadily growing, reaching 33,000 ha nowadays. Despite this recorded growth within Europe as well as worldwide, the hemp fibre production for textile and apparel does not eminently benefit from this development yet. Other parts of the crop are more profitable, namely the seeds, biomass as well as the secondary fibres, which cannot be used for textile purposes. They are applied in bio composites or for pulp and paper production. The focus on other end-uses in Europe leads to minor investments and consequently slow progress in improving the production of high quality fibres.

By means of the findings from this research, it can be said that the sustainability aspects of hemp are superior to those of commonly used raw materials. The minor application of hemp in fashion clearly originates from economic circumstances. Due to the afore-mentioned technical obstacles, hemp cannot compete with other raw materials in the fashion industry. The inconsistency in quality of hemp fibres along with the much higher price, both deriving from unimproved processes in the production, lead to a minor demand from apparel producers. As long as the quality cannot be increased and costs cannot be decreased, hemp fibres will not be economical for all participating parties within the fashion supply chain and are therefore unattractive. Nonetheless, with the aid of investments for research into different directions, hemp could get the overall qualifications to become a sustainable alternative for the fashion industry.

Chapter 1 – Introduction to research

1.1 Definition of the Problem including Context and Reason for Research

Hemp is a valuable raw material for the textile industry, as well as for other industries. It is a robust plant that needs almost no pesticides and less water compared to cotton when cultivating. Hemp is durable, breathable and very tear-resistant (Bengtsson, 2009). At first glance it seems that hemp does not have any disadvantages compared to other natural fibres. It even shows benefits over cotton as a raw material when it comes to several factors, such as higher UV-resistance (Jianchun, 2008). Therefore, it needs to be determined, why it is not so broadly applied in the apparel sector, why it is not cultivated more in Europe. Goal is to create a whole image on the use of hemp as textile fibre on the European market. The cultivation of hemp in Europe is growing, but just on a slow level. Which factors are influencing the production and use of Hemp, which factors were influencing the development in the past, and what factors need to change for a greater success and market share of hemp. It is to determine the future possibilities and to find out preconditions that have to be provided to guarantee a greater cultivation, production and integration of hemp on the fashion textile market in Europe. The research is focused on the hemp production for the European market of fashion textile products out of hemp fibres. It is to outline the history of hemp, the state of the art and the future possibilities of this raw material. It is to find out, how hemp is cultivated, processed and used nowadays. Furthermore, it is evaluated what advantages and disadvantages the fibre has in properties and processing compared to cotton. What are the threads and possibilities when cultivating, processing and further integrating hemp as a raw material for the textile industry? Why is it not as broadly used as Cotton? A whole portrait of hemp as raw material and textile product is made, including factors of historical development, cultivation, industry, climate, application areas, sustainability and also on a legal level.

1.2 Exploratory Literature Research

Hemp is a raw material, which is used for several different applications. It is a variety of Cannabis Sativa and it grows very fast under several different soil conditions (Hemp University, 2016). Its fibres derive from the stalks. Hemp fabrics are known to be highly absorbent, breathable, warm and long lasting (Hanfsamen.net, 2017). The history of hemp in Europe begins far before Christ. First findings of Hemp date back to 5500 B.C. in Eisenberg, Germany (Hanffaser, 2015). In history it has been proven as a valuable asset for the production of e.g. paper, sailing canvas, ropes and uniforms. In the 1960s, before the prohibition of industrial hemp cultivation, the world cultivation of hemp fibres was around 300,000 metric tons, whereas it amounted just to 75,000 metric tons in 1996 (Robins, 2013). The quantity of hemp harvested in Europe in 2010 was around 26,000 metric tons, that equals a cultivation area of 14,000 ha. In 2013, the main producer within Europe was France with a cultivation share of 8,000 ha. Germany amounted to about 1,000 ha of cultivation area (Carus, Karst, Kauffmann, Hobson, & Bertucelli, 2013). The demand on industrial hemp is growing. New application areas, such as bio composites, bio fuel or in the food industry come up, and still the European agriculture just slowly adapts to this development. In Europe the amount of hemp being cultivated stayed stable between 10,000 ha and 15,000 ha from 1996 to 2012 (Carus, Karst, Kauffmann, Hobson, & Bertucelli, 2013). The world share of hemp in the textile industry is quite low. Whereas the percentage of cotton fibres is around 25% in 2015, the amount of other natural fibres in the global fibre consumption is only 5 %, in which hemp is included. A big impact is the further development of man-made fibres, but still it is obvious that the percentage of hemp in textiles is not comparable to that of cotton (ICAC, 2015).

1.3 Research questions

Main question:

- Which factors influence the market share/ awareness of Hemp as raw material for the Fashion industry on the European market?

Sub questions:

- Which historical developments were crucial for the state of the art?
- Which industrial, legal, climatic factors are of great importance?
- What is the image of hemp as a plant?
- How much hemp is cultivated in Europe/ Germany?
- What properties of hemp need to be modified for more success?

1.4 Description of the Report Structure

After this introductory chapter, the report continues with an explanation of the research methodology, including the different research methods being applied. The main focus is put on a widely spread literature review, that creates a whole image of the state of the art of the topic, to be able to answer all formulated questions. Additional to that, a questionnaire is prepared, given to brands, researchers and other experts that are working with hemp as raw material. Chapter 3 therefore deals with the outcome of both research methods. The sub-chapters 3.1 until 3.5 are connected to the literature research, offering the major part of the results. These 5 sub-chapters are separated into the following topics: A historical overview, industrial hemp and its uses, hemp cultivation & processing, hemp and the apparel industry, and cotton versus hemp. Sub-chapter 3.6 finally gives an overview of the answers given to the developed questionnaire. Thereafter the results are summarized in Chapter 4.1, conclusions are displayed and recommendations are given, based on the questions that need to be answered throughout this research. As the research is performed independently, no company recommendation is included. The offered discussion and recommendations aim at lining out the bottlenecks in the production of hemp and give advise concerning conditions that need to change in favour of promoting the use of more hemp for apparel. The research reflection in Chapter 5 serves to interpret the results of this research and the whole realization of the study. It critically explains, if all questions could be answered, how the entire execution went and what could have been done to improve the outcome, in terms of completion, reliability and availability of information needed. At the end, a list of references is given and necessary annexes are presented.

Chapter 2 – Research methodology

2.1 Introduction to Methodology

Since the aim of this research was not to gather numerical information and to assess it, but to define the factors from the past, presence and future that influence the usage and application of hemp on the European market the whole report is compiled on the basis of qualitative research. Gathering background information as well as literature research concerning different possible influencing factors take place during the whole graduation process. At the end the main factors are determined and summarized to find a solution for the main question and the sub questions. Therefore, the majority of the research is focused on outlining the central and most relevant facts, and giving a complete overview on different levels that affect the use and market share of hemp as a raw material for the fashion industry. Furthermore, a short questionnaire is conducted, which is send to experts, companies and brands working with hemp as a raw material on several levels. Throughout this questionnaire, opinions and knowledge about hemp from different sectors are collected. By this an insight of the people's point of view who have a connection to hemp as researchers, processing facilities and end product sellers is acquired.

2.2 Literature Review

The objective of this method is to gather varied information about the hemp plant in general, its history, the image of the crop, the cultivation and processing, its application areas, the worldwide and European hemp industry, as well as the connection of this raw material to the fashion industry. By means of this diverse analysis of different areas connected to hemp, major factors for the little cultivation in Europe and application of hemp as raw material for the fashion industry are determined. The results are delineated in sub-chapters in Chapter 3, to create a coherent picture of the state of the art. From the previous research it is to mention that plenty of research was performed in the past about hemp, which also included the consideration of reintegrating it into the fashion industry. Nevertheless, it mostly was a side-topic in relation to the whole research objective. Therefore, this method was chosen to combine all major research outcomes available into one bigger picture. In the framework of this research method, a large variability of sources and keywords was used to create an objective overview about the topic. The list of databases and websites, as well as all keywords used are displayed in Annex I and II.

2.3 Questionnaire

As afore mentioned in 2.1, the aim of this research method was to find out the perceptions of people, who are working with hemp as raw material. The reason why the questionnaire is added to the main research method of literature review, is to gain insight into the actual industry, to incorporate different opinions, and to fill the gap of information, which is not possible to acquire through the literature research. Moreover, the questionnaire aims at collecting attitudes and positions towards hemp in general, towards its market potential in Europe and its reintegration into the fashion industry. Additionally, arguments are gathered, both for and against the cultivation for apparel in Europe and the general potential of hemp in fashion. A questionnaire was conducted, including three sub-categories. The first part of the questionnaire is meant for all respondents, the second part is meant for researchers and research institutions and the third part addresses brands and companies processing or selling hemp fibres or products. All questions are kept as open as possible, to make it feasible for the respondent to truly reveal his or her own professional and personal opinion about the topic. These questionnaires preferably serve as basis for personal or telephonic interviews, which

are recorded to be assessed later. In case, the respondent is not willing to have an interview for different reasons, it is also possible for him or her to fill it out and send it back for evaluation. The execution of this method within the scope of this research raises no claim to completeness, as only a couple of people are polled, preferably from different areas of expertise. Even if it is attempted to collect as many opinions as possible, it is to say that this method is not performed in a quantitative manner, which is already impossible through the design of the open questions. It still needs to be kept in mind that the questionnaires are only an adventitious method, having the goal to capture industry opinions and further supporting the results of the literature research. The conducted questionnaires, both in English and German, can be found in the Annexes III and IV. In the last sub-chapter of Chapter 3, the results of the questionnaires are presented. Answers are compared to show if there is consensus about the questions asked or if the opinions differ widely. For the deeper interpretation, all statements of the respondents are sorted in a table, regarding different topics. After rough structuring, every statement is specified with a code. After that, the assigned codes are counted and its relevance, regarding the scope of research, is ascribed. Relationships between different codes are ascertained to create main groups of response pools (Verhoeven, 2011). Subsequently, the partial percentages of those main groups are calculated and a ranking of the codes is determined (see Annex VI). This determination serves to facilitate the description of results and to arrive at a valid conclusion, being related to this research method.

Chapter 3 – Results

This chapter exhibits all results that are ascertained during the literature review, and is divided into sub-topics. Additionally, the outcome of the open questionnaire is summarized in the last sub-chapter, by creating an overview of the different industry opinions that are noted. All sub-topics are examined to draw reasonable conclusions regarding the formulated main-question and sub-questions.

3.1 Historical Overview

3.1.1 America

America and the hemp industry look back to a long joint history. Already in 1777, hemp was stated as "one of the most profitable productions the earth furnishes on the northern climate and worthy of serious attention." by the American Philosophical Society in Philadelphia (Torrella, 2011) , which also was implemented for several hundred years. Between the 1630s and 1800 hemp was even accepted as medium of exchange in the USA (Torrella, 2011) and was the most used crop until 1937, which shows the degree of familiarity and acceptance within society at that time (McCorristin, 2003). A notable cause decreasing this wide distribution is seen in two inventions of the 18th century: the invention of the spinning jenny in 1768 by Hargreaves and the invention of the cotton gin in 1793. These breakthroughs in the cotton processing led to a downturn in the European and American hemp industry, since cotton processing became less labour intensive and simpler, leading to lower prices (Westerhuis, 2016). In 1914, the hemp decorticator was invented, making the hemp crop competitive again. However, first anti marijuana laws were introduced in the USA, connecting the industrial crop to its recreational uses (Francis, 1996). Even if the hemp cultivation was not illegal and it was still used industrially, e.g. for a car body containing hemp by Henry Ford in 1920 (Figure 1.), hemp went through a negatively construed image campaign in America in the next 20 years (Cordell & Bruer, 1996). One positive development within the hemp industry was the invention of hemp harvesters,

Figure 1. Ford's Hemp Car (Truth Theory)

which were able cutting the crops, laying them on the ground in a position, easily to pick up after drying the stalks in the 1930s by the International Harvester company of New Jersey (Francis, 1996). In recent times, in the year 1933, the alcohol prohibition was annulled in the USA and with the founding of the U.S. Federal Bureau of Narcotics the campaign against hemp was largely extended by the government, other industry lobbies and the public media. The image created was narrowed down to hemp as a drug for recreational purposes, implying violent behaviour, crime affinity and insanity when exposed to it (Addlesperger, 2015). Furthermore, strict regulations and high taxes were used to limit the production and distribution of hemp. Without any examination of the plant, Harry Anslinger, director of the U.S. Federal Bureau of Narcotics, declared the countrywide prohibition of hemp in 1937 (Addlesperger, 2015), which is known as the Marijuana Tax Act. In the book "The emperor wears no clothes", by Jack Herer, it is stated that this development was highly driven by lobbyism of the cotton, timber and especially the chemical industry. At that time, the petro-chemical company DuPont developed a more efficient method of pulping wood for the paper production. Furthermore, the company had a big share on plastic developments and invented the nylon fibre. Moreover, Herer outlines a personal connection between Anslinger and Andrew Mallon. Mallon was

chief of the Treasury Department and Anslinger was married to his niece. Authorized by his position, Andrew Mallon appointed Anslinger to be the director of the U.S. Federal Bureau of Narcotics, while Mallon was the main investor of DuPont at that time (Herer, 2017).
The prohibition was strictly executed, until the hemp crop was desperately needed again during World War II for the production of textiles, like uniforms and parachutes, as well as for food. Under the slogan "Hemp for Victory" a short image film was released to encourage farmers cultivating industrial hemp again (Decorte, 2011). After 1945, the plant was banned again, and Harry Anslinger brought the negative image campaign against hemp into the United Nations as representative of the USA (Cordell & Bruer, 1996). Throughout his role in the UN, he achieved the complete prohibition of all member states, by "The Single Convention on Narcotic Drugs". This convention was justified in the cause of health and human welfare (Cordell & Bruer, 1996).

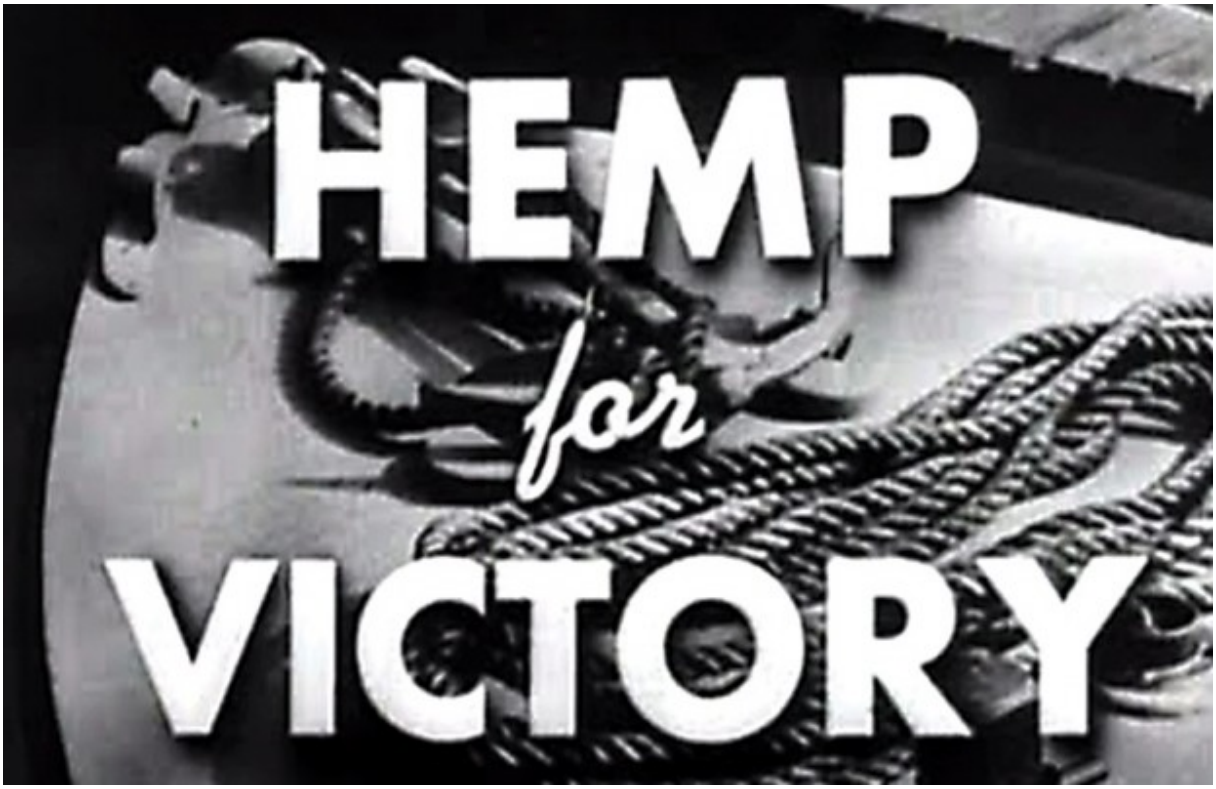


Figure 2. "Hemp for Victory" slogan from the USA in 1942 during World War II (Cannabis Now, 2015)

3.1.2 Europe and Germany

Just as in America, hemp was an important plant in Europe, using it for food, paper and clothing. It was important for the seafaring, using hemp textiles for canvas sails, ropes as well as for work-wear (Addlesperger, 2015). From the 16th to the 20th century hemp cultivation was steadily growing in Europe (Amaducci, et al., 2014). Until the 18th century, hemp and flax were the most used raw materials for textile yarns in Europe and until the end of the 19th century 75-90 % of all paper worldwide was made out of hemp (Decorte, 2011). Even if setbacks, like improved processing methods for cotton, the invention of steam-powered ships and cheaper hemp from Russia and China, arose, European hemp stayed one of the most important crops for a long time (Addlesperger, 2015). Still in the first half of the 20th century this plant was broadly used for different applications. Rudolf Diesel introduced the prototype of his first engine around 1900 (Decorte, 2011), running with hemp oil and approaches were done in the 1920s throughout Europe to improve breeding methods

for higher fibre yields (Bengtsson, 2009). Just like in the USA it was an essential crop during World War II and the hemp industry remained substantial in Europe until the 1960s (Pari, Baraniecki, Kaniewski, & Scarfone, 2014) when hemp cultivation was prohibited through the "The single convention on Narcotic drugs" (Herer, 2017). For decades, the hemp industry stayed extinct, meaning a standstill in research and technical developments for hemp processing (Schumann, Peil, & Weber, 1999).

Due to a change of European regulations, the prohibition of cultivating industrial hemp was abandoned in the EU in 1992 (Decorte, 2011). Several countries started allowing the industrial hemp cultivation again, Germany following it in 1996 (nova-Institut, 1997). Hemp as renewable resource, was rediscovered on a global level, the demand on fibre hemp for the fashion industry grew, promoting research initiatives throughout Europe and Germany. The Netherlands, for instance, invested 150 million Schilling for the development of THC free hemp seeds (Cordell & Bruer, 1996). In Germany, investigations on domestic fibre hemp production was performed, processing plants were built in almost all Federal States of Germany and the first German hemp products were introduced in 1997. Identifying the potential of hemp for a variety of textile applications, like geo-textiles, insulation material, bio-composites as well as for apparel use, led to large investments of the industries (nova-Institut, 1997). Through this rediscovery of the crop in the 90s, the demand for hemp fibres for the clothing industry grew as well (Westerhuis, 2016). In Germany, the goal was to create a decentralised, regional industry being transparent and guaranteeing quality (nova-Institut, 1997). A problem the new growing industry was facing in whole Europe, was the lack of knowledge about the cultivation, harvesting and processing technologies. For decades there had been no research and technical development and no long-term investments concerning industrial hemp. The whole industry had to be rebuilt (BR, 2014). Flax processing chains were used, but the field of research considered two different approaches. Researchers wanted to either adjust the existing machines to the crop, or modify the crops to the machines. It turned out to cause a big conflict between engineers and agronomists, since no profitable adjustment could be developed, especially not for the high quality fibre processing, where the so-called primary fibres need to be separated (Venturi, Amaducci, Amaducci, & Venturi, 2007). Some developments led to a better processing for other purposes, like specialty pulp and paper, where the short secondary fibres are needed, or for the better harvest of the seeds (HempFlax, 2016). Within this time, the demand on fibre hemp decreased again, especially due to inefficient processing technologies. Almost all built processing plants in Germany closed, notably those meant for the high quality textile processing, and the whole hemp industry shifted in other directions. Nowadays, multi-purpose crops are used, which leads to a decrease in fibre quality (Amaducci, et al., 2014). Furthermore, the seed harvest has a big economic share when cultivating hemp and the fibres are further used for technical and industrial applications (see 3.2).

3.1.3 Today's Hemp Image

Industrial hemp, also called Cannabis Sativa (L.) in botany is facing an image problem. It is often confused with hemp for recreational uses, and therefore associated with the drug use. A lot of brands that offer hemp products use the distinct leave shape as their label, since it is easily recognizable. On the other hand, products and organizations, connected with the legalization of Cannabis, use the hemp leaf as well for their campaigns. This naturally leads to confusion for the layman. What the general public does not know is the fact that Cannabis Sativa is a crop, which has more than hundred varieties. Furthermore, different crops are developed for either achieving a high amount of THC - which gives the psychoactive effect - or a high fibre/seed yield in the plant (Decorte, 2011). Nowadays, some hemp products, like the seeds for the food industry, are en vogue. In the 1990s

one was not sure if it is advisable to eat the seeds or use the oil. Therefore, the Bundesinstitut für gesundheitlichen Verbraucherschutz (Federal institute for health consumer protection) in Germany claimed in 1997 that the consumption of those could be health risky (nova-Institut, 1997). The amount of THC in industrial hemp crops is so low that it is impossible to extract it from the plants. The allowed THC content in industrial plants cultivated in Europe is 0.2% maximum, whereas crops cultivated for recreational use reach THC contents of 8-10% or higher (BR, 2014). Due to the lack of knowledge within society the scepticism towards hemp was really high at the stage of reintroducing the cultivation of this crop in Europe. By the negative image spread about hemp for decades in

Figure 3. A banner to avoid confusion (Hempethics)

the past worldwide, it became the prevalent mind-set to reduce the crop to its psychoactive effect, which is non-existent in the industrial varieties (Decorte, 2011). A common argumentation of hemp opponents is the fear of farmers hiding a high-THC-content variety area within the fields of regular industrial hemp crops, to have a higher economic benefit through the sale of marijuana (Decorte, 2011). What is commonly unknown in that context is the fact that the cross-pollination of both crops would lead to a decrease of the THC content, which would be highly unfavourable for the drug end use (Bengtsson, 2009). Furthermore, the way of cultivating industrial hemp and recreational hemp is different. Industrial hemp crops often have a high sowing density, which means they are planted close to each other to achieve a maximum height of the plants. In contrast, the goal of the recreational variety cultivation is to keep them small, but achieve the highest amount of flowers and branches possible for a maximum harvest of those for the sale of marijuana (Decorte, 2011). Therefore, the sowing density is much lower compared to the industrial crops, farther leading to additional conflicts in the combined cultivation. Even if there was an approach of planting those two varieties together, it would be difficult for the recreational varieties to compete with the steadily growing plants, which further have advantages in the sunlight and water uptake. On these grounds, the worries of the opponents are unsubstantiated. Sometimes, this biased image of hemp also leads to issues for the industrial crop farmers. Within their living locations, they are facing accusations being considered as “drug farmers” and are occasionally blamed to be responsible for the drug consumption of individuals within the commune. For these reasons they have to deal with reputational damage (BR, 2014). To solve the lack of differentiation of the layman, institutions that promote industrial hemp call for an increase of education within society, to clear out misunderstandings towards Cannabis Sativa (Bengtsson, 2009).

Figure 4. Poster Hemp vs. Marijuana (CBD, 2016)

3.2 Industrial Hemp and its uses

3.2.1 Properties and Application Areas

Hemp offers robust bast fibres, which are divided in primary and secondary fibres. The primary fibres are longer and finer, whereas the secondary fibres are shorter and coarser. For the textile use, only primary fibres can be processed, since the size of the secondary fibres makes it impossible to process and spin them into homogenous yarns (Westerhuis, 2016). Nevertheless, the secondary fibres are valuable for other end-uses. In general, the fibres have a length from 5 to 55 mm and their diameter varies from 16 to 40 µm (Bengtsson, 2009). They are highly moisture absorbent, offer a good breathability and thermal insulation (Ebskamp, 2002) and have a superior UV resistance. Furthermore, it was found out that hemp fibres have anti-bacterial properties and a high absorbability of toxic gases (Jianchun, 2008). The primary and particularly the secondary fibres harvested in Europe are used for a variety of application areas. Still, the majority of the fibres is used for the production of pulp and paper, but they also gain importance in the use for bio composites, technical textiles and as insulation material. The amount of European hemp fibres used for clothing only amounts to 0.1% (see Figure 5). When cultivating hemp, no waste arises, since all parts of the plant can be used for different purposes (Jianchun, 2008). The Shivs are a by-product during the separation of the fibre from the core. At the so-called decortication process one kilogram of fibres leads to 1.7 kilograms of shivs. Since the shivs are highly absorbent, the biggest market for them is in the field of animal bedding, having a share of 63 %. Other application areas are in the use for garden mulch (19 %) and steadily growing in the construction area (16 %), e.g. as hempcrete (Guarini, 2012). Another profitable market for the farmers of industrial hemp is in the field of hemp seeds and oil. In Europe, the seeds have been almost completely disregarded in the past, but the great demand for hemp seeds on the food market led to a production increase of 92 % from 2010 to 2013. The most apparent rise of hemp products is recognisable in the production of flowers and leaves for pharmaceutical and food supplement industries. An increase of 3,000 % between 2010 and 2013 has been observed in this sector, to extract Cannabidiol from these parts of the crop (Carus & Sarmento, 2016). Additional to these application areas, the large amounts of biomass produced through cultivation gains further attention as biofuel and biogas alternative (Alcheikh, 2015).

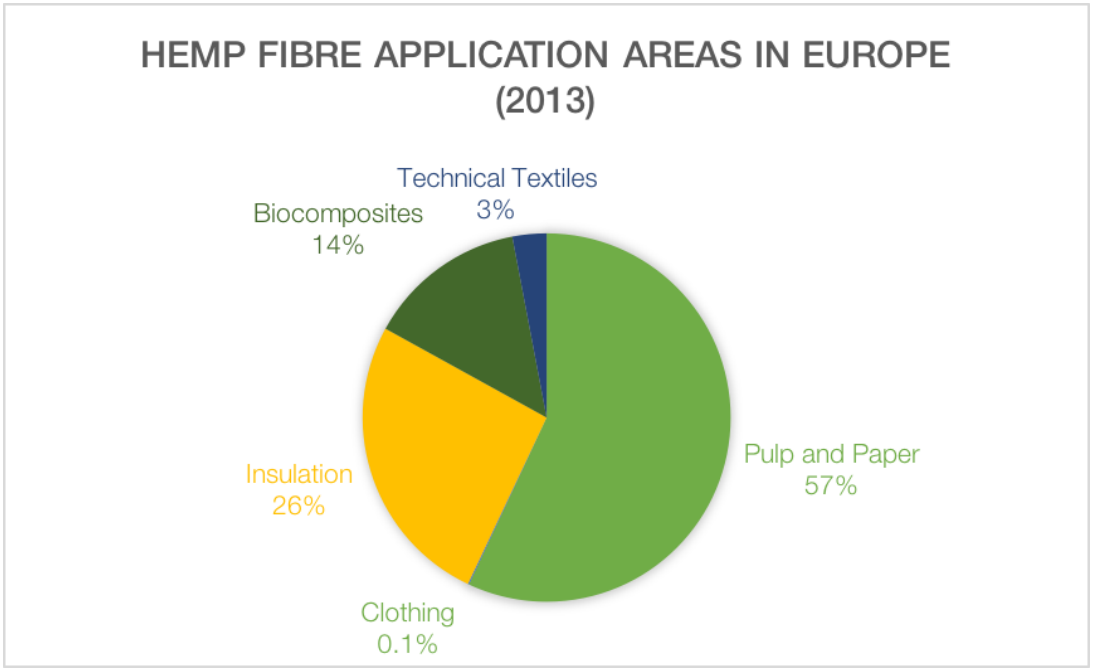


Figure 5. Application Areas of Hemp Fibres in Europe from 2013 (Carus & Sarmento, 2016)

3.2.2 Hemp Cultivation in Europe and Germany

About 20 years ago, the hemp cultivation in Europe was permitted again and since then the cultivation area highly varied in Europe and Germany, which can be seen in Figure 7. in 2001, the demand on hemp was higher than the actual supply in Europe. Due to a decrease of EU subsidies, the planned cultivation area increase could not be realized (Karus, 2002). The lowest cultivation area recorded since 1994, was in the year 2011, where it decreased to 8,000 ha. After 2011, the cultivation area increased again bit by bit reaching an area of 33,000 ha in 2016, which shows a significant growth. Still in 2013, only 10,000 to 15,000 ha were cultivated in the European Union, of which the main producers were France, United Kingdom and the Netherlands (Karus, 2002). Nowadays, hemp is industrially grown in 13 EU member states (EIHA, 2014). The main producing countries are France, the Netherlands and Lithuania (EIHA, 2016). Hemp is seen as a sustainable raw material for several different end uses, whereby the use in bioenergy production is considered as the market with the highest potential (Amaducci, et al., 2014). As mentioned before, the European hemp industry currently focuses on the cultivation of hemp straw for technical uses and on the seeds, where the demand is increasing rapidly in the past years (Decorte, 2011). The main target markets at the moment are using hemp for bio-composites, insulation and building material, as well as the nutrition market, since the growth expectations lie between 4 to 6 times for the future (Carus, Karst, Kauffmann, Hobson, & Bertucelli, 2013). Low and medium value fibre products are mainly made from European hemp, focusing on the total fibre line, which is cheaper, optimized and more efficient compared to the long fibre line. The latter is needed for high quality fibres and higher prices can be achieved on the market by processing those, but they highly depend on imported fibres from the Chinese textile industry (Carus, et al., 2008). In the past 20 years, a lot of different research projects towards hemp were executed. The latest EU project MultiHemp (Figure 6) was a collaborative project with Research Institutions, Universities, as well as small and medium enterprises from all over Europe. Participant parties were from Germany, France, the Netherlands, Slovenia, Italy, Latvia, Spain, the Czech Republic, Finland, The United Kingdom and Belgium. One goal of the project was to develop systems and techniques in the cultivation and processing, which make it possible to maintain both, seed as well as fibre yield on quality and quantity level. Existing technologies complicate the joint harvest of both parts, leading to inefficiency and economic losses (Amaducci, et al., 2014).

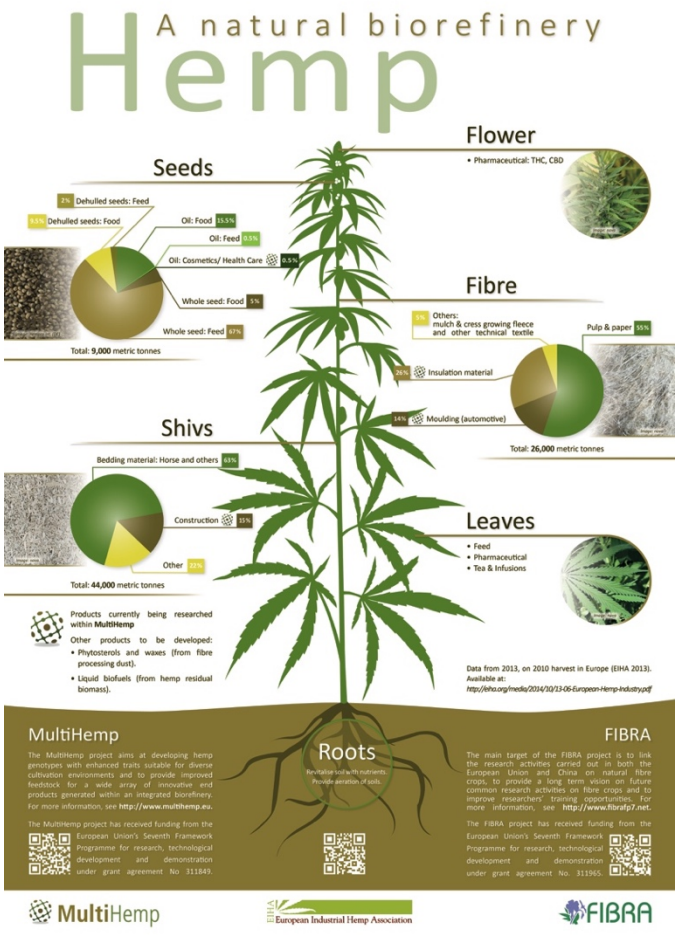


Figure 6. Poster of the EU Project MultiHemp (MultiHemp)

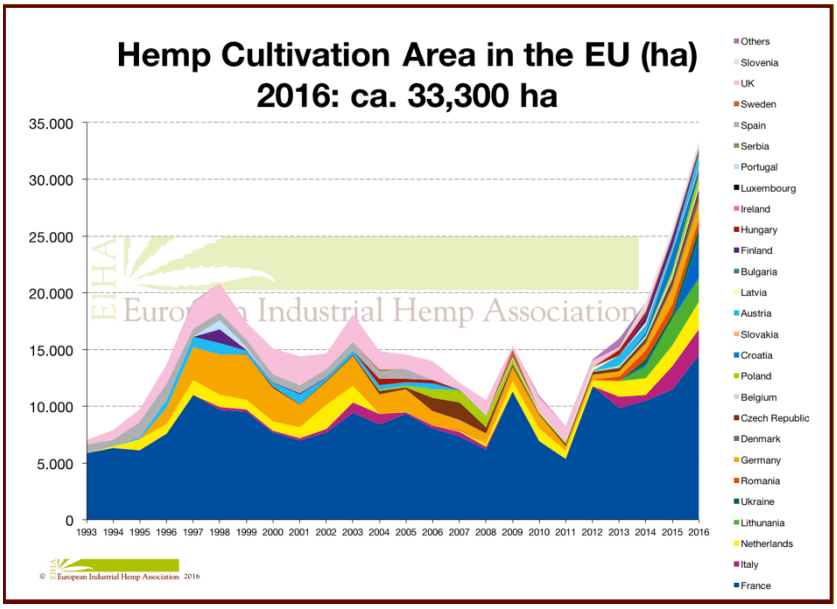


Figure 7. Cultivation Area in Europe from 1993 – 2016 (EIHA, 2017)

At the beginning of the German hemp industry in 1997 the country's cultivation area amounted to 2,800 ha Five fibre decortication plants were in operation, nine were in the building state. One of these was also suitable for processing the fibres for apparel and higher quality fibres and textiles (nova-Institut, 1997). The desired 30,000 ha of the German hemp industry in 1997 were just 0.2 % of the whole arable land in Germany, which would not have led to a big impact or scarcity in cultivation areas for other crops (nova-Institut, 1997). Nevertheless, this desired amount was never achieved and as shown in Figure 7, almost 20 years later the whole European Union firstly reported a cultivation area of more than 30,000 ha. The competition with bioenergy and biofuel crops led to an enormous decrease of hemp cultivation in Germany in 2011. This was caused by the assurance of high subsidies when cultivating those. It further led and still leads to unequal pre-conditions as the financial support of hemp crops is still lower (Carus & Sarmento, 2016). Just as in other European countries, hemp seeds make the biggest profit for the German farmers. The processing for hemp products is limited in Germany and thus more likely a niche industry (see Table 1). There are some small enterprises in Germany that strive to build up a garment value chain in Germany for domestic plants, focusing on hemp as raw material, like the BaFa GmbH situated in Malsch. However, the lack of suitable processing technology and the low willingness of the industry to invest makes it difficult to step out of the niche market. The existing harvesting method in Germany does not keep the fibres as intact as preferable for high quality fibres processing. The length of the fibres is decreased and the fibre surface is affected by that. The 4-meter-high stalks are cut in shorter ones with the combine harvester, and until now no other harvesting method for hemp exists in Europe. (BR, 2014).

Table 1. EU Hemp producers in 2014

Country	Company	Area (ha)	Country total
The Netherlands	HempFlax	534	
	Dun Agro	928	1,462
Germany	HempFlax (west)	209	
	HempFlax/BaFa (east)	127	
	Hanf Farm	150	486
Austria	BaFa	550	550
United Kingdom	Different small growers	160	160
France	LCDA	5,400	
	Internal Eurochanvre	1,700	
	Planet Chanvre	850	
	Cavac	1,100	
	CCPSC	730	
	Est Chanvre	120	
	All others (independent farmers)	600	10,500
Italy	Assocanapa	500	500
Romania	HempFlax Europe S.R.L.	650	
	Agraficient	100	750
Hungary	Hempro Int. GmbH & Co KG	250	
	Hemp Factory	100	350
Denmark	Dun Agro	162	162
Czech Republic	Different small growers	210	210
Slovenia	Different small growers	500	500
Slovakia	Different small growers	67	67
Croatia	Different small growers	300	300
Lithuania	Different small growers	1,061	1,061
Latvia	Different small growers	250	250
Estonia	Different small growers	210	210
Portugal	CANAPOR	5	5
Total			17,523

Note: Adapted from "Total Hemp cultivated area in Europe 2014" by European Industrial Hemp Association, 2015 ***(EIHA, 2015)***

3.2.3. Trends Worldwide

36 countries permit the hemp cultivation worldwide (Amberznectarz, 2016) and there is an increasing bast fibre demand on the world market for textile applications of high quality (Alexopoulou, 2016).
In 2011, the worldwide cultivation area for industrial hemp was 85,000 ha, of which 60,000 ha were cultivated for fibre purposes. The main areas were situated in China and Europe (Westerhuis, 2016). In several countries a growth in cultivating industrial hemp is observed. Canada focused on hemp cultivation for the use of seeds for the food and cosmetic industry in the past. Recently, the country also started to grow hemp for fibres, for the application in bio-composites, insulation and building material. Moreover, an increasing amount of states in the USA allows the cultivation of hemp (Figure 8), by which a growing hemp industry for fibres and seeds is anticipated in the country (EIHA, 2014). China is the most important country with regard to fibre hemp cultivation. The country produces the traditional long fibre as well as enzymatic cottonized hemp fibres for the export to Europe and Northern America (Carus, et al., 2008). China rapidly increased its hemp cultivation area in the past 10 years. In 2016, the country cultivated about 100,000 ha of hemp and rising (Woodford & Cui, 2016). Moreover, the government aims at cultivating 660,000 ha of hemp by 2020 (Bio-based News, 2009). Since several years already, the country has substituted its cotton production with hemp (Westerhuis, 2016) and in 2011, the organic cotton cultivation in China was much lower than the hemp cultivation area (Textile Exchange, 2012). In 2013, the sales of Chinese hemp yarns grew by 145.2 % compared to 2012 (Amberznectarz, 2016). Since China is strongly increasing its cultivation area of hemp, being the biggest supplier of hemp fibres, it was stated that the European hemp industry could only be competitive, if it is able to offer fibres of high quality instead of high quantities (Westerhuis, 2016).

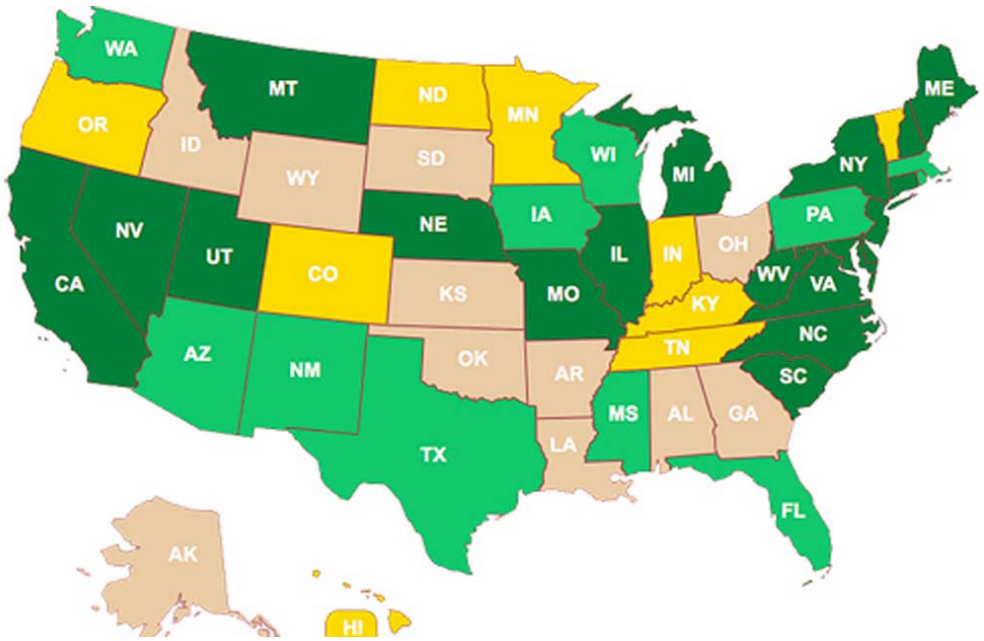


Figure 8. Map of the USA illustrating the current Hemp cultivation; Yellow: states that legally growing industrial hemp, dark green: states that passed the legislation in favour of hemp cultivation, light green: states considering the legislation (Haas, 2016)

3.3 Hemp Cultivation & Processing

3.3.1 General

Figure 9. Industrial hemp field (Hearst, 2013)

Hemp is an annual plant, growing from the seed every year. Depending on sowing density, it can reach heights from one to five metres, having a stalk diameter between 2 to 2.5 cm (Francis, 1996). The complete growing season of a hemp plants from germination to seed maturity takes between 4 to 6 months on average (Bengtsson, 2009). Under optimal weather conditions the plants grow from 6 to 10 cm per day (Bengtsson, 2009). This fast growth is beneficial for the weed control, since the crop is suppressing the weeds by that. This is the reason why hemp is one of the only crops where no herbicides and pesticides need to be utilised in the cultivation (Schumann, Peil, & Weber, 1999). They grow on almost every soil, taking into account that the preferred soil for hemp cultivation is sandy loam or clay loam having a pH of 6.0 to 7.5 (Amaducci, et al., 2014).

Since the roots can grow down to half a metre belowground, the plant takes its required water uptake from the ground water (BR, 2014). For the whole growing period about 500 to 700 mm of precipitation is needed (Bengtsson, 2009). In case of additional water irrigation, the crops height and stem diameter can be further increased, which however is not required in Germany (Schäfer, 2005). As no water irrigation and weed control needs to be performed, it is also called low-input cultivation, as it causes less work than other crops (Amaducci, et al., 2014). The plants root system additionally has a positive effect for farmers, as it aerates and improves the soil structure. (Bengtsson, 2009). The way of cultivation is always based on the crop purpose (Amaducci, et al., 2014). The hemp varieties largely differ in their fibre content. Therefore, the variant needs to be well chosen (Westerhuis, 2016). Often, monoecious plants are used for the fibre production, as they show an advanced uniformity in growth (Bengtsson, 2009). Monoecious plants are plants, which have male and female organs on the same plant, but in different flowers (Dictionary.com Unabridged). On the other hand, male plants are frequently preferred for fibre use, since they grow taller, the stems are thinner (Bengtsson, 2009), and their fibre composition is superior compared to female plants (Schumann, Peil, & Weber, 1999). As already mentioned before, industrial hemp contains primary and secondary fibres of which the primary fibres are utilisable for the textile end use. These primary fibres are produced during the so-called vegetative growth phase of the plant before flowering (Bengtsson, 2009). The flowering generally occurs between 70 to 90 days after sowing, the harvest of the seeds normally happens 4 to 6 weeks later (Sheppard, 2017). When cultivating fibre crops, the sowing density is higher than for seed crops, as the plants are primarily growing in height and less in width. This leads to a higher stem yield, even if not necessarily to a higher bast fibre yield (Francis, 1996).

3.3.2 Climate

Industrial hemp plants can stand cold and heat (BR, 2014). They have the ability to grow under mild and cool climates, preferably having a humid atmosphere for fibre production (Bengtsson, 2009). The plant endures light frosts, which outlines advantages towards other crops, e.g. corn (Francis, 1996), being able to survive cold temperatures down to -8 to -10 C° for a shorter time. The fibre yield increases in rainy years during the growth phase of the crop (Schäfer, 2005). For an increase of the total growing time, early sowing is frequently done. A thread in doing this is the risk of the plants being frostbitten by that (Amaducci, et al., 2014). Hence, early seeding can be risky, but it also increases the total fibre yield and can enable the farmer to harvest and ret before sudden frost occurs (Francis, 1996). The favoured cultivation temperature lies between 19 to 25 C°, even if they are also growing well from 14 to 27 C° (Bengtsson, 2009). Depending on weather conditions, the retting time on the field needs to be taken into account. Cold and rainy weather leads to lower quality harvest, since it impacts the retting procedure negatively (Venturi, Amaducci, Amaducci, & Venturi, 2007).

3.3.3 Legal factors, regulations and subsidies

When farmers decide to cultivate a specific crop, they need to inform themselves about the given rules and regulations that are related to it. Furthermore, their decision is linked to the work and time effort, the profitability, as well as to the amount of subsidies that can be granted by federal institutes. On the European and German level there are high regulations for hemp cultivations (Decorte, 2011). Every year, the EU decides which varieties are allowed for the cultivation. If a variety can be cultivated in the coming year, depends on tests concerning the THC content. If a variety, that has been grown in the preceding year, contains more than 0.2 % of THC it will be removed from the list for the next year (Bengtsson, 2009). This list can be changed until mid of March of the new cultivation year. The cultivation of hemp has to be registered at the government and only certified seeding material must be used. Its labels have to be sent to the federal offices to provide evidence (BLE, 2017). In 1996, just 12 varieties were registered in the EU (Schumann, Peil, & Weber, 1999). The increased research and development in low-THC types of the past 20 years for different end uses led to a total list of 52 varieties being authorized nowadays (Table 2). After the registration, the farmer can apply for subsidies, which amount to 300 € per hectare in Europe (and 90 € per tonne of hemp fibre) (Decorte, 2011). In some countries it is even mandatory by law to apply for those, to consider the crops as legal and not as use for narcotic application (Bengtsson, 2009). Moreover, the hemp farmer cannot decide freely when he wants to harvest the crops and the flowering must be reported to the federal institutes (BLE, 2017). For monitoring purposes, the flowers have to be analysed and therefore harvesting before, and until ten days after the flowering is completely forbidden. Only if the seed maturity is completed already, the plants can be harvested at an earlier state (Bengtsson, 2009). All the above-mentioned rules count for the German hemp industry as well and no other crop has so many regulations when it comes to cultivation in Germany (BR, 2014). Depending on those policies and economy frameworks the hemp industry can be in- or decreased (nova-Institut, 1997).

Table 2. Hemp variety list 2017

Variety names	
Antal	KC Dora
Armanca	KC Virtus
Beniko	KC Zuzana
Cannakomp	Kompolti
Carma	Kompolti hibrid TC
Carmaleonte	Lipko
Chamaeleon	Lovrin 110
Codimonto	Marcello
CS	Markant
Dacia Secuieni	Monoica
Delta-Ilosa	Rajan
Delta-405	Ratza
Denise	Santhica 23
Diana	Santhica 27
Diocia 88	Santhica 80
Eletta Campana	Secuieni Jubileu
Epsilon 68	Silvana
Fedora 17	Szarvasi
Felina 32	Tiborszallasi
Ferimon	Tisza
Fibranova	Tygra
Fibrol	Uniko B
Finola	Uso-31
Futura 75	Wielkopolskie
Ivory	Wojko
KC Bonus	Zenit
Total	52

Note: Adapted from "Anbau von Nutzhanf – Sortenliste" by Bundesanstalt für Landwirtschaft und Ernährung, 2017, ***Official form sheet (BLE)***

3.3.4 Harvesting, Processing Steps and Machinery

3.3.4.1 Harvesting, Retting and Decorticating

Figure 10. Hemp fibre harvest (CHTA, 2017)

As well as in the cultivation, the harvesting and processing techniques vary with the end use of the crop. There are three major steps, excluding after treatments, being executed until the spinning preparation processes, like hackling or drawing takes place. These steps are the actual harvesting, the retting, and the decortication (Figure 12) and they have a big impact on the later fibre quality. In the following sub-chapter, these steps regarding hemp fibre end-use are described.

First of all, the harvest time of hemp for fibre end-use is of great importance. Factors, like optimal fibre separation and fibre quality are most crucial. A low lignin content in the plant is essential to reach a high quality fibre. When the primary fibres are formed in the vegetative phase, the amount of lignin is on its lowest stage (Bengtsson, 2009). On the other hand, the harvest time of the plants concerning ideal separation of the fibres from the shivs and bark is determined to be at the beginning of seed maturity, right after the vegetative phase, after flowering (Bengtsson, 2009). On a quality and cost level it is of high importance for the fibre hemp farmer that the decortication, the separation of the fibres from the core, can be performed as easy as possible. The more difficult the decortication of the fibres from the stem is, the more negative is the impact of this mechanical process in terms of fibre quality (Amaducci, et al., 2014). Nowadays, fibres and seeds are usually harvested at the same time (BR, 2014), even if the optimal harvest time for the fibres is before until immediately after flowering and before seed maturity takes place (Francis, 1996). As mentioned above, the primary fibres are formed in the vegetative growth before flowering. From the beginning until the end of flowering the fibre content can decrease to 5% (Schäfer, 2005). After flowering, the amount of fibres stays the same but at that stage until seed maturity, the quality of the remaining fibres decreases (Amaducci, et al., 2014), as the secondary fibre amount increases with plant weight (Westerhuis, 2016).
There are two different harvesting methods being most commonly used in Europe nowadays. The first one is called whole stem harvesting, where the whole stem length is retained for the subsequent processing steps. This technique leads to longer fibres, but the required machinery for that is rare in Europe. The second method being applied more often, due to higher machine availability, is the cut stem harvesting. Here the stem is separated or shredded in different sections, which consequently leads to shorter fibres of lower quality (Pari, Baraniecki, Kaniewski, & Scarfone, 2014). To facilitate the further processing steps and guarantee higher quality of the end product it is important that the cut stems are laid down as parallel as possible. After the harvest, the retting needs to be carried out. The retting process is one of the most important steps in the hemp process chain. There are two different kinds of retting.

Figure 11. Hemp field retting (CHTA, 2017)

The first one is the field or dew retting (Figure 11), which is commonly performed in Europe, even if its outcome is highly dependent on weather conditions of the season. While regularly monitored and being turned for several times, the stems are left on the field for 4 to 6 weeks. This method is inexpensive and eco-friendly, due to little labour effort and no use of water. The second method is the water retting. In the course of this method, the parallel aligned stems are gathered after harvesting into fibre bundles and immersed in water, e.g. tanks. This method leads to a more uniform outcome of the fibres, offering a higher quality (USDA). On the contrary, this method is highly labour intensive and huge amounts of water are needed. Therefore, this method is widely abandoned in European countries and almost exclusively applied in China. In both techniques, under- as well as over-retting should be avoided. If a yield is under-retted the bast fibres will be coarser, whereas over-retting leads to a decrease in fibre strength (Bengtsson, 2009). After the retting process is successfully performed, the separation of the fibre from the woody core, the so-called decortication, takes place. It generally consists of two steps. The first one, is the breaking, where the retted hemp stalks are passed through fluted rollers, breaking the core into small pieces, called shivs or hurds. In the second step, the scutching, the remaining shivs are removed and the short and long fibres are separated by passing the fibre bundles through rubber belts and transporting them to revolving drums with projecting bars, to beat the fibre bundles. These processes can also be performed in a combined machine, called decorticator (USDA). After the completion of the afore-mentioned steps, the hemp fibres are transported to the hackling machine, which is combing the fibres and further separates the shorter from the long ones. Subsequently, the produced slivers go through several drawing stages to achieve evenness for the spinning. Fibres that are meant for the high quality end-use, undergo finishing processes to facilitate spinning and create softer feel of the produced yarn. There are different after treatments, which can be applied to hemp to allow improved fibre properties. These are further explained in section 3.3.5. After the finishing, the sliver is wet spun or dry-spun, whereas the wet spinning process is most common for bast fibres (Kiron).

Figure 12. Graphic showing the Hemp fibre processing steps before spinning preparation

3.3.4.2 Machinery factors

Figure 13. HempFlax Double Cut Combine (HempFlax, 2016)

Hemp fibre processing nowadays, commonly takes place on conventional flax processing machinery. These machines have a maximum harvesting and processing length of one metre, which means the long hemp stems need to be cut in several pieces for these operations (Pari, Baraniecki, Kaniewski, & Scarfone, 2014). On a technical level it is possible to develop machinery of 2 to 3 m length, but until now profitability and expenses are unbalanced and the flax fibre market is still higher than the hemp fibre market, leading to minor investments (Venturi, Amaducci, Amaducci, & Venturi, 2007). Flax harvesting and processing machinery can be used in a better way for Baby Hemp, which is purposely grown in lower height. However, an obstacle farmers are facing while harvesting, is a loss of seeds (Venturi, Amaducci, Amaducci, & Venturi, 2007). Moreover, differing stem diameters make it difficult to adapt the harvesting machine in order to minimize the losses of seed as a result of shaking plants. This happens especially when the stem diameter of the crop stems is highly variable. To allow the harvest of every single part of the hemp crop, the Dutch company HempFlax developed a harvester called double cut combine (Figure 13). The machine makes it possible to harvest the stems, the seeds and the leaves at the same time. HempFlax is one of the few companies in Europe that is specialized in harvesting and processing machinery for hemp crops and also offers wood, seeds and fibres (HempFlax, 2016). Nevertheless, their production line focuses on the total fibre line, which excepts the production of high quality fibres.

The variety in diameters of different stems or stem regions (bottom and top), leads to another issue at the stage of fibre separation. Separating the fibres from thicker stems, causes higher residues from the core, while the separation of fibres from thinner areas causes high damage to the fibres. Resulting from that, the decorticated fibre bunch is highly variable in size, fineness and cleanliness, which makes it difficult to spin high quality yarns from that (Venturi, Amaducci, Amaducci, & Venturi, 2007). Additionally, there is a lack of harvesting and processing machinery in Germany and Europe, which leads to complications for the hemp farmers. Often, hemp farmers are sharing their machinery in specific regions. This regularly leads to bottlenecks and delayed harvesting, further causing economic and time-dependent problems (BR, 2014). In cases of high quality textile processing the existing machinery needs to be further adjusted to create a more profitable process chain. If the demand on high quality fibres out of hemp was higher, it would be more attractive to adjust the

machinery. On the other hand, adjusting the machinery would make it more attractive for the high quality textile market to integrate hemp in their products, due to higher efficiency and therefore lower production costs (nova-Institut, 1997). The owner of a hemp processing chain in Germany, Bernd Frank states in an interview with Bavarian Broadcasting (BR) that his produced hemp fibres are only applicable for pellets, which are used for bio-composites in the industry. The lack of investors makes it impossible for him to develop a long fibre line for the production of high quality fibres. (BR, 2014).

Figure 14. Green hemp decortication with a combine (ETH, 2006)

In general, it is to say that there are almost no existing long fibre lines in Europe and Germany. Furthermore, it is still difficult to automate the whole production process of hemp fibres, since some manual process steps could not be optimally replaced by machinery yet. Therefore, more time and labour is needed, which further leads to higher end-prices of the products (Leupin, 2009).

Additional to that, the processing and production facilities necessary in the textile value chain have moved to lower wage countries, particularly in Asia (Stegg, 2001). This development of the last decades ruined the European textile industry and makes it less attractive to shift back production steps of the textile supply chain to Europe. An approach to shorten the processing and avoiding fibre damage, due to field retting, at the same time was made in Switzerland, where the so-called green hemp decortication was approached (Figure 14). In this process the hemp is decorticated directly after harvesting without any retting process. In the further process chain trial, the hemp fibres were degummed through a chemical treatment, dried and subsequently drawn to produce a sliver. After that, they were ring or rotor spun and yarns of 50tex fineness could be produced (ETH, 2006). However, pure hemp fibres were difficult to be spun and they had to be blended with cotton, Viscose or Lyocell. This shows that a pure hemp yarn production still turns out to be difficult, as machinery is not adjusted to it, leading to inefficiency and hemp yarn prices up to 50 times higher than comparable cotton yarns (Leupin, 2009).

Figure 15. Hemp yarn produced during project in Switzerland (ETH, 2006)

3.3.5 Modifications of Hemp

Improving the quality of an end product can be achieved through a variety of attempts within the production chain. Initially, the problem needs to be determined, followed by the reason causing this problem. The same applies to hemp as raw material for textile applications. Therefore, different means of achieving high quality hemp fibres were developed and considered in the past decades.

3.3.5.1 Finishing Techniques

To improve hemp fibres in terms of quality, feel and easier processing, different methods were developed in the past. All of these methods are generally known as cottonization of hemp. The goal of these processes is to decrease or eliminate the lignin or pectin content of the fibre. Pectin is part of the plants' cell wall and important for the binding of the cells (Mohnen, 2008), whereas lignin fills the spaces within the cell wall, between pectin and other components, like cellulose and hemicellulose (Haak, 2017). Therefore, both components are essential during the growth of the crop, although these components are highly unfavourable for high-quality fibre processing, as they make the fibres stiffer, coarser and hence more difficult to process. The cottonization process primarily performed in China aims at decreasing the lignin content from 8-10 % to 0.2 % through a physical-chemical degumming technique. Firstly, the hemp fibres are immersed in acid for an hour at 50 C°. Secondly, the fibres are boiled in an alkaline solution for three hours at a temperature of 100 C°. After that, the fibres are dried, opened and stretched and have a cotton-like feel (Figure 16) (Yu, 2013). Another method that is applied, is the so called steam-explosion. It was invented at the Hochschule Reutlingen, and further developed by the Dutch company StexFibers in collaboration with the University of Wageningen (StexFibers BV). In this process the fibres are put in a container with a warm aqueous alkaline solution. The container is put under pressure up to 15 bar. After opening the pressure valve and the followed pressure drop, the water in the fibres vaporizes and the fibres bundles are opened. In this way, the fibres become cleaner, finer, better separated, and more uniform (BR, 2014). The third method is the CRAILAR technique, developed by an US American company in collaboration with the Canadian National Research council. After decades of research, the company developed a patented method that removes all pectin in the hemp fibre. It is an enzymatic process through which the fibres become softer and are able to be spun and further processed on conventional cotton machinery. The company already works together with companies like IKEA and Adidas (Long, 2015).

Figure 16. Cottonized hemp from China (Yu, 2013)

3.3.5.2 Cultivation

Despite the approach of improving the fibre through after treatments, the modification can already take place along the cultivation (Amaducci, et al., 2014). Apart from choosing the right variety for the purpose of high fibre yield, other cultivation factors need to be examined to achieve an optimal fibre harvest. The fibre content of hemp crops is higher on sandy soil, compared to plants growing on loamy soil (Schäfer, 2005). If a soil is too marshy, holding too much water, the fibre's tensile strength is negatively affected (Bengtsson, 2009). Moreover, it is said that growing shorter crops, increases the fibre quality, since they are easier to harvest and lead to more homogenous fibres (Westerhuis,

2016). Naturally, longer stalks offer more fibres, but only thinner stalks contribute to a better fibre quality (Bengtsson, 2009).The use of fertilizers, like Nitrogen, should be avoided for fibre crops. Even if it increases the height, diameter and total biomass of the plant, it has been observed as unfavourable for the fibre content of the crop (Schäfer, 2005). Keeping the amount of secondary fibres low during the cultivation is crucial to achieve high quality yarns from the harvest, since the separation of the primary fibres from the secondary fibres is technically challenging and the secondary fibres are too short to be spun properly. (Westerhuis, 2016). Consequently, the quality could be increased with earlier harvest time (BR, 2014).

3.3.5.3 Molecular Determination

Since no optimal processing machinery exists for the textile end use, the crop often has to be modified to work well with existing machinery (Venturi, Amaducci, Amaducci, & Venturi, 2007)
Therefore, another approach is set even earlier, before the cultivation. It starts in the field of molecular plant biology, aiming at improving the plant starting material (seeds). Researchers try to understand molecular processes of hemp, concerning cell metabolism. Fibre properties are determined by the cell wall composition of the plant. It consists of different cellulose, hemicellulose, lignin and pectin complexes, and structural proteins. Finding the optimal composition of these, and developing seeds offering it, which would further lead to fibres of higher quality, is another interesting method. One specific idea is to decrease the amount of lignin in hemp. The higher the amount of lignin in the plant while harvesting, the lower is the fibre quality. A decreased lignin level therefore could lead to improved fibres, offering better comfortability through increased softness of the fibres (Ebskamp, 2002). As already mentioned before, farmers are driven by economic aspects to harvest the hemp plants when the seeds are ripe, since those generate the highest income for hemp cultivation. Hence, another idea is to develop a crop, where fibre quality is optimal at stage of seed maturity (Amaducci, et al., 2014). In this case farmers would not have to choose between the seeds and a higher fibre quality in the plants. Hitherto, this approach was not yet achieved, but it could eliminate an essential issue for the industrial hemp farmers.

As outlined in this section, there are miscellaneous attempts to improve the performance of hemp fibres. Despite the molecular determination, chemical-physical methods, and the improvement by cultivation methods, researchers investigated in other chemical and enzymatic treatments for improved retting processes and for a facilitation of the decortication process, to decrease the extent of fibre damage during this process (Ebskamp, 2002). China, moreover, delved into another direction concerning hemp fibres. The country already has the most specialized hemp industry for high quality textile uses. As mentioned before, it cottonizes hemp to improve the fibre properties (Figure 16). Furthermore, China developed hemp viscose filament and staple yarns (Figure 17) out of the hemp shivs, which are a by-product during the fibre decortication. These yarns are very fine and have strong anti-bacterial characteristics. From 3 kg hemp shivs, 1 kg viscose yarns could be produced (Jianchun, 2008).

Figure 17. Chinese Hemp Viscose fibres (CPT)

3.4 Hemp and the Apparel Industry

3.4.1 Hemp Demand in the Fashion Industry

Even if the first Levi's Jeans was made out of hemp and 80 % of the clothing was made from hemp until the 1920s (Eartheasy, 2014), the crop has fallen into oblivion as raw material for apparel. Nowadays, pure hemp is only produced for high value niche markets. Until now, the demand of high quality fibre hemp is still too low (BR, 2014). This low demand originates from very different developments in the past and is also influenced by changes and evolutions within the fashion industry, which complicate the competitiveness of hemp. There is a variety of factors that need to be taken into account when deciding for a specific raw material. Depending on the end application, the morphology of the fibres, the fineness, surface characteristics and tensile strength are some major factors (Amaducci, et al., 2014). When machines for the hemp processing were introduced, the main purpose was to decrease the labour-intensive steps within the process chain. On the downside, the fibre quality being achieved by that was suffering compared to the manual processing (Venturi, Amaducci, Amaducci, & Venturi, 2007). Even today, the industry is still facing the issue of limited availability of high quality fibres (Jianchun, 2008). Additionally, the technological gap in processing high quality fibres leads to increased raw material costs for brands that are considering to use hemp in their products (Alexopoulou, 2016). Hitherto, no growing potential for hemp in the apparel industry is stated (Carus, Karst, Kauffmann, Hobson, & Bertucelli, 2013)

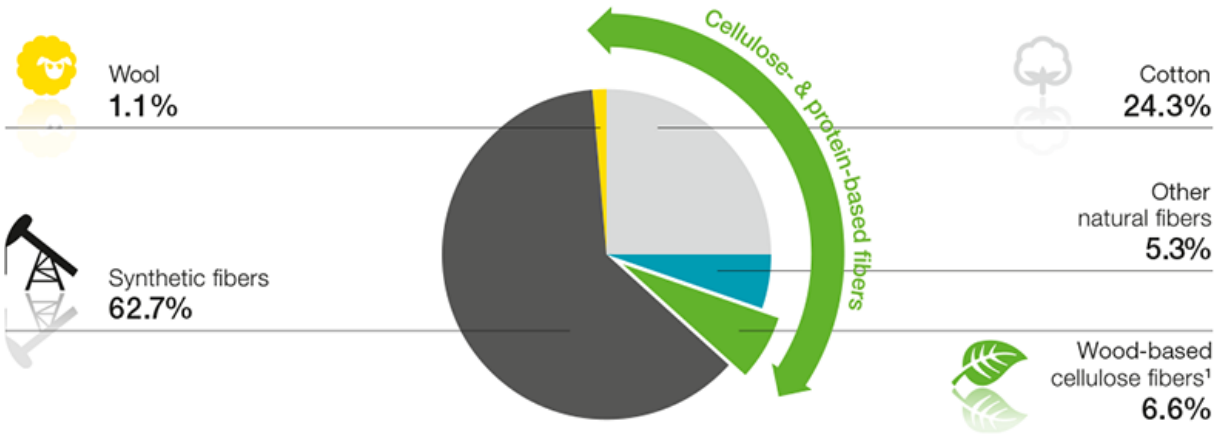


Figure 18. Global fibre consumption in 2016 (Lenzing Group, 2017)

3.4.2 The Global Fibre Market

Another influencing factor also lies in the current global fibre consumption of conventional fibres. Even if it is anticipated that the worldwide fibre demand will exceed the availability in the coming 15 years (Figure 19), the present demand on fibres is nearly covered by cotton and man-made fibres (Figure 18). Both together make up the largest part of fibres used, amounting to nearly 90 % of the world share (Westerhuis, 2016). Moreover, hemp is also facing high competition with exotic fibres, like kenaf, bamboo, or sisal. To guarantee a fairer competition on the European market, the European Industrial Hemp Association (EIHA) is promoting the introduction of a sustainability certificate for all imported as well as domestic natural fibres (Carus & Sarmento, 2016). Additionally, fibre hemp competes with a domestic fibre, as well. Linen is easier to process and therefore has a lower market price (Westerhuis, 2016). Although hemp has a more fertile yield, needs less herbicides and shows less impurities in the hemp straw than flax, hemp still cannot compete economically with its domestic competitor (nova-Institut, 1997). On the other hand, the most used fibres nowadays, cotton and

man-made fibres, are causing big environmental issues (Westerhuis, 2016). The production of man-made fibres needs large amounts of energy, chemicals and fossil oil, which only exists in limited quantities, leading to higher prices in the long run (Davies R. , 2016). Furthermore, these produced polymer yarns are not biodegradable and the garments are releasing micro fibres, which are smaller than 5 mm length, while washing. The brand Patagonia found that 1.7 g of these fibres are discharged per synthetic fleece jacket, each time it is being washed (Paddison, 2016). By that, the fibres can contaminate the water ways and food chain. After a paper published in 2011 by Marc Browne, a senior research associate nowadays, the approach on saving resources and reducing waste, by recycling the polymers is questioned as well. It was found that the recycled fabrics are releasing more and smaller micro fibres, which are consequently even more difficult to be filtered out (Messinger, 2016). Cotton cultivation and production is also known to have a negative impact on the environment. Large amounts of pesticides, herbicides and fertilizers are needed for the crop, poisoning rivers and groundwater. Since the cotton cultivation is restricted to sub-tropical climates, a lot of irrigation water is applied to the plants and its intensive monoculture in some areas leads to soil salinization and degradation (WWF, 2017). The cotton further has an impact on the regions, where it is cultivated. These necessarily large amounts of water being applied to the crops cause drying up of natural water resources and promote droughts in these areas. Therefore, the population has to deal with water scarcity (Organic Cotton). The life cycle assessment for different hemp products confirms a high potential for ecological product lines. The variety of end products and the complete exploitability, meaning no waste production, are attractive in this sense (nova-Institut, 1997).

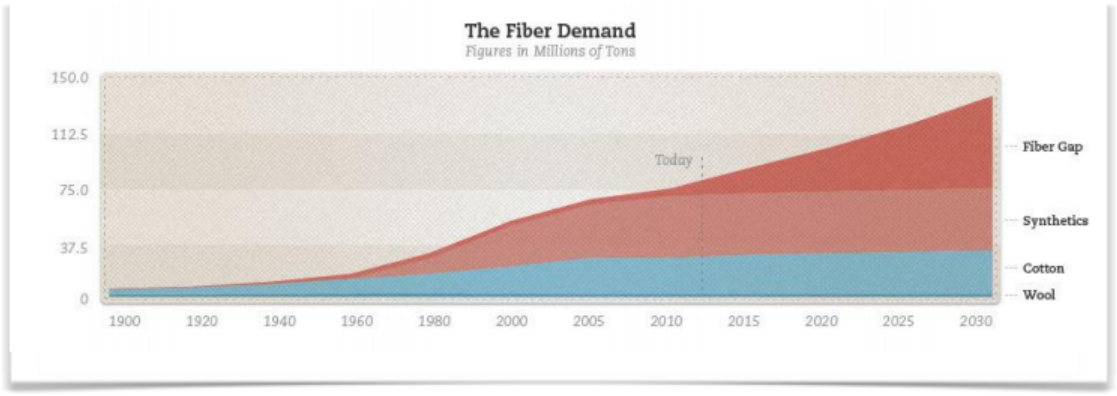


Figure 19. Global fibre market development and forecast until 2030 (Long, 2015)

3.4.3 The Fashion Industry

Step by step the fashion industry reacts towards unsustainable practices within its supply chain, also by substitution of conventional fibres. On the other hand, there is another change in the fashion industry being counterproductive towards these practices: fast fashion. Fast fashion and sustainability are the biggest trends in the fashion industry nowadays. These two major developments though, act conflicting to each other. The amount of fashion cycles per year is increasing, resulting to a higher amount of items offered (Johansson, 2010), whereas the fashion industry also tries to improve its value chain towards sustainability. Even if their market share increases, fair trade and GOTS certified items still represent a small percentage. With a total of two-thirds of the world sales,

the EU is the most important region for fair trade. The biggest market within the EU is United Kingdom, followed by Germany (Davies R. , 2014). Nevertheless, these products still operate in a niche market. Many producers of clothing aspire to change their unsustainable supply chain, which also includes using more sustainable raw materials. Nowadays, the brands' focus is commonly put on organic cotton or recycled materials, like recycled polyester to create a more environmental friendly value chain. C&A's goal being set for 2020, is to use 67 % sustainable raw materials in their products. Moreover, the brand wants to increase their organic cotton use from 40 % in 2015 to 100 % in 2020 (C&A, 2015). The latter vision also applies for the H&M group. Other goals, the H&M group sets is to use 100 % sustainably sourced or recycled raw materials by 2030 and become climate neutral and further even climate positive by 2040 (H&M group, 2016). These examples of two global players in the fashion industry show that there is a positive change towards more sustainable sourcing of apparel. On the other hand, these visions can only be realized in the long run, if consumers are willing to pay more and if they act according to that as well (Davies R. , 2014). NGOs and campaigns, like the Fair Wear Foundation or Fashion Revolution, are trying to raise the awareness of the end consumers and support brands in improving their supply chains concerning sourcing and production. These campaigns not only focus on environmental consciousness, but also on enhancing the conditions for textile workers around the globe (FWF, 2017). The Fashion Revolution campaign came up with a hashtag encouraging consumers contributing to a change in the fashion industry. By referring to the hashtag '#whomademyclothes' (Figure 20) consumers address their favourite brands directly and demand more transparency, sustainability and ethics. By that, the movement wants to create a closer dialogue between brands and consumers. In promoting more involvement, it makes the supply chain more tangible for the end consumer (Cadwell, 2017).

3.4.4 Consumer Behaviour

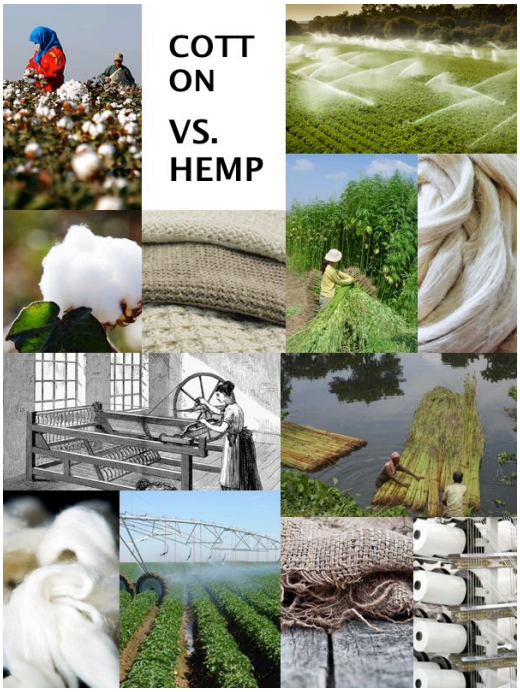
The increase of individualism, especially within Western societies, led to an increased consumption of fashion items, promoting the fast fashion movement. Especially for younger people it is important to have a diversified closet, which makes them rather buying several cheaper items than just one garment being costlier (Harris, Roby, & Dibb, 2016). The dominant factors when buying a garment are price, quality and style.

Figure 20. Poster by Fashion Revolution (Ruhrstyle, 2016)

For most consumers the textile value chain is too complex, environmental impacts of production and fibre use are intangible for the end consumer (Harris, Roby, & Dibb, 2016). Even if the awareness towards sustainability is growing, it is still limited to a small target group. One reason for this is that sustainable clothing is still perceived as less stylish, less fitting and uncomfortable (Harris, Roby, & Dibb, 2016). Another reason is the fact that, according to studies, the consumer's awareness about sustainability issues within the textile industry does not automatically lead to consequent action (McNeil & Moore, 2015). A study has shown that more than 40 % of the Europeans would be willing to pay more for sustainable clothing, but not all of them act according to this statement. Still, factors like price, taste, brand and fit are of great importance when buying clothing. Furthermore, it was ascertained that older consumers rather buy ethical textile products than young people. Women make a greater contribution to buying ethical fashion than men, and the higher the education level, the higher is the amount of people buying sustainable clothing (Davies R. , 2014).

3.5 Cotton versus Hemp

3.5.1 Cultivation & Processing



Cotton is the most used natural fibre in the textile and apparel industry. Like hemp, its cultivation and processing has long tradition in the human history. Some reasons why hemp is considerably less used in the fashion industry are already stated in the previous sub chapters. This sub chapter serves to directly compare cotton and hemp in terms of cultivation, processing and properties.

2.4 % of the worldwide arable land is used for the cotton cultivation (Westerhuis, 2016), resulting to about 25% of global fibres used (Lenzing Group, 2017), and about 20 million tons production per year (WWF, 2017). The global hemp fibre use for textiles amounts to less than 1% (Cherrett, Barrett, Clemett, Chadwick, & Chadwick, 2005) with a total production of 69,000 tons (Averink, 2015). The regions, in which cotton can be grown are limited to those in sub-tropical climates, whereas hemp can grow almost everywhere (Bengtsson, 2009). 73 % of the cotton production derives from areas, where the soil needs to be irrigated (WWF, 2017), whereas hemp crops mainly grow in moderate climate regions, where almost no irrigation is needed (Bengtsson, 2009). Additionally, most cotton cultivation areas are situated in water scarce regions. This water shortage is further increased through the cotton production (Averink, 2015). For the production of 1kg cotton fibres the required amount of water is around 10,000 litres (Cherrett, Barrett, Clemett, Chadwick, & Chadwick, 2005), but can rise up to 20,000 litres according to WWF (WWF, 2017). For the production of 1 kg hemp fibre the water being necessary for it amounts to about 2,100 litres (Cherrett, Barrett, Clemett, Chadwick, & Chadwick, 2005). This means, the water use for cotton exceeds the hemp water use in a range of 5 to 10 times. Including all processing steps for hemp and cotton textile, from cultivation to fabric, the total water footprint of cotton is more than three times larger than the one of hemp. When growing hemp, nearly no herbicides, pesticides and fertilizers are applied to the crops (Bengtsson, 2009). As opposed to this, 50 % of the pesticides being used in the USA and developing countries, and 25 % of the globally utilized insecticides result from the cotton cultivation (Westerhuis, 2016). In case of further processing, cotton has key advantages in many areas. First of all, the processing of cotton fibres is easier than the processing of hemp fibres. Concerning energy use and efficiency, cotton is taking the lead. Since the invention of the cotton gin and the spinning jenny in the 18th, the machinery for cotton production and processing could be more and more refined in the past 250 years. Most processing technology for natural fibres being developed in the textile industry focuses on the use of cotton as raw material (Max, 2017). This is deduced from the fact that cotton still is the most used natural fibre. Comparing the processing technology of hemp and cotton fibres, it is visible that the majority of the machinery used for hemp was not directly developed for operating with hemp crops and fibres. Moreover, these machines derive either from the cotton or linen harvesting and processing, even if sometimes slightly adjusted for hemp. Due to the prohibition of cultivating industrial hemp in many countries in the past for many decades, little research and progress was made, in terms of optimizing the crop, cultivation, processing and machinery. The spinning process

being applied to spin long bast fibres for instance, is slower than existing cotton spinning processes (van Dam). The production of cotton fibres nowadays, is cheaper and more efficient by comparison with hemp fibres. Consequently, the hemp fibres become more expensive on the global fibre market, making them less attractive for the sourcing managers. The cellulose content per hemp plant is lower compared to cotton plants, leading to a lower fibre yield, whereas on the other hand, the fibre yield per cultivated hectare is two times higher, as more hemp than cotton plants can be cultivated on the same area (Bengtsson, 2009).

3.5.2 Fibre Properties

Since hemp as well as cotton are natural fibres, they have many similar properties, such as good breathability and thermal insulation when wearing (Ebskamp, 2002). Table 3 displays some data specifications comparing cotton with hemp. First of all, cotton generally has longer fibres than hemp. Moreover, a major disadvantage of hemp fibres towards cotton fibres is their lack of uniformity. The hemp fibres highly vary in length and diameter, which makes it more difficult to process and spin them into uniform yarns (Ebskamp, 2002). Furthermore, cotton fibres are finer, leading to a softer feel of the garment on the skin. On the other hand, hemp fabrics become softer and more lustrous through laundering and therefore comfortability is increased with time (O Ecotextiles, 2010). The cotton fabric degradation occurs faster and hemp fabrics turn out to be more durable and wear-proof than cotton fabrics (Decorte, 2011). Despite higher durability, hemp fabrics are less flexible (see Table 3) but their tensile strength is better in comparison with cotton (Decorte, 2011). In terms of heat resistance, hemp shows outstanding results over cotton. Additionally, hemp is superior to cotton regarding moisture absorption and dissipation. The stated values for hemp in Table 3 are almost twice as high in comparison with cotton. This absorbency rate is also beneficial for dying processes, where hemp fabrics are more capable to absorb and retain the dyes being applied (O Ecotextiles, 2010). Furthermore, it was found that the mechanical properties of hemp/cotton blends are generally 15 to 20 % better compared to pure cotton fabrics. (BR, 2014).

Table 3. Test results comparing hemp and cotton fibres

		Raw material	
Specifications	Unit	Hemp	Cotton
Fibre length	mm	20-25	25-31
Fineness	tex	0.22-0.38	0.12-0.20
Tenacity	N.tex	>0.48	0.22
Breaking elongation	%	2.22-3.2	7.12
Heat resistance	C°	370	190
Moisture absorption	Mg/min	2.18	1.33
Moisture dissipation	Mg/min	4.4	2.37

Note: Adapted from "Natural Fibres in China," by Z. Jianchun, 2008, ***Proceedings of the Symposium on Natural Fibres, p. 56.***

Some additional advantages of hemp over cotton are further to be stated. As the hemp crops are able to absorb high amounts of CO_2, the carbon footprint is positively affected, and very low compared to other natural fibres (Barth & Carus, 2015). Therefore it is stated that using hemp as a raw material for a variety of products can make a major contribution on creating a more sustainable and eco-friendly economy (Carus, Karst, Kauffmann, Hobson, & Bertucelli, 2013). Additionally, it was found that hemp fibres show high absorbability of other toxic gases (Jianchun, 2008). The nearly non-existent use of agrochemicals in the processing, leads to fibres not being charged with any of these. Furthermore, hemp is barely affected by mites or insects (Decorte, 2011), the fibres show anti-bacterial characteristics and have an outstanding resistance to UV-rays, making them highly suitable for home textiles (Jianchun, 2008). To display a clear overview of the comparison between cotton and hemp, a summarizing table of the presented results can be reviewed in Annex V.

3.6 Results Questionnaire and Interview

3.6.1 Introduction

In the following sub-chapter, the results from the questionnaire, which were answered by different people related to the hemp industry, are formulated. As already stated in Chapter 2, the aim of including this method was to get an insight of diverse opinions from producing companies, researchers and brands that are working with hemp as raw material, not only in the fashion industry. After contacting various institutions, brands and people, the outcome of people who were willing to answer the questions was narrow. From more than 40 people that were contacted, only 10 people responded, from which one person was interviewed and 9 people filled out the questionnaire. Nevertheless, it was achieved that responses of brand owners, producing companies (for cultivation and processing), as well as researchers could be collected. Therefore, stances from different areas and origin could be incorporated. In the following section not every question out of the questionnaire is discussed, but the given answers were analysed and sorted into different topics to give a comprehensive summary of viewpoints. The topics are discussed in the following order: 'Properties and Application in Fashion', 'End-use potential', 'Cultivation and Processing', 'The Fashion Industry', 'Hemp from Europe for Apparel'. As this methodology was not focused on quantitative research and since open questions were used, no percentages or shares of specific responses or viewpoints are displayed. The amount of respondents does not offer a complete coverage of the industry and therefore does not allow a generalization of opinions being stated. It only serves to collect different mind-sets towards hemp in general, in the fashion industry and in Europe and to substantiate, complete, or challenge findings of the literature review.

3.6.2 Properties and Application in Fashion

All respondents are convinced that hemp is a valuable resource with outstanding properties for a variety of application areas. Having strong fibre characteristics, it can offer a sustainable material solution for different end-uses. Furthermore, there is no doubt that hemp would be a valuable raw material for apparel. It is stated that hemp has the required clothing physiology and comfortability to be integrated in the fashion industry and even has the chance to substitute cotton in the future. Having similar fibre characteristics, the use of hemp could be a more sustainable approach compared to the cotton use, as it is more environmental friendly in cultivation and allows a domestic value chain for clothing in Europe. Nevertheless, it is emphasized that hemp cannot compete with cotton yet, due to different issues. One reason would be that the final end price of hemp is too high, making it impossible to be used in mass customization. Moreover, it is posed that the quality of hemp fibres is too low and the offered fibres on the market do not offer consistency. Some people further mention, the fibre would be too coarse for a widespread acceptance in the fashion industry. A researcher working on hemp processing chains to improve the fibre quality indicated that the hemp fibre length and diameter have to approach those of cotton to be more competitive on the market. To get into product classes, which could not be reached with 100 % hemp fabrics, hemp is often blended with other materials. Despite the lack of availability of high quality fibres and the comparably high price, other reasons would be to achieve a finer drape and softer feel of the fabric which are easier to care compared to pure hemp fabrics, since hemp clothing tends to wrinkle. Applying finishes onto 100 % hemp fabrics would be another solution but pure hemp fibres are generally difficult to be spun. Furthermore, 90 % of the spinning mills worldwide were for cotton spinning, on which pure hemp is not spinnable.

3.6.3 End-use Potential

Upon the respondents, there is a coherent opinion about the markets, in which hemp would have the highest potential as raw material. One respondent emphasized that hemp has so various properties that it could be applied almost everywhere. Though, the most mentioned application areas are in the field of composites, insulation material, building material and construction. Other appointed sectors would be in the food and automotive industry, as well as exerting hemp for medical use. Nonetheless, more than half of the respondents sees a high potential of hemp in the textile and fashion industry as well. One of them states the most positive environmental impact of hemp products might probably be when broadly using it in the fashion industry. Hemp could be used for textile products in which the wrinkling properties are of minor importance, like jeans, T-shirts, underwear, bedclothes or towels. Furthermore, it is indicated that people need to be convinced in using more hemp in apparel, by capturing the sustainability factor of the crop and communicating it publicly.

3.6.4 Cultivation and Processing

Respondents underline the sustainability factor of hemp during cultivation, as it grows easily, no pesticides are needed, and it has a higher fibre yield than cotton. Additionally, it aerates the soil and allows regional cultivation in Europe. Even if hemp is a renewable fast growing crop, it is stated that its value depends on how the fibres are processed. Some researchers see no potential for the traditional processing line. It would be too labour intensive, including a lot of manual labour. Efficiency of the machines would be too low and these technical issues would keep hemp being applied in fashion. Machines needed to be adjusted and automated to offer a more productive system. The processing chain would not be improved enough and therefore leads to higher costs. One brand, which sources their hemp products from China, stated that it uses a processing machine being 120 years old. It would be impossible to provide fabrics of good quality without this machine, since no better technology was available on the market. It was underlined that the development progress would be very slow, also due to a lack of expertise. It was proposed to develop better hemp breeds for fibre end use of high quality and that the fibres must become softer and easier to spin. Other approaches that were mentioned are eliminating quality variations due to field retting and making it possible to process hemp on cotton spinning mills, to achieve a more economical process chain and more attractive end products.

3.6.5. The Fashion Industry

The slow progress in improved cultivation and processing methods in hemp fibre production would keep hemp in a niche market within the fashion industry. The market value would be far too low compared to work and energy input. As already mentioned, a high potential to substitute cotton with hemp is perceived, under the condition that fine and high quality fibres, equal to cotton, can be produced. The low competitiveness, also due to the much higher price is further emphasized. The high competition in the fashion sector with different raw materials being cheaper would complicate a broader prominence within the industry and the consumers. Therefore, there would be few brands interested to implement hemp in their products, further leading to a lack of investments from the industry. It is said that high financial means would be needed to make hemp easier to process and to market the fibre. Some respondents ask for the industry's own impulse taking more risks and volition to invest in the prospective profitability in order to get a sustainable raw material for the future in fashion. Others intend continuing on their own projects to be able to convince the industry with newly developed machinery and processes being ecologically and economically sustainable.

3.6.6 Hemp from Europe for Apparel

The hemp cultivation and industry in Europe in general is rising and predictions of respondents are a further growth. It was stated that the cultivation area in Europe could easily be increased if the demand is given. It was mentioned that nowadays, only low value fibre products were produced in processing plants in Europe, since the machinery was only able to perform the total fibre line. Underlining the absence of modern technology for hemp textile production of high quality in general, the collective opinion is that more research needs to be done concerning cultivation and processing issues. Research results of the past 20 years would be sobering compared to the research funds that were allocated. Speaking of increasing cultivation in Europe particularly for textile use, opinions are differing. Since only 25 % of the yield material could be produced into textiles, multi-purpose cropping would be recommendable. Others question the cultivation of hemp for quality fibre purpose entirely. Firstly, it is posed that for a planned growth of fibre hemp cultivation, demand as well as processing plants must be existent for it. A renewed and sustainable processing chain would be needed to guarantee an economical outcome. A recent positive outcome in regulation change for hemp cultivation in the EU might lead to a more favourable precondition for farmers. According to one respondent, it will soon be allowed to grow hemp two times a year, since the sowing of hemp seeds after the 30th of June of a year would be permitted by law. Nevertheless, the long prohibition of hemp cultivation would have led to loss of knowledge about cultivating and processing hemp, making it difficult to rebuild the industry. Even if some participants intend to cultivate hemp again in Europe for textile and apparel use, it is emphasized that the value chain must be available on a regional level, to save transporting time and costs, and to further guarantee a sustainable end-product. Another issue, which was repeatedly expressed, is the fact that there is no complete supply chain available anymore in Europe. The decrease of textile processing facilities in whole Europe, due to the shifted textile industry to low-wage countries, would complicate the hemp production for fashion immensely. Several respondents don't see a real chance for hemp textiles from Europe. Firstly, it would not be possible to revive a completely disappeared fashion industry, secondly the hemp textile industry would be dominated by China. The country had increased its cultivation and investments towards hemp in the last years, and Chinese would be convinced that hemp can be the crop of the future, not only for textiles. Even if hemp might still be more expensive than cotton, the people in China would be naturally willing to pay more for hemp clothing. One respondent outlines that this attitude derives from the fact that hemp was never prohibited in China and therefore it would not be tainted with a biased image of the plant. Additionally, it was stated that the textile Industry would have to be improved and influenced in the main producing regions and that the supremacy of these made it difficult for the European region to still be competitive.

Chapter 4 – Conclusions, Discussion & Recommendations

4.1 Conclusions and Discussion

4.1.1 Conclusions

The factors influencing the state of the art of hemp in the fashion industry in Europe and in general are diverse. Hemp is a forgotten crop, having a big potential for many application areas, including clothing. Though too many bottlenecks hinder hemp from being integrated in Fashion. In the following chapter an overview of major factors is given, from which conclusions and recommendations are drawn.

4.1.1.1 History

The historical developments have a big impact on the image and market share of industrial hemp and it all started in the USA. Firstly, the facilitation of cotton processing in the 18th century, through the invention of the spinning jenny and the cotton gin, boosted the cotton cultivation and industry immensely. It was less labour-intensive to produce cotton fabrics, and therefore became cheaper and more attractive. It led to a drawback of the hemp industry. Nevertheless, this development did not make the major contribution. The Anti-marijuana laws accompanied with a widespread negative image campaign against the whole crop in the 20th century, based on Cannabis for recreational use, led to a prohibition of hemp cultivation. First it was limited to the USA, but with the aid of Harry Anslinger the prohibition was set for all UN-countries in the 1960s, including Europe. The lobbyism of the cotton, timber and chemical industry turned out to be successful and still profits from these decisions nowadays. The hemp image is damaged and the industry suffers from that. The general public is not aware of the fact that Cannabis and Industrial hemp plants are different varieties, of which industrial hemp could never be used for recreational use. Thus, the industry has to tackle this confusion, which is followed by scepticism. Additionally, this ongoing prohibition in Europe led to a loss of knowledge about the cultivation and processing, which made it difficult to entrench the production again of a totally vanished crop for decades.

4.1.1.2 Cultivation and Processing

The hemp industry in Europe has recovered slightly since the allowance of cultivating hemp 20 years ago. After slow growth, also due to higher subsidies for other crops, the industry starts to become established throughout Europe. Particularly in the past 4 years the cultivation area grew steadily, now amounting to 33,000 ha. The number of different application areas for the plant increases steadily. The crop's high potential, especially due to its environmental friendly cultivation, is more and more perceived. Nevertheless, hemp for high quality textile use does not profit from that. The share of hemp fibres produced for apparel purposes stays low. The competition within the different parts of the plant is too high. Seeds, biomass and low value fibre lines are more efficient and therefore more profitable to produce. Thus, the variety of application areas of industrial hemp are not beneficial for apparel end use. The lack of machinery that is able to keep optimal quantity and quality of seeds, fibres and leaves at harvest forces farmers to decide for the most profitable parts of the crop. The high pile of regulations that come along with hemp cultivation offer additional obstacles for the farmers. Despite the mandatory registration, followed by monitoring from official ministries, but especially the legal prohibition of harvesting before flowering of the crop has a negative impact on cultivating for fibre purposes. Fibre quality decreases after flowering due to increased secondary fibres and rising lignin content. At usual harvest time, at the stage of seed maturity, these plant

developments are far progressed. Based on that, the primary fibre yield decreases and it becomes harder to separate the fibres from the low value secondary fibres, as well as from the shivs and bark. Consequently, the probability of fibre damage during decortication is higher. Differing stem diameters of the plants complicate the separation likewise, since no decorticator is designed to handle these variations. Over- as well as under-retted yield also leads to quality decrease and has to be avoided accordingly. All these factors must be kept in mind when cultivating hemp for fibre purposes. The quality and quantity of fibre yield are highly dependent on the way of harvesting, the harvesting time, the retting and the decortication. Since hemp can grow almost everywhere, the climatic conditions during cultivation are not so crucial, but precipitation and frost while retting have a negative impact on the quality. It is not hard to see that these conditions are not adjusted in favour of quality fibre production and that they offer a variety of risks that can affect the fibre quality negatively.

4.1.1.3 Production

When cultivating hemp for high quality fibres in Europe, another issue comes up. There are no bulk purchasers for high quality fibres, due to nonexistence of long fibre processing plants for hemp in Europe. Additionally, the whole textile industry has moved to lower-wage countries out of Europe, causing difficult conditions for a whole (hemp) apparel value chain. The overall competition with these countries, because of lower labour costs as well as more locally accessible supply chains, is very high and therefore risky in the realization. In general, it lacks in optimized and automated processing machinery for hemp, which is one of the major factors keeping hemp in the niche market for apparel. The value of hemp fibres depends on the processing and the traditional production line is too inefficient. Process and machinery must be adjusted to offer better quality. Nonetheless, machinery being productive enough is not offered on the market, which derives from a low demand on hemp for textiles. There are approaches towards processing optimization, but none of them are viable enough for the industrial production. As long as no renewed and improved processing chain is delivered, the hemp primary fibre production is not economical. This issue is one major reason for the limited availability of high quality hemp textiles having a reasonable price, making it unattractive for the fashion industry. Due to that fact and for the reason that the European hemp industry itself profits from other end applications, the progress in improvements is very slow. Not only the processing steps of hemp straw into combed fibres before spinning cause difficulties, also the spinning process itself and the subsequent processes are challenging parts in the hemp textile production. The high quality differences of delivered hemp fibres, e.g. in cleanliness, fineness and length, cause difficulties in the spinning process. If at all, the spinning mills are barely able to spin pure hemp into yarns, for what reason it is often blended with other fibres. If a hemp yarn is produced, it often lacks in uniformity, which naturally derives from the quality of raw hemp fibres available. The fact that high quality hemp fibres and yarns cannot be guaranteed as it still depends on too many processing factors, which are not automated and adjusted in favour of fibre quality, leads to unsolicited variations in properties.

4.1.1.2 Demand & Properties

The general hemp fibre properties offer the potential for the use in apparel. Comfortability and favoured clothing physiology are given. Hemp clothing is breathable, absorbent, and highly durable. Moreover, it is anti-bacterial and UV- as well as heat resistant, and offers optimal heat insulation. Although the hemp clothing characteristics are similar to those of cotton, the hemp fibres need to be modified. Length, diameter, fineness and uniformity have to approximate those of cotton. The above-mentioned areas of improvement play a major role at achieving that, since optimized cultivation,

harvest and processing could deliver more consistent fibres of better quality. In addition to these necessary enhancements, the molecular determination as well as the cottonization approaches could intervene to achieve higher fibre qualities, particularly in fineness.
Nevertheless, the global demand for hemp is very low. Even if China steadily increases the hemp cultivation for textile end use and dominates the hemp fibre market globally, the demand on fibres for textiles nowadays is still covered by cotton and man-made fibres. Yet, there is no need for the fashion industry to substitute their commonly used raw materials. Another factor that makes hemp highly unattractive for the mass production is the price. As a result of inefficient processing technologies the end price of hemp fibres, yarns and fabrics is much higher than comparable products out of cotton. This low interest in hemp by the fashion industry further does not lead to improved production chains, since no investments from that industry can be generated. Thus far, the trend of fast fashion and hemp clothing are not compatible with each other, even if a combination of both could make that trend more sustainable than it is right now. Compared to cotton, hemp is much more sustainable in the cultivation, even offering a higher fibre yield per hectare. The water footprint and the use of agrochemicals is much higher for cotton. Cotton grows in water scarce regions and occupies large amounts of arable land in those. Therefore, a substitution of cotton by hemp could lead to a more sustainable sourcing of raw materials for clothing.

4.1.2 Discussion

Two major factors can be concluded from the above-mentioned factors, namely quality and price. These factors hinder hemp to experience a breakthrough in fashion. If only an inconsistent quality is available on the market to a comparably high price, serious intentions of clothing brands to source hemp fibres for their garments are scarcely to be expected. Until the point where uniform hemp quality textiles can be offered to a reasonable price, no demand can be anticipated. Furthermore, the fashion industry is not forced to substitute common raw materials, as the supply of those is still guaranteed. Although the fashion industry rethinks its supply chain in terms of sustainability and the use of organic cotton and recycled polyester seem to be a good alternative, other environmental issues emerge from that. Consequently, measurable improvement in their application is to be doubted in the long run. The positive sustainability factor of industrial hemp is scientifically proven, at least in terms of cultivation. Therefore, the recorded cultivation growth in Europe as well as worldwide is hardly surprising, as sustainability plays an essential role for the value of countless products on the market. Precisely because of this diversity of application areas and the obtained market entry of industrial hemp products into different industries, where the production is more profitable and generally easier to perform, the high quality hemp fibre production is susceptible to a high competition within its own applications. Even if hemp used to be the most used raw material in the past, hemp textiles nowadays are left far behind in terms of technological developments towards other end-use applications and raw materials. The historical developments led to a loss in expertise and awareness about a valuable crop for apparel, which further results in insufficient knowledge and intentions to invest in improving the processing chain of hemp for textiles.
Nevertheless, some global developments could turn out to be beneficial for the whole hemp industry, and therefore could also promote progress in terms of hemp textile processing. As already mentioned before, China invests in the hemp cultivation and processing for several years, aiming at cultivating 660,000 ha by 2020. Canada, that focused its industrial hemp industry on seed production in the past, also shifted to a cultivation for fibre purposes. Additionally, industrial hemp production in the USA is growing, as more and more US-states legally allow the cultivation again. All these developments lead to a rising prominence of the plant, as the industry is growing steadily.

Furthermore, this expansion boosts the research and development towards improvements of different hemp products. It promotes research projects and collaborations of institutions and companies from different countries. Even if other hemp branches are bigger, this could also lead to enhancements in the production of hemp textiles.

Another stated trend, the value of sustainable products for industry and consumer could be of advantage for hemp in apparel in the future as well. Already today, the awareness on fair traded and sustainable clothing is growing, if only by slow degrees. NGOs and campaigns promote the consumer behaviour towards more conscious purchase of textile products, further increasing the amount of eco-fashion brands, as the demand increases especially in Europe. Likewise, a change of established fashion brand's policies towards improved social and environmental conditions in the value chains is perceived. The increasing awareness concerning these poor conditions provoke the whole textile industry to act accordingly. Major changes in the complete production have to be considered, from raw material sourcing until final product. The increasing fibre demand and anticipated fibre shortage of 40 million tons by 2030 further forces the industry to look out for alternatives. Cotton cultivation reaches its limits, as it can only be cultivated under specific climatic conditions and the fossil oils for man-made fibre production will become scarce, consequently more expensive on the market as well. All these developments could offer chances for industrial hemp to gain prominence in the textile and apparel industry.

Although a high potential for the hemp industry in the quality textile sector can be concluded from that, a rising demand cannot be guaranteed if the price and quality ratio is not balanced. Essential improvements have to be developed throughout the whole hemp processing chain. A viable, economical and renewed production line needs to be realized that ensures consistent quality to a competitive price. Only then, hemp for textiles will be an attractive alternative being profitable for farmers, producers and brands. Only then it is appealing for the end-consumer, as the price is still of great importance in the decision-making of buying a garment. However, even under optimal processing conditions for high quality hemp fibres, it would be challenging for Europe to revive its textile industry and to compete with established textile production regions. Furthermore, Chinas dominant position in hemp cultivation and production for textiles is highly prejudicial to the development of a European quality hemp fibre production. The competition with China and other textile producing countries is high, due to lower overall costs, and Europe might only resist it, if an added value of European hemp textiles could be achieved. Despite advanced production technology, a higher quality, and regional as well as more transparent value chains could be incentives for brands to buy European hemp textiles. In spite of all that, it has to be kept in mind that even a more high-grade product cannot last in a broad range of fashion products, if the price is still too high compared to commonly used raw materials, especially when it comes to the trend of fast fashion where quantity counts more than quality.

4.2 Recommendations

The low demand on hemp for fashion and the consequent low production of hemp for textile purposes in Europe traces back to the comparably high price of hemp textiles that further comes along with inconsistent quality of those. To achieve greater success of an industry branch, these quality variations need to be eliminated, which derive from the lack of optimized processing machinery for the primary fibre production. With the aid of changes that make the processing chain more efficient and productive, an increase in quality as well as a cost decrease can be achieved. The following recommendations are addressing the European hemp industry that aims at focusing on the primary fibre processing, as part of the research objective was to find better preconditions within Europe for this branch. Part I of the recommendations shows which changes could be beneficial for hemp farmers and producers in the mentioned branch. Annex VII serves to look up a rough visualization of those factors. Furthermore, Part II gives suggestions to the complete branch of primary fibre processing for textile and apparel purposes in Europe, to promote these changes. Additionally, threats and opportunities are listed in Part III (see Annex VIII) for the European market that could hinder or facilitate the market entry of hemp textiles from Europe.

4.2.1 Part I

Improved pre-conditions for Farmers through:

- Development of optimized breeds for fibre purposes to guarantee higher fibre yields, better homogeneity of the fibres and a lower lignin content for better fibre separation
- Development of multi-purpose crops, where highest fibre yield and quality are at the stage of seed maturity, as the seeds still generate major income for farmers, whereupon they cannot relinquish at the moment
- Change of regulations regarding harvest time and two times sowing per year, to generate better fibre yields and higher incomes
- Development of harvesting machinery adjusted in favour of hemp fibres to avoid fibre damage
- Improved or alternative retting techniques for the avoidance of quality variations due to, e.g. bad weather conditions. An interesting approach here is the green decortication, where the retting is completely skipped

Improved pre-conditions for Producers through:

- Delivery of fibres with a low lignin content for better fibre separation, which avoids fibre damage (see above)
- Better quality and quantity yield of delivered fibres from preceding steps (see above), to guarantee more profitable outcome
- Delivery of crops with less differing stem diameters (e.g. Baby Hemp) to facilitate the decortication and avoid damage of the fibre or
- Adjusted machinery that is able to decorticate stems of different diameters
- Development of overall productive and sustainable process chain that guarantees minimized fibre damage, lower labour and energy input, and further saves costs and time
- Delivery of improved fineness and overall properties of fibres that facilitate subsequent processing steps, to e.g. enable the spinning on cotton mills: either achievable through above-mentioned approaches or by applying finishing techniques like CRAILAR or STEX

4.2.2 Part II

In the following, actions are listed that should be taken from the whole European branch for primary fibre processing. The founding of an alliance that only focuses on hemp production for high quality fibre purposes, including all parties within the value chain, is recommended, as the number of people in this area is limited in Europe.

- An alliance would offer cooperation of enterprises that want to establish hemp textiles from Europe on the market and
- Joint action to tackle bottlenecks within the production through collaborative funding, research, and the build-up of a strong industry branch and value chain
- Within the alliance the formation of a board of lectureship aiming at educating the public and the fashion industry to eliminate the biased perception, inform about future possibilities of hemp for textiles and particularly about the sustainability benefits, is advisable
- Collaboration of alliance with NGOs focusing on fair fashion
- Connect with the European fashion industry to convince brands of the hemp potential for textiles and apparel, with regard to sustainability and a more transparent as well as local supply chain, which could generate an added value to their products. Fashion and Textile brands have to be convinced that they invest in the future success of their company if they support the alliance

If these factors can be improved and actions are taken to promote that, the hemp industry for textiles could have a real chance to penetrate the fashion market in the future. If the industry invests in improved conditions for the primary fibre hemp production, it will have a more sustainable alternative to commonly used and less environmental friendly raw materials. Nevertheless, the fashion and textile industry has to be strongly convinced in order to be willing to provide financial means for research and development in the hemp primary fibre production. At this time, the pressure to substitute the raw materials is not high enough yet, even if building up slowly. Only if the quality increases and the price becomes competitive, an increasing demand and a profitable outcome for all participating parties can be generated, making it possible to apply hemp even in the mass production. Contrary to the majority of industry opinions stated in this report, that advises a pull market strategy, it is to question if this approach could be realized without major investments beforehand to improve the competitiveness of hemp as raw material in the fashion industry.

Chapter 5 – Research Reflection

First of all, it needs to be said that a research focused on a literature review is a challenging task. The approach of offering a clear answer to the main question turned out to be more complex than expected. Within the time of gathering literature and data needed, it became clearer how broad the scope of influencing factors is. A lot of literature is available about hemp. Ascertaining that the sources and information are well chosen to guarantee a reliable research outcome and give a comprehensible overview of all factors that have an impact on the state of the art of hemp in the fashion industry in Europe is complicated within the scope of a Bachelor Thesis. Offering a good structure of the sub-chapters was challenging as almost all topics are dependant on each other and the right order needed to be carefully determined. As the major outcome relies on the chosen literature, it was valuable to integrate industry opinions through the filled out questionnaires. Findings from the literature could be confirmed, partly extended and emphasis could be placed for final conclusions and recommendations.

When starting to work on the research topic, the expectations towards reintegrating hemp fibres from Europe into the fashion industry were high. After a preliminary literature study, it was anticipated that hemp only has positive properties, which could lead to a more sustainable textile value chain, which still is not to query. Though, at that stage of the research, it could not be recognized how broad the scope of influencing factors, with regard to the low application of hemp in the fashion industry, really is. It was assumed that the main reasons for the state of the art are traced back to the negative image of the plant and to the supremacy of the cotton industry. As can been seen from the research outcome, these are crucial factors, but merely not the only ones. It is a chain reaction of factors depending on each other, starting at the history via technical, legal and agricultural thematic priorities, through to fashion market developments. The more detailed information was collected, the more it became obvious how diverse the different areas of improvement in the hemp value chain are. A new perspective, which was not primarily taken into account at the beginning, was the actual hemp cultivation. Especially this step of hemp production needs to be reinforced, speaking of change in regulations for the farmers or the competition within the different plant components. The optimal solution for harvesting all of them at the same time and keeping a good quality for the end products is not yet found. Logically, farmers intend the optimal harvest of the component being most profitable, consequently the seeds. The labour-intensive processing of (primary) fibres and the nonexistence of modern technology to facilitate it create unfavourable and uneconomical preconditions. Throughout the results of the questionnaire, it became clear that hemp is a valuable crop for a variety of applications, likewise the opinions about hemp fashion made in Europe are differing. Even if there is unanimous assent about the sustainability and potential of the plant, the opinions on if it is advisable to cultivate hemp in Europe for textile apparel use are divided. Some companies and researchers follow the so-called push-market strategy, by developing processes and products, aiming at convincing industry and consumers. Nevertheless, the prevalent standpoint throughout the respondents is that first, the demand is needed to be able to penetrate the market, thus applying the pull-market strategy.

Even if a huge potential of the crop is observed, the obstacles for integrating it in the textile value chain in Europe are higher than expected. The main factors, which were determined throughout the research, namely quality and price, may not be easy to get solved soon, as they depend on demand, initial investments and consequently on optimizing the whole production process of hemp. It was anticipated that the technical progress made in the past 20 years, since hemp cultivation is allowed again in Europe, would not create an inefficient processing anymore with a lack of qualitatively

consistent fibres and fabrics. The low demand for European hemp fibres, due to hemp from China and the natural fibre coverage by cotton, keep the industry, e.g. machine manufacturers, from developing more productive processes and machinery. Additionally, the increased cultivation of hemp in China for instance, which leads to high competition, was unknown at the beginning of this research.

As already mentioned before, the chosen topic offers complexity and various angles that need to be taken into account. With the aid of the chosen methodologies the main- as well the sub-questions could be answered properly, conclusions could be drawn and some recommendations could be given for the future. All in all, the report offers a satisfactory outcome concerning the goal of the research. Considering the numerous determined factors retrospectively, which were not all perceived and known from the beginning, it might have been interesting to narrow down the research to one of the specific topics discussed in the report getting more into detail of the chosen one. Due to complexity not every single topic could be discussed in depth. However, this research was focused on delivering an overall picture, which could be supported by the developed questionnaire as well, being answered by people working with hemp. Although the rate of respondents could have been higher, this methodology and asking open questions led to a good insight of viewpoints towards hemp in Europe and in fashion. It supported the major methodology and provided expert knowledge. It is to mention that it would have been beneficial getting the answers mainly in a personal interview, as the extent and depth of the answers might have been increased by that. A personal interview gives the space to ask additional questions for a better understanding and argumentation of the respondent. Unfortunately, it was already difficult recruiting people who agreed answering the questionnaire. For getting a more detailed and representative result of opinions within the hemp industry in Europe broadly conceived surveys on a quantitative level would be advisable. After the major factors were determined in this research, it could be valuable conducting a survey addressing the whole hemp value chain, including farmers, producers, researchers, as well as other processing companies and brands. This could serve to find out the weighting and further importance of the determined factors, and to find a reliable ranking of these. By the means of this outcome, major problems within the various factors could be defined in depth, promoting international research, with the emphasis on most crucial bottlenecks in every part of the chain. Additional to that, the most promising research approaches could be concluded and further developed. Collecting such kind of quantitative data from the hemp industry might lead to more goal-driven results and faster progress of the stated technical obstacles. Though, due to complexity of the topic and the aim of collecting perceptions about the state of the art in an industry, the application of open questions to keep respondents as impartial as possible and free to mention their opinions, turned out to be helpful.

Different approaches at different branches within the hemp value chain are in progress to improve the production. It was very revealing to deal with diverse domains, of which some were completely new. Broad knowledge could be acquainted about this industry and numerous perspectives were conceived through this research. Even if the anticipation of the higher probability to realise a hemp textile value chain in Europe could not be satisfied by this research and the state of the art, it is to say that hemp has a future potential as textile raw material in general, if some factors within the whole production will be improved.

Bibliography

Addlesperger, E. (2015). Hemp. ***Journal of Agricultural & Food Information***, 196-202.

Alcheikh, A. (2015). ***Advantages and Challenges of Hemp Biodiesel Production:.*** Gävle University, Faculty of Engineering and Sustainable Development. Gävle: Gävle University .

Alexopoulou, E. (2016, October 7). ***Final Report Summary - FIBRA (Fiber Crops as a Sustainable Source of Bio-based Materials for Industrial Products in Europe and China).*** Retrieved April 28, 2017, from CORDIS - Community Research and Development Information Service: http://cordis.europa.eu/result/rcn/189680_en.html

Amaducci, S., Scordia, D., Liu, F., Zhang, Q., Guo, H., Testa, G., & Consentino, S. (2014, July 14). Key cultivation techniques for hemp in Europe and China. ***Indsutrial Crops and Products***(68), 2-16.

Amberznectarz. (2016, Augsut 27). ***Hemp Production Around The World***. Retrieved April 20, 2017, from Hemp Edification - Hemp can save the planet! : https://hempedification.wordpress.com/2016/08/27/hemp-production-around-the-world/

American Psychological Association. (2013). ***Concise Rules of APA style.*** New York, US: American Psychological Association.

Averink, J. (2015). ***GLOBAL WATER FOOTPRINT OF INDUSTRIAL HEMP TEXTILE.*** Thesis, University of Twente, Water Engineering and Management, Enschede.

Barth, M., & Carus, M. (2015). ***Carbon Footprint and Sustainability of Different Natural Fibres for Biocomposites and Insulation Material .*** Hürth: nova Institut GmbH.

Bengtsson, E. (2009). ***Obtaining high quality textile fibre from industrial hemp through organic cultivation.*** SLU, Sveriges Lantbruksuniversitet, LTJ Faculty. Alnarp: SLU, Sveriges Lantbruksuniversitet.

Bengtsson, E. (2009). ***Obtaining high quality textile fibre from industrial hemp through organic cultivation.*** SLU, Sveriges Lantbrukuniversitet, LTJ Faculty - Horticultural Programme. Alnarp: Sveriges Lantbruksuniversitet.

Bio-based News. (2009, June 5). ***Hemp boom in China ahead?*** Retrieved April 18, 2017, from Bio-based News: http://news.bio-based.eu/hemp-boom-in-china-ahead/

BLE. (2017). ***Anbau von Nutzhanf - Anbauanzeige.*** Retrieved April 28, 2017, from Bundesanstalt für Ernährung und Landwirtschaft: http://www.ble.de/DE/Themen/Landwirtschaft/Nutzhanf/nutzhanf_node.html

BLE. (2017). ***Anbau von Nutzhanf - Meldung über Beginn der Blüte.*** Retrieved April 28, 2017, from Bundesanstalt für Landwirtschaft und Ernährung : http://www.ble.de/DE/Themen/Landwirtschaft/Nutzhanf/nutzhanf_node.html

BLE. (2017). ***Anbau von Nutzhanf - Sortenliste.*** Retrieved April 28, 2017, from Bundesanstalt für Landwirtschaft und Ernährung : http://www.ble.de/DE/Themen/Landwirtschaft/Nutzhanf/nutzhanf_node.html

BR (Director). (2014). ***Rohstoff Hanf - Faszination Wissen*** [Motion Picture]. Germany.

C&A. (2015). ***Material Impacts - Global Sustainability Report 2015 - Summary.*** Sustainability Report, Düsseldorf.

Cadwell, A. (2017). ***Who Made My Clothes? How To Get Involved During Fashion Revolution Week***. Retrieved April 25, 2017, from The Good Trade: http://www.thegoodtrade.com/features/who-made-my-clothes

Cannabis Now. (2015, October 21). ***Video: Building houses with hemp.*** Retrieved April 12, 2017, from Cannabis Now: https://cannabisnow.com/video-building-houses-with-hemp/

Carus, M., & Sarmento, L. (2016). ***The European Hemp Industry: Cultivation, processing and applications for fibres, shivs, seeds and flowers.*** European Industrial Hemp Association. Hürth: EIHA/ nova.

Carus, M., Gahle, C., Pendarovski, C., Vogt, D., Ortmann, S., Grotenhermen, F., . . . Schmidt, C. (2008). ***Gülzower Fachgespräche Band 26 - Studie zur Markt- und Konkurrenz- situation bei Naturfasern und Naturfaser- Werkstoffen (Deutschland und EU).*** Bundesministerium für

Ernährung, Landwirtschaft und Verbraucherschutz. Hürth: Fachagentur Nachwachsende Rohstoffe e.V.

Carus, M., Karst, S., Kauffmann, A., Hobson, J., & Bertucelli, S. (2013). ***EIHA 2013 - 06 - 1 - The European Hemp Industry: Cultivation, processing and applications for fibres, shivs and seeds.*** European Hemp Association.

CBD. (2016, March 29). ***CBD hemp oil.*** Retrieved April 13, 2017, from Pinterest: https://de.pinterest.com/pin/253679391490444205/

Cherrett, N., Barrett, J., Clemett, A., Chadwick, M., & Chadwick, M. (2005). ***Ecological Footprint and Water Analysis of Cotton, Hemp and Polyester.*** Stockholm Environment Institute. Stockholm: Bio Regional & WWF.

CHTA. (2017). ***Fibre Production - Fibre Harvesting Equipment.*** Retrieved May 2, 2017, from Canadian Hemp Trade Alliance : http://www.hemptrade.ca/eguide/fibre-production/fibre-harvesting-equipment

Cordell, M., Bruer, J. (Producers), & Chobocky, B. A. (Director). (1996). ***The Billion Dollar Crop*** [Motion Picture]. United States of America.

CPT. (n.d.). ***2. HEMP VISCOSE FIBER.*** Retrieved May 2, 2017, from China Populus Textile Limited: http://populustex.com/hempviscosefiber.html

Davies, R. (2014). ***Fair trade and consumers in the European Union.*** European Parliamentary Research Service. European Union.

Davies, R. (2016, November 16). ***World could face oil shortage by end of decade, says IEA***. Retrieved May 15, 2017, from The Guardian: https://www.theguardian.com/business/2016/nov/16/world-oil-shortage-international-energy-agency

Decorte, T. (2011). ***Fibre hemp and marihuana: assessing the differences between distinct varieties.*** Geneva Centre for the democratic control of armed forces, International Police Executive Symposium. Geneva: IPES; DCAF; COGNITA.

Dictionary.com Unabridged . (n.d.). ***monoecious. (n.d.)***. Retrieved April 14, 2017, from Dictionary.com : http://www.dictionary.com/browse/monoecious

Eartheasy. (2014). ***Hemp Clothing***. Retrieved April 24, 2017, from Eartheasy - Solutions for sustainable living: http://eartheasy.com/wear_hemp_clothing.htm

Ebskamp, M. J. (2002). Engineering flax and hemp for an alternative to cotton. ***Trends in Biotechnology, 20***(6), 229-230.

EIHA. (2014, May 28). ***Worldwide growth in industrial hemp – fibres, shivs, seed & oil and pharmaceuticals***. Retrieved February 01, 2017, from Bio-based News: http://news.bio-based.eu/worldwide-growth-industrial-hemp-fibres-shivs-seed-oil-pharmaceuticals/

EIHA. (2015, January 13). ***Total Hemp cultivated area in Europe 2014.*** Retrieved April 25, 2017, from European Industrial Hemp Association: http://eiha.org/document/total-hemp-cultivated-area-europe-2014/

EIHA. (2016, May 24). ***Continuous growth in the European Hemp Industry*** . Retrieved April 17, 2017, from Bio-based News: http://news.bio-based.eu/continuous-growth-in-die-european-hemp-industry/

EIHA. (2017, March 28). ***ihemp Cultivation Area 2016 in the EU: 33,300 ha.*** Retrieved April 25, 2017, from European Industrial Hemp Association: http://eiha.org/document/ihemp-cultivation-area-2016-in-the-eu-33000-ha/

ETH. (2006, October 26). ***Hochwertige Textilfasern aus Industriehanf - Viel Hanfarbeit.*** Retrieved May 4, 2017, from ETH life - Wissen was läuft: http://archiv.ethlife.ethz.ch/articles/sciencelife/hanfbistextil.html

Francis, S. K. (1996). ***Hemp (Cannabis Sativa L.) as an Alternative Fibre Source for Noav Scotia.*** Dalhousie University . Halifax: Dalhousie University .

FWF. (2017). ***About us***. Retrieved April 25, 2017, from Fair Wear Foundation (FWF): https://www.fairwear.org/about/

Guarini, D. (2012, July 13). ***Hempcrete, Made From Hemp, Used To Build Houses***. Retrieved April 28, 2017, from TheHuffingtonPost.com, Inc.: http://www.huffingtonpost.com/2012/05/10/hempcrete-hemp-house_n_1506662.html

H&M group. (2016). ***THE H&M GROUP SUSTAINABILITY REPORT 2016.*** Sustainability Report, Stockholm.

Haak, D. (2017). ***Lignin: Definition, Properties & Functions***. Retrieved April 16, 2017, from Study.com: http://study.com/academy/lesson/lignin-definition-properties-function.html

Haas, S. (2016, February 11). ***2016 could be the year for industrial hemp.*** Retrieved April 25, 2017, from Boulder Weekly: http://www.boulderweekly.com/boulderganic/2016-could-be-the-year-for-industrial-hemp/

Hanffaser. (2015). ***Hanffabrik***. Retrieved February 1, 2017, from Botanik - Geschichte - Fabrik : http://www.hanffaser.de/hanf/Allgemeines.htm

Hanfsamen.net. (2017). ***Kleidung aus Hanf - Ihre Vor- und Nachteile***. Retrieved from Hanfsamen: http://www.hanfsamen.net/kleidung-aus-hanf-ihre-vor-und-nachteile/

Harris, F., Roby, H., & Dibb, S. (2016). Sustainable clothing: challenges, barriers and interventions for encouraging more sustainable consumer behaviour. ***International Journal of Consumer Studies, 40***, 309-318.

Hearst, W. (2013, October 28). ***Hemp: The Miracle Plant.*** Retrieved April 25, 2017, from The Gearedlife: http://thegearedlife.com/hemp/

Hemp University. (2016). ***History of Hemp***. Retrieved February 01, 2017, from Hemp University: http://www.hempuniversity.com/history-of-hemp/

Hempethics. (n.d.). ***What is Industrial Hemp?*** Retrieved April 25, 2017, from Hempethics: http://hempethics.weebly.com/what-is-industrial-hemp.html

HempFlax. (2016). ***About HempFlax***. Retrieved May 2, 2017, from HempFlax: http://hempflax.com/en

HempFlax. (2016). ***Harvesting***. Retrieved May 2, 2017, from HempFlax: http://hempflax.com/en/equipment/harvesting

Herer, J. (2017). Die Hanfprohibition. In J. Herer, & M. Bröckers, ***Die Wiederentdeckung der Nutzpflanze Hanf*** (Vol. 43, pp. 69-75). United States of America: Nachtschatten Verlag AG.

ICAC. (2015). ***The Global Fibre Market***. Retrieved February 02, 2017, from Lenzing Group: http://www.lenzing.com/en/investors/equity-story/global-fiber-market.html

Jianchun, Z. (2008). Natural Fibres in China. ***Proceedings of the Symposium on Natural Fibres*** (pp. 53-61). Rome: Symposium on Natural Fibres.

Johansson, E. (2010). ***Slow fashion- the answer for a sustainable fashion industry?*** University of Boras - The Swedish School of Textiles. Boras: The Swedish School of Textiles.

Karus, M. (2002). ***Europäische Hanfwirtschaft 2001: Anbau, Weiterverarbeitung und Produktlinien.*** Hürth: nova institut.

Kiron, M. I. (2017). ***Process Flow Chart of Hemp Spinning*** . Retrieved May 2, 2017, from Textile Learner: http://textilelearner.blogspot.jp/2012/05/process-flow-chart-of-hemp-spinning.html

Lenzing Group. (2017). ***The Global Fiber Market in 2016.*** Retrieved April 24, 2017, from Lenzing - Leading fibre innovation: http://www.lenzing.com/en/investors/equity-story/global-fiber-market.html

Leupin, M. (2009). ***Industriehanf als umweltverträgliche Ergänzung und Alternative zu Baumwolle - Eruierung der Materialeigenschaften, des Marktpotentials und der Marktchancen von Hanf-Textilien.*** Kommission für Technologie und Innovation KTI. Bern: KTI.

Long, P. (2015, May 21). ***Crailar Technologies: A Little Hemp Start-Up Seeded For Growth***. Retrieved April 16, 2017, from Seeking Alpha: https://seekingalpha.com/article/3204416-crailar-technologies-a-little-hemp-start-up-seeded-for-growth

Max, B. (2017). ***Types of Machines Used in Textile Industries***. Retrieved May 11, 2017, from Chron - Hearst Newspaper, LLC: http://smallbusiness.chron.com/types-machines-used-textile-industries-67500.html

McCorristin, K. (2003). ***Cannabis Sativa and its varied issues.*** Bachelor Thesis.

McNeil, L., & Moore, R. (2015). Sustainable fashion consumption and the fast fashion conundrum: fashionable consumers and attitudes to sustainability in clothing choice. ***International Journal of Consumer Studies, 39***, 212-222.

Messinger, L. (2016, June 20). ***How your clothes are poisoning our oceans and food suppl***. Retrieved April 25, 2017, from The Guardian: https://www.theguardian.com/environment/2016/jun/20/microfibers-plastic-pollution-oceans-patagonia-synthetic-clothes-microbeads

Mohnen, D. (2008, June 11). ***Pectin structure and biosynthesis***. Retrieved April 16, 2017, from NCBI: https://www.ncbi.nlm.nih.gov/pubmed/18486536

MultiHemp. (n.d.). ***FP7 – MultiHemp – Multipurpose hemp for industrial bioproducts and biomass.*** Retrieved May 15, 2017, from MultiHemp: http://multihemp.eu/

nova-Institut. (1997). ***Hanf in Deutschland – 1997, das zweite Jahr. Umsetzung und Perspektiven & Das Hanfproduktlinienprojekt (HPLP), Zusammenfassung und Ausblick.*** Hürth: nova-institut.

O Ecotextiles. (2010, June 2). ***Characteristics of hemp***. Retrieved April 27, 2017, from O Ecotextiles: https://oecotextiles.wordpress.com/2010/06/02/characteristics-of-hemp/

Organic Cotton. (n.d.). ***The risks of cotton farming***. Retrieved April 25, 2017, from Organic cotton: https://organiccotton.org/oc/Cotton-general/Impact-of-cotton/Risk-of-cotton-farming.php

Paddison, L. (2016, September 27). ***Single clothes wash may release 700,000 microplastic fibres, study finds***. Retrieved April 25, 2017, from The Guardian: https://www.theguardian.com/science/2016/sep/27/washing-clothes-releases-water-polluting-fibres-study-finds

Pari, L., Baraniecki, P., Kaniewski, R., & Scarfone, A. (2014, October 1). Harvesting strategies of bast fiber crops in Europe and in China. ***Industrial Crops and Products***(68), 90-96.

Robins, L. (2013). Economic considerations for growing industrial Hemp. Kentucky, United States of America: Department of Agricultural Economics, University of Kentucky.

Ruhrstyle. (2016, April 24). ***Die Schuld im Gewissen und ein voller Kleiderschrank!*** Retrieved April 25, 2017, from Ruhrstyle: http://www.ruhrstyle.com/de/die-schuld-im-gewissen-und-ein-voller-kleiderschrank/

Schäfer, T. (2005). The Influence of Growing Factors and Plant Cultivation Methods on Biomass and Fibre Yield as Well as on Fibre Quality of Hemp (Cannabis sativa L.) . ***Journal of Natural Fibers, 2***(1), 1-14.

Schumann, E., Peil, A., & Weber, W. E. (1999). Preliminary results of a German field trial with different hemp (Cannabis sativa L.) accessions. ***Genetic Resources and Crop Evolution***(46), 399-407.

Sheppard, L. M. (2017). ***Volume 6 - Industrial Hemp***. (Advameg, Inc) Retrieved April 19, 2017, from Made How - How Products are Made: http://www.madehow.com/Volume-6/Industrial-Hemp.html

Stegg, W. (2001). ***The textile and clothing industry in the EU.*** Office for Official Publications of the European Communities. Luxembourg: European Communities.

StexFibers BV. (n.d.). ***ABOUT***. Retrieved April 16, 2017, from Stex Fibers: https://www.stexfibers.com/about

Textile Exchange. (2012). ***Textile Exchange - Creating Material Change***. Retrieved April 17, 2017, from Growing Regions - China: http://farmhub.textileexchange.org/learning-zone/growing-regions/china

Torrella, C. L. (2011). ***Hemp vs. Marijuana: The Federal battle to control the meaning of cannabis.*** Indiana University , Department of History . Indianapolis: Indiana University.

Truth Theory. (2017, February 15). ***Henry Ford Invented Hemp Cars That Ran On Hemp Fuel.*** Retrieved May 4, 2017, from Truth Theory - Keep your mind open: https://truththeory.com/2017/02/15/henry-ford-invented-hemp-cars-ran-hemp-fuel/

USDA. (n.d.). ***Harvesting, Retting, and Fiber Separation.*** Retrieved April 24, 2017, from Globalhemp: http://www.globalhemp.com/wp-content/uploads/2000/01/ages001Ee.pdf

van Dam, D. J. (n.d.). ***Optimisation of methods of fibre preparation from agricultural Raw materials .*** Agrotechnological Research Institute (ATO-DLO), Department Fibres and Cellulose. Wageningen: ATO-DLO.

Venturi, P., Amaducci, S., Amaducci, M. T., & Venturi, G. (2007). Interaction Between Agronomic and Mechanical Factors for Fiber Crops Harvesting: Italian Results–Note II. Hemp. ***Journal of Natural Fibers, 4***(3), 89-97.

Verhoeven, N. (2011). Qualitative Analysis. In N. Verhoeven, ***Doing Research - The Hows and Whys of Applied Research*** (Vol. III, pp. 290-294). Den Haag , The Netherlands: Eleven International Publishing.

Westerhuis, W. (2016). ***Hemp for textiles: plant size matters.*** Wageningen University. Wageningen: Wageningen University.

Woodford, E., & Cui, X. '. (2016). ***The Chinese Hemp Industry .*** Seed - Cultivating Financial Security . Seed CX Ltd. .

WWF. (2017). ***Cotton Farming - Cotton: a water wasting crop***. Retrieved April 26, 2017, from WWF - Worldwide Fund For Nature: http://wwf.panda.org/about_our_earth/about_freshwater/freshwater_problems/thirsty_crops/cotton/

Yu, C. (2013, October 31). ***Processing and products of refined flax and hemp.*** Retrieved April 16, 2017, from Fibra 7: http://www.fibrafp7.net/Portals/0/Chongwen_Yu_Day_1.pdf

Annexes

Annex I – List of databases and other websites consulted

Name	URL
aboutorganiccotton.org	http://aboutorganiccotton.org/
ACI Scholarly Blog Index	http://scholar.aci.info
Bio based news	http://news.bio-based.eu
Biodiversity Heritage Library	http://www.biodiversitylibrary.org
Biofach	https://www.biofach.de
Bioregional	http://www.bioregional.com
BLE	http://www.ble.de
BMZ	https://www.bmz.de
Boulder Weekly	http://www.boulderweekly.com
Brill Reference	http://referenceworks.brillonline.com.saxion.idm.oclc.org
Bündnis '90 die Grünen	https://www.gruene-bundestag.de
Cannasystems	http://cannasystems.ca
CountryReports	http://www.countryreports.org.saxion.idm.oclc.org/
Digitalcommons	http://digitalcommons.unl.edu
DRO	http://dro.deakin.edu.au/
EBSCOhost	http://web.a.ebscohost.com.saxion.idm.oclc.org
EIHA	http://eiha.org/
EnviroTextiles	https://envirotextile.com
Epsilon Archive for Student Projects	http://stud.epsilon.slu.se
ESA - European Society for Agronomy	http://www.european-agronomy.org
Ethical Consumer	https://www.ethicalconsumer.org
Ethical Fashion Forum	http://www.ethicalfashionforum.com/
EURACTIV.com	http://www.euractiv.com
EURATEX	http://euratex.eu
Euromonitor	http://www.euromonitor.com/
European Environment Agency	https://europa.eu/european-union/about-eu/agencies/eea_en
European Parliament	http://www.europarl.europa.eu
Eurostat	http://ec.europa.eu/eurostat/de
Fairtrade International	https://www.fairtrade.net/
FAOSTAT	http://www.fao.org/faostat/en/
Fashion Revolution	http://fashionrevolution.org
Fashion United	https://fashionunited.com
Federal Statistical Office Germany - GENESIS-Online	https://www.destatis.de
Fair Wear Foundation	https://www.fairwear.org
Fibre2fashion	http://www.fibre2fashion.com
Fibra	http://www.fibrafp7.net
Forbes Magazine	http://www.forbes.com/
GET CHANGED	THEMA STANDARDS
Global Hemp	http://www.globalhemp.com/
Global Mana	http://globalmana.org
Google scholar	http://www.scholar.google.com
Greenpeace	https://www.greenpeace.de
Hanffaser	http://www.hanffaser.de
Hanfjournal	https://hanfjournal.de
Hanflobby	http://www.hanflobby.de/
Hanf Magazin	http://www.hanf-magazin.com
Hanfverband	https://hanfverband.de/

HathiTrust Digital Library	https://babel.hathitrust.org
Hemp Farm	http://www.hempfarm.org
HempFlax	http://hempflax.com
Hemp Fortex Industries Ltd	http://www.hempfortex.com
Hempro	https://www.hempro.de
Hemp Technologies Collective	http://www.hemp-technologies.com
HempToday	https://hemptoday.net
Hemptrade	http://www.hemptrade.ca
Hemptraders	https://www.hemptraders.com
Hemp University	http://www.hempuniversity.com/
High Times	http://hightimes.com
Hindawi Ltd	https://www-hindawi-com.saxion.idm.oclc.org
Huffington Post	http://www.huffingtonpost.com
IEEE Xplore Search Results	http://ieeexplore.ieee.org.saxion.idm.oclc.org
International hemp association	http://www.internationalhempassociation.org
IYNF	http://www.naturalfibres2009.org
Journals of Rezekne Academy of Technologies	http://journals.ru.lv
Kentucky Digital Library	http://kdl.kyvl.org/
Leafly	https://www.leafly.com
Lenzing Group	http://www.lenzing.com
Nova Institut	http://www.nova-institut.de
NZZ	https://www.nzz.ch
O Ecotextiles	https://oecotextiles.wordpress.com
Oeko-Fair.de	http://www.oeko-fair.de
Oxford Academic	https://academic.oup.com
Plant variety database - European Commission	http://ec.europa.eu/food/plant/plant_propagation_material/plant_variety_catalogues_databases
planung & analyse	http://www.planung-analyse.de
Proplanta	http://www.proplanta.de/
ProQuest	http://search.proquest.com.saxion.idm.oclc.org/
PubliCatt - Repository Pubblicazioni Università Cattolica	https://publicatt.unicatt.it
Report linker	http://www.reportlinker.com
Research Gate	https://www.researchgate.net
Ruhrstyle	http://www.ruhrstyle.com/
ScienceDirect	http://www.sciencedirect.com.saxion.idm.oclc.org
Springer Link	http://link.springer.com.saxion.idm.oclc.org
Statista	https://de.statista.com
SuperBIO	http://www.h2020-superbio.eu
Taylor & Francis Online	http://www-tandfonline-com.saxion.idm.oclc.org
Texperium	http://texperium.eu/en/
Textile Exchange	http://textileexchange.org/
Textiles Intelligence	http://www.textilesintelligence.com.saxion.idm.oclc.org/
Textile World	http://www.textileworld.com/
Textilie.com	http://www.textilie.com/
The Geared Life	http://thegearedlife.com
The Guardian	https://www.theguardian.com
The Hempest	http://www.hempest.com/
Umweltbundesamt	http://www.umweltbundesamt.de
University of Gent – Publications	https://biblio.ugent.be
University of Helsinki	https://helda.helsinki.fi
University of Twente	http://utwente.nl
Wageningen University & Research	http://edepot.wur.nl.saxion.idm.oclc.org
waste2wear	http://www.waste2wear.com
Wiley Online Library	http://onlinelibrary.wiley.com.saxion.idm.oclc.org
World Cat .org	http://saxion.worldcat.org.saxion.idm.oclc.org
WWF	http://wwf.panda.org
Zukunftsinstitut	http://www.zukunftsinstitut.de

Annex II – List of keywords used sorted by Sub-topics

Sub-topic	Keyword
General	Hemp / Hanf / Chanvre
	Hemp fibre / yarn / fabric/ textiles
	Hemp (fibre/fabric) properties
	Hemp advantages / disadvantages
	Hemp (negative/positive) image
	Hemp perception/ public opinion
	Hemp and Marijuana
	Cannabis sativa
	Industrial hemp (fibre/ crop)
	Hemp producers Europe/ Germany
	Hemp projects Europe/ worldwide
	Hemp primary fibres/ secondary fibres
	Hemp sustainability /
	Global water/ carbon footprint hemp
	Hemp industry size and markets
	Industrial hemp research
	Industrial hemp supply / demand
	Multihemp
	Fibra
	Hemp-SYS
	Natural fibres
	Bast fibres
	Bast fibre processing
	Hemp books
History	Hemp history
	America history hemp
	Europe hemp history
	Prohibition hemp Europe/USA
	Industrial Hemp Germany
	Hemp for victory
	Hemp boom
Application	Hemp applications
	Hemp end uses
	Hemp products
	Hemp technical applications
	Hemp lobby
	Hemp processing plants Europe / Germany
	Hemp economy
	Hemp research and market development Germany/Europe
Cultivation	Cultivation area hemp worldwide/ Europe/ Germany
	Regional hemp textile chain Germany / Europe
	(Industrial) Hemp cultivation Germany/ Europe
	Hemp china production
	Hemp industry china
	Growing industrial hemp
	Hemp monoecious/ dioecious / male/ female plants/crops
	Hemp cultivation
	Regulations hemp cultivation
	Hemp EU subsidies
	Hemp climate
	Hemp harvest /ing/er
	Hemp flowering
	Hemp lignin/ pectin impact
	Natural fibres in China
Processing	Hemp processing machinery
	Hemp processing steps

	Hemp processing technology
	Hemp machinery
	Hemp production processes
	Hemp processing limitations
	Hemp fibre production
	Hemp retting/ hackling/ breaking/ decortication
	Hemp short/ long / whole fibre line
	Existing fibre lines hemp
	Hemp fibre spinning
	Hemp weaving
	Product lines hemp
Hemp in the apparel industry	Hemp brands
	Hemp fibre share global apparel
	Hemp clothing
	Hemp fashion industry
	Hemp in apparel/ fashion / clothing
	Market share hemp fibres
	Global fibre market (development)
	Organic cotton
	Recycled hemp
	Sustainable fibres
	Sustainability in fashion
	Sustainable fashion brands
	Pros and cons organic cotton
	Raw material impacts
	Hemp life cycle (fibre/yarn/ fabric)
	Environmental impacts raw materials used
	Consumer behaviour fashion
	Consumer behaviour fair trade
	Consumer behaviour sustainable fashion/ clothing/ apparel
	Consumer market fair fashion
	Consumer awareness sustainable fashion
	Sustainability fast fashion
	Textile import & export Germany/Europe
	Market share sustainable clothing/fashion/brands in Europe/ Germany
	Ethical fashion Europe
	Fair fashion
	Demand sustainable fashion
	Green textiles/ clothing
Cotton and Hemp	Comparison hemp cotton
	Hemp and cotton
	Characteristics of hemp
	Cotton fabric
	Cotton fibre price
	Hemp benefits textile
	Hemp fibre price (development)
	Hemp long fibre price (development)
Modifications	Improved hemp fibres
	Modified hemp fibres
	Hemp fibre modification
	Cottonized hemp
	Hemp fibre quality
	Genetic improvement hemp

Annex III – Questionnaire English Version

Questionnaire for the use in a Bachelor Thesis conducted
at Saxion University of Applied Sciences,
Enschede, The Netherlands
by Laura Sophie Kramer

Questionnaire about use of hemp for textile applications in the fashion industry

Date:

Name:
(Institution/ brand or person)

I – General questions for all respondents

1. In what way do you have a connection to industrial hemp?

2. Why are you working with hemp as raw material?

3. In which end-uses do you see the most potential concerning industrial hemp?

4. What are your predictions and hopes concerning the hemp industry in Europe?
(including cultivation, processing, different end-uses etc.)

5. Do you think hemp is a valuable resource for the fashion and apparel industry? Why?

Spring 2017

Questionnaire for the use in a Bachelor Thesis conducted
at Saxion University of Applied Sciences,
Enschede, The Netherlands
by Laura Sophie Kramer

6. Do you think hemp has a future in the fashion and apparel industry?
If yes, why do you think that? If no, why and what are the main obstacles, hindering hemp to be integrated to the fashion market on a big scale?

7. What do you think of building up a large scale cultivation of industrial hemp in Europe and why? (in general, independent of end-use)

8. What do you think of building up a large scale cultivation of industrial hemp in Europe for the end-use in the fashion and apparel industry?

9. What do you think, are the main factors that contribute to the small distribution/ use of hemp in the textile/ apparel industry?

10. What do you suggest to make hemp more popular and attractive for different industries within Europe? (More research/ improvements, more subsidies, marketing etc.)?

Spring 2017

Questionnaire for the use in a Bachelor Thesis conducted
at Saxion University of Applied Sciences,
Enschede, The Netherlands
by Laura Sophie Kramer

II – Questions for researchers or research institutions:

1. How long have you been doing research connected to hemp?

2. What exactly were you working on in the past concerning hemp?

3. What are you working on at the moment concerning hemp?

4. Do you have any recent findings in the research about hemp that you would like to mention/ emphasize here?

5. What, from your point of view, are the main obstacles within the hemp process chain for different end applications until now?

Spring 2017

Questionnaire for the use in a Bachelor Thesis conducted
at Saxion University of Applied Sciences,
Enschede, The Netherlands
by Laura Sophie Kramer

III – Questions for brands and companies using or processing hemp

1. What is the end market/ are the the end markets of your products?

2. Which products are you offering, consisting out of hemp or blended hemp?

3. Where does the hemp, used in your products, come from?

4. In which other countries/ regions your textile value chain is placed?

5. How big is the share of hemp used concerning all your products? How big is the percentage of your products being out of 100% Hemp or partly out of hemp?

6. Which other raw materials are you using besides hemp?

Spring 2017

Questionnaire for the use in a Bachelor Thesis conducted
at Saxion University of Applied Sciences,
Enschede, The Netherlands
by Laura Sophie Kramer

7. If you are using blended fabrics with hemp, what are the other raw materials combined with it?

   a. If it applies:
      Why are you using blended hemp fabrics and not just 100% hemp? (because of the price, unavailability, fineness of the fabric, style, comfortability, processability etc.)

8. Why are you using hemp for your products/ collections?

9. How important is sustainability, fairness and transparency for your company and how much is it connected to your decision of integrating hemp in your products?

Thank you a lot for answering my questions!

Laura Sophie Kramer

Spring 2017

Annex IV – Questionnaire German Version

Fragebogen im Rahmen einer Bachelorarbeit geschrieben an
der Saxion University of Applied Sciences,
Enschede, Niederlande
von Laura Sophie Kramer

Fragebogen über die Verwendung von Hanf für textile Produkte in der Modeindustrie

Datum:

Name:
(Institution/ Marke oder Person)

I – Allgemeine Fragen für alle Befragten

1. Auf welche Art haben Sie eine Verbindung zu Industriehanf?

2. Warum arbeiten Sie mit oder an Hanf als Rohstoff?

3. In welchen End-Anwendungen sehen Sie das meiste Potential bezogen auf Industriehanf?

4. Was sind Ihre Zukunftsprognosen bezogen auf die Hanfindustrie in Europa?
(einschließlich Anbau, Verarbeitung, unterschiedliche Endprodukte usw.)

5. Glauben Sie, dass Hanf ein wertvoller Rohstoff für die Bekleidungs- / Modeindustrie ist?
Ja oder Nein? Warum?

Frühjahr 2017

Fragebogen im Rahmen einer Bachelorarbeit geschrieben an
der Saxion University of Applied Sciences,
Enschede, Niederlande
von Laura Sophie Kramer

6. Glauben Sie, dass Hanf als Rohstoff eine Zukunft in der Bekleidungs- /Modeindustrie hat?
   Ja oder Nein? Warum?

7. Was halten Sie davon, Industriehanf wieder auf großen Flächen in Europa anzubauen und warum? (allgemein betrachtet, nicht auf einen bestimmten Zweck begrenzt)

8. Was halten Sie davon, Industriehanf wieder auf großen Flächen in Europa für die Bekleidungs- / Modeindustrie anzubauen?

9. Was sind Ihrer Meinung nach die Hauptfaktoren, die zu der geringen Verbreitung von Hanf in der Bekleidungs- / Modeindustrie beitragen?

10. Was schlagen Sie vor, um Hanf als Rohstoff in Europa für unterschiedliche Industriezweige populärer und attraktiver zu machen? (Bspw. mehr Forschung, Verbesserungen innerhalb der Wertschöpfungskette, mehr Subventionen, Marketing usw.)

Frühjahr 2017

Fragebogen im Rahmen einer Bachelorarbeit geschrieben an
der Saxion University of Applied Sciences,
Enschede, Niederlande
von Laura Sophie Kramer

II – Fragen für Wissenschaftler oder Forschungsinstitute

1. Wie lange betreiben Sie bereits Forschung in Bezug auf Hanf?

2. Woran genau haben Sie in der Vergangenheit in Bezug auf Hanf gearbeitet?

3. In welchem Bereich betreiben Sie zurzeit Forschung, bezogen auf Hanf?

4. Haben Sie neue wissenschaftliche Erkenntnisse über den Rohstoff Hanf, die Sie hier erwähnen / betonen möchten?

5. Was sind bisher, von Ihrem Standpunkt aus gesehen, die Hauptprobleme/ Hindernisse innerhalb der Hanf-Wertschöpfungskette für unterschiedliche Endanwendungen?

Frühjahr 2017

Fragebogen im Rahmen einer Bachelorarbeit geschrieben an
der Saxion University of Applied Sciences,
Enschede, Niederlande
von Laura Sophie Kramer

III – Fragen für Marken und Firmen, die Hanf verwenden und/ oder verarbeiten

1. Welchen Endmarkt/ welche Endmärkte streben Sie mit Ihren Produkten an?

2. Welche Produkte, bestehend aus Hanf oder Hanfmischungen, bieten Sie an?

3. Aus welchem Land/ welcher Region stammt der Hanf für Ihre Produkte?

4. In welchen Ländern/ Regionen befindet sich ihre textile Wertschöpfungskette?

5. Wie groß ist der Hanfanteil ihres Warenbestandes? Wieviel Prozent Ihrer Produkte besteht aus 100% Hanf oder teilweise aus Hanf?

6. Welche weiteren Materialien verwenden Sie neben Hanf?

Frühjahr 2017

Fragebogen im Rahmen einer Bachelorarbeit geschrieben an
der Saxion University of Applied Sciences,
Enschede, Niederlande
von Laura Sophie Kramer

7. Falls Sie Hanfmischungen für Ihre Produkte verwenden, mit welchen anderen Materialien sind jene gemischt?

   a. Falls zutreffend:
   Warum benutzen Sie auch bzw. nur Hanfmischungen und nicht reine 100% Hanfstoffe? (Bspw. aus Preisgründen, Verfügbarkeit, aufgrund der Stoff-/ Produktanforderungen, Komfort, Style, Feinheit usw.)

8. Warum benutzen Sie Hanf für Ihre Produkte/ Kollektionen?

9. Wie wichtig sind Faktoren wie Nachhaltigkeit, Fairness und Transparenz für Ihren Betrieb und inwieweit ist Ihre Entscheidung, Hanf in Ihre Produkte zu integrieren, damit verbunden?

Vielen Dank für die Beantwortung meiner Fragen an Sie!

Laura Sophie Kramer

Frühjahr 2017

Annex V – Summary of cotton and hemp comparison

Topic		Raw material	
		Hemp	Cotton
Cultivation area	Cotton needs twice as much for same fibre yield	+	-
Climate	Hemp grows almost everywhere Cotton can only grow in sub-tropical areas	+	-
Water use	5 to 10 times higher for Cotton	+	-
Pesticides	No pesticides needed for hemp whereas cotton needs large amounts	+	-
Crop rotation	Cotton damages arable soil through monoculture Hemp aerates the soil	+	-
Processing	Cotton processing is much easier and more economical	-	+
Machines	Cotton machinery is much better developed for textile use	-	+
Fibre homogeneity	Better in cotton fibres	-	+
Demand	Much lower demand on hemp for textile end-use	-	+
Fibre market price	Cotton prices vary around 1€/kg hemp fibres can cost up to 5 times more	-	+
C02 footprint	Hemp is carbon neutral to negative	+	-
Properties			
Durability	Higher for hemp	+	-
Thermal insulation	Better when wearing hemp	+	-
Breathability	Better in hemp fabrics	+	-
Tensile strength	Better in hemp fabrics	+	-
Dye-ability	Higher in hemp fabrics	+	-
Moisture management	Better in hemp fabrics	+	-
Fineness	Higher in cotton fabrics	-	+
UV resistance	Higher in hemp fabrics	+	-
Heat resistance	Higher in hemp fabrics	+	-
Comfortability	Cotton is softer from the beginning, Hemp wears in within time	n	n
Breaking Elongation	Hemp is less flexible than cotton	-	+

This table refers to the results stated in section 3.5.

Explanation of the symbols

+ Result to the advantage of hemp/cotton
- Result to the disadvantage of hemp/cotton
n Neutral outcome

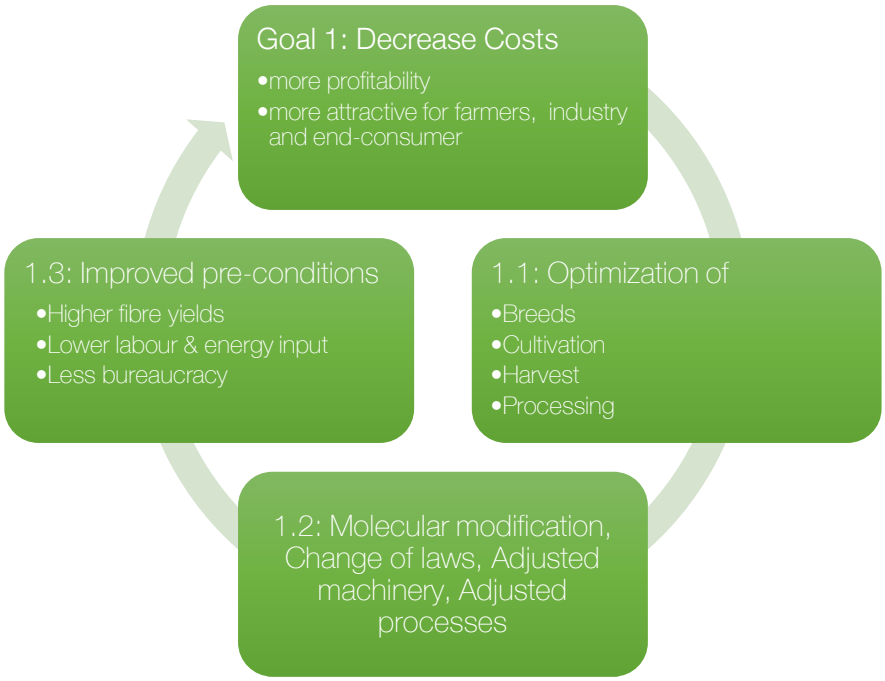
Annex VI – Open Coding Overview

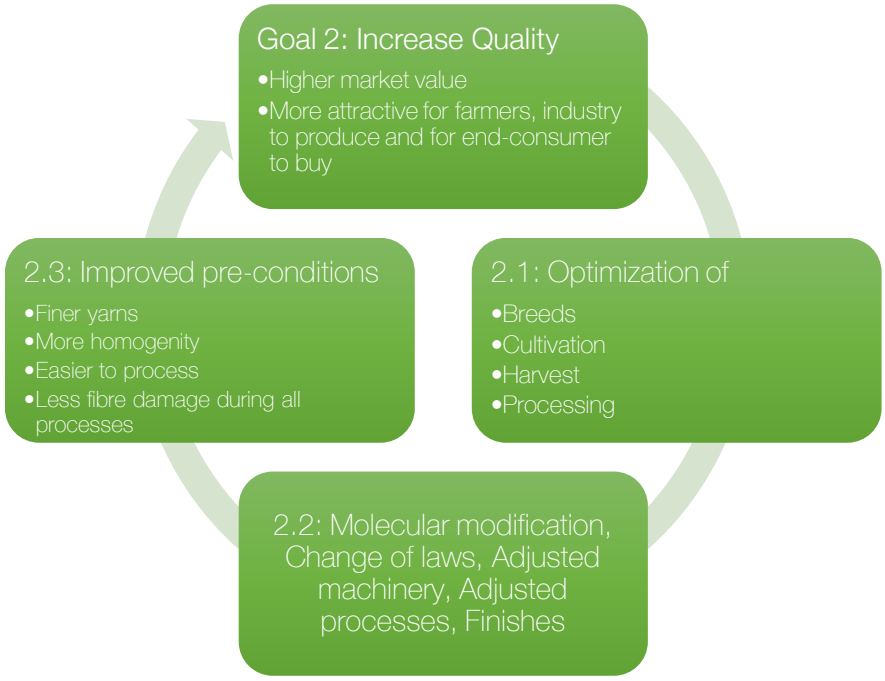
Codes / Factors	Named how many times (% share of codes)	Importance 1-5	Rank concerning importance and repetition
	40 (14.8%)		**1**
Competition	14 (5.2%)	4-5	
Price	12 (4.4%)	4	
Profit	14(5.2%)	4	
	34 (12.6 %)		**2**
Quality	20 (7.4%)	4-5	
Properties	14(5.2%)	4	
Processing	**33 (12.2%)**	4-5	**3**
Cultivation	**26 (9.6%)**	4	**4**
	29 (10.7%)		**5**
Industry	22 (8.1%)	3-4	
Investments	7 (2.6%)	4	
	26 (9.6%)		**6**
Know-how	11 (4.1%)	4	
Research	15 (5.6%)	3-4	
	27 (10.5%)		**7**
Applications	16 (5.9%)	3	
Future Material	11 (4.1%)	3-4	
Market development	**22 (8.1%)**	3-4	**8**
Sustainability	**17 (6.3%)**	4	**8**
	8 (3.0%)		**9**
History	6 (2.2%)	4	
Image	2 (0.7%)	3	
China	**4 (1.5%)**	4	**10**
Consumer	**4 (1.5%)**	3	**11**
Codes/Factors Total: 19 *Applied Total: 270 times within 135 statements*			

Steps taken for listed outcome:

1. Summary of answers from interview and questionnaires
2. Filling table sorted by topics
3. Implementing several codes to every statement
4. Counting and sorting the codes, ascribing relevance to every topic on a scale from 1-5 (1=least important, 5=most important)
5. Relevance ranking derives from literature review
6. Rank codes related to how often a code has been used, and to the ascribed relevance of the code
7. 19 codes were used; to make a better overview, relationships were spotted, and by that, codes are merged in main groups
8. Resulting from the merging of codes, 11 main groups were determined, of which the share of responses regarding theses main groups were calculated

Annex VII – Overview Models to overcome main influencing factors





Annex VIII - Part III: Threats and Opportunities for Hemp Apparel from Europe

Threats	Opportunities
Lack of interest from the fashion and textile industry resulting to minor investments	Trend of fair, sustainable, transparent and more regional supply chain beneficial for Hemp from Europe, as it generates and added value of end products
The large competition with other hemp products that are easier and cheaper to produce	The general growth and awareness of hemp for different products
The dominant role of China for fibre hemp and the rising cultivation in other developed countries	Developing a production chain that is of superior quality compared to China Hemp fibres and are produced on domestic ground
The big competition with cotton and man-made fibres	The predicted increase on fibres for textile applications accompanied with fibre shortage in the future
The dominant role of textile producing nations in lower wage countries and therefore low availability of a whole textile value chain in Europe	The possibility to combine sustainability and fast fashion in a better way in the future if consistent hemp fibres of competitive price can be produced for the market

Notes