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Study:

Value Chain of Soybeans in China and Germany

Summarized Results of a Study Conducted by LI Yumei and an Analysis of the German Market and Potential Sino-German Cooperation

By Lea Siebert and Karin Tränkner-Benslimane

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Chapter 1 is based on the study "Investigation on the Value Chain of Soybean in China – from Breeding, Planting to Processing" by **Li Yumei**. The full study by Li Yumei is available for download on the DCZ-Website.

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Executive Summary:

This study aims to provide insights into the soybean value chains in China and Germany, respectively, and outlines current research endeavours to improve soybean breeding, planting and processing. The part on the German value chain and its actors provides understanding of the actual state of research and production models like the demo farms in Southern Germany. The identified interest for an enhancement of domestic soybean production in China and Germany as well as unresolved challenges on the way to an efficient and sustainable soybean production, suggest a beneficial cooperation between scientific institutes, the agribusiness and politics from both countries.

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List of Abbreviations

AECM	Agri-environment-climate Measures
BDOel	Federal Association of Decentralized Oil Mills and Vegetable Oil Technology
BMEL	German Federal Ministry of Food and Agriculture
CAP	European Common Agricultural Policy
CHU	Crop Heat Units
FiBL	Research Institute of Organic Agriculture
GMO	genetically modified organisms
Grofor	German Association of Wholesale Traders in Oils, Fats and Oil Raw Materials
LfL	Bavarian State Research Center for Agriculture
LTZ	Agricultural Technology Center Augustenberg
MG	Maturity Groups
OVID	Association of the Oilseed Crushing and Oil Refining Industry in Germany
UFOP	Union for the Promotion of Oil and Protein Plants
ZALF	Leibniz Centre for Agricultural Landscape Research

Introduction

According to the White Paper "Food Security in China" released by the State Council Information Office of the People's Republic of China, October 2019, China achieved up to 95 percent self-sufficiency in staple grains (rice and wheat) (1). Reaching self-sufficiency also in oil plants such as rapeseed and soybeans is another strategic target. The trade tensions between China and USA led to a reduction of soybean-imports from US-farmers. In order to reduce dependency on imports in general, China aims at increasing its own soybean production.

Soybean plays a leading role in Chinas agriculture, nearly 15 million hectares of agricultural land ("protected areas") are foreseen to produce soybeans in Northeast of China and the North China Plain. From oil-processing, as a high value by-product, protein feed for animals is obtained, but also a wide variety of traditional food products for human consumption are made, such as tofu. China can look back to more than two thousand years of tofu processing. Furthermore, soybean facilitates crop rotation in less diverse cultivation systems, enrich the soil as a nitrogen-fixation plant and finally diversify farmers income. A main concern in China's soybean strategy - besides the increase of production areas – relates to the reduction of production costs. In Germany, soybean plays an increasingly important role in agricultural production, mainly as protein feed in the animal industry. The increase of domestic production is also caused by the rising awareness of the German citizens of the negative environmental impacts of soybean production in Latin America (e.g. deforestation by logging and burning). Furthermore, consumers are getting aware about negative environment and climate impacts of meat consumption. Among the young generation, many change their diets and consumption patterns and become vegetarians or vegans.

China and Germany both have an intrinsic interest in increasing the production of protein plants, namely soybean and therefore, the Agricultural Policy Dialogue of the Sino-German Agricultural Centre (DCZ) aims at identifying potential bilateral research opportunities. Based on a literature review and written in consultation with several Chinese research partners, this study provides insights into important aspects of the soybean value chain in China in comparison to the actual status quo of soybean production in Germany. Firstly, the comprehensive study on the value chain of soybean in China by Li Yumei is summarised and secondly, the status quo of German soybean production is examined. Finally, challenges and opportunities regarding soybean production and processing in both countries are analysed and potentials for Sino-German cooperation are identified.

Chapter 1: Summary of "Investigation on the Value Chain of Soybean in China – from Breeding, Planting to Processing"

1.1. Status of Genetic Resources of Soybeans in China

Soybean cultivation in China has a long history of about 5000 years, developing the most diverse genetic resources of soybean in the world. Until 2000, researchers have collected more than 23000 cultivated soybean germplasm resources. Originally, soybeans mainly grew in northern China, especially in the mountains and basins of Liaoning, Hebei and Shanxi, whereas nowadays three main categories of cultivated soybeans developed: spring soybeans in the far Northeast, summer soybeans in Huang Huai Hai Plain, south of Beijing and multi-cropping breeds in southern China. Under the general objective of increasing soybean yields, the choice of cultivated soybean breeds is influenced by regional climatic factors. In northern China early maturing breeds are adapted to limited light and heat resources, whereas in southern China early, medium and late breeds are grown. At present, soybean breeds with a high adaptability to a wide range of different growing conditions are popular, such as Zhonghuang 13 and Zhonghuang 39. These breeds are suitable for monoculture as well as multiple cropping systems across different climate zones. Besides the adaptability to regional factors, the choice of soybean breed is affected by the intended uses: specific forage soybean breeding aim at improving the quality of soybean pulp with regard to protein and oil levels. Furthermore, feed breeds require a higher resistance as they are often grown mixed cultivation systems together with other feed crops. In order to select the most suitable soybean breeds, several national soybean experiments were conducted, for instance within the scope of the National Soybean Breeding Cooperation Network, which was established in 2007. At the same time, modern soybean breeding in China includes molecular design breeding technology. However, in contrast to research progresses with other crops there is still a lot of potential regarding gene mining in the field of soybean research.

1.2. Adaptation of Soybean to Climate Change and Agricultural Geographical Zones

It is expected that climate change will increase global CO_2 concentrations until 2030 by 40-110%, with expected changes in precipitation and temperature. In China, a temperature rise of 1°C might increase local irrigation demands in China by 5-6%. With regard to soybean plants, increased CO_2 levels are expected to promote plant photosynthesis which is beneficial to plant growth. However, an increase of carbon might lead to a corresponding decrease of nitrogen in the plants which results in lower soybean protein contents. Rising temperatures decrease soybean plants' water use efficiency due to raised transpiration rates. Even though higher CO_2 concentrations might compensate these negative effects, in a certain temperature range water stress and oxidative damage outweigh growth-enhancing CO_2 levels. During the last 5000 years of soybean cultivation, soybean breeds have adapted differently to local conditions. As a result, photoperiod and temperature response sensitivity of soybeans differ across China according to their geographic location. These differences in various soybean breeds become obvious when they are grown under the same conditions: the number of breeding days differs by 10 to 15 days and hence, they are categorised in different maturity groups (MG). In each of the three main soybean production areas in China – the northeast, Huang Huai Hai

Basin and the south – several representative soybean breeds developed that were best adapted to local conditions.

1.3. Yield and Quality of Major Soybean Breeds in China

Different types of soybeans are classified in five categories according to their seed coat colour and grain shape: yellow, green, black and other soybeans and feed beans. The most widely cultivated type in China are yellow soybeans which are used to make various soy products as well as soy sauce. Furthermore, they are suitable for protein extraction and processed to bean dregs or ground meal yellow soybeans are commonly used for livestock feed. Green soybeans are rich in unsaturated fatty acids, phospholipids, saponin, protease inhibitors, isoflavones, molybdenum, selenium as well as in protein and fibre. In addition, green beans are one of the main sources for vitamin B foods, while containing also vitamin A, C and K. Black soybeans – also called cowpeas or black beans – are rich in protein and low in calories.

From 2001 to 2015 the soybean planting area in China decreased by 44 million mu (i.e. 2,93 million ha) to 98 million mu, leading to a decline of domestic soybean production from 15.4 million tons to 11.78 million tons. As a result of national policies, soybean planting areas increased again since 2016. However, in response to rising consumer demands for meat and poultry, increasing amounts of soybeans are imported. Since 2002, when domestic yields were still higher than soybean imports, the rapidly growing soybean imports reached 95.542 million tons in 2017, while domestic production provides less than 20 million tons (2017). As these production numbers are insufficient to meet domestic demands, soybean production has been continuously increased since 2015.

The grain yield of soybeans is seen as a product of the number of plants per unit area, the number of pods per plant and the number of pods per 100 grains. As the number of pods per 100 grains is genetically determined by the number of seeds, this factor is stable. Furthermore, the number of plants per ha is limited by natural conditions and hence, the focus of breeding research lies on the number of pods per plant which varies widely. The number of pods per plant can be raised by increasing the effective number of nodes and branches. However, soybean plants with many branches with large angles automatically limit the number of plants per unit area and therefore, it is recommended to increase the yield by choosing breeds that are suitable for dense planting.

1.4. Core Value-adding Procedures in the Soybean Processing Industry

China is an important soybean producer and the largest soybean consumer in the world with a large number of domestic soybean processing enterprises. As a result of an increasing dependence on soybean imports, international market fluctuations impact both domestic soybean prices as well as soybean processing enterprises, while more foreign capital is flowing into the Chinese soybean crushing market. Within the soybean industry in China soybeans are processed in several value-adding steps, resulting in a number of products and by-products, such as soybean oil, soybean meal or whey. Out of the domestic demand of 14.9 million tons (2017) of soybean oil, 90% are used as edible oil, whereas the industrial demand only amounts to 10%. Most of soybean meal in China is used for livestock feeding: 53% for poultry, 29% for pork, 7% for beef cattle and 6% for dairy cattle. Even though domestic demand for soybean meal in China increased from less than 10 million tons in 1995 to about 60 million tons in 2015, domestic production kept pace and amounted to 61.2 million tons in 2015.

Despite rapid technological developments in the soybean oil processing industry over the last ten years, the majority of Chinese soybean processing enterprises expanded without corresponding investments in modern equipment leading to high production and operation costs and low product quality. Several modern technologies aim at reducing operation costs by addressing energy consumption and labour costs. Firstly, as coal burning causes more than 50% of production costs in soybean oil industry, replacing common coal-fired furnaces by a fluidized bed boiler significantly reduces coal consumption. Due to a higher thermal efficiency of 82%, in contrast to a 62% thermal efficiency rate of current furnaces, 9 kg of coal per ton of processed soybeans can be saved. Calculating with a 3000 t/d soybean production line, the investment costs of 4 million RMB could be recovered within one year. Secondly, unnecessary reactive power consumption amounts to more than 30% of electric energy consumption in the oil industry and could be reduced by applying a DJNB power saving device controller. In a soybean production line with 3000 t/d investment costs of 3.15 million RMB annual energy costs of 2.1 million RMB could be saved. Thirdly, labour and management costs could be reduced by implementing a Programmable Logic Controller (PLC) computer operation and monitoring system. By setting certain quality indicators, product quality is automatically monitored, and production processes are adjusted accordingly. Equipment failures can be prevented more easily by installing smoke and gas detectors as well as pressure sensors. Furthermore, besides production costs, also product quality could be improved by using high-performance process equipment, such as more efficient extrusion machines or packed deodorization towers instead of plate deodorization towers.

The production of soybean oil also generates several by-products which can be further processed to extract phospholipids, vitamin E, xylose oligomer or plant protein. The soybean protein processing industry requires high-level technology in order to generate high added value products, such as soybean protein isolate, soybean protein concentrate, soybean peptide, soybean saponins and isoflavones or soybean tissue proteins. Different steps in soybean processing also involve biotechnological methods such as enzyme engineering or fermentation engineering. The processes to isolate and concentrate soybean protein generate by-products, for instance whey, which can be processed again to extract soybean oligosaccharides and isoflavone. Soybean processing generates wastewater in the form of yellow slurry water with high concentrations of organic matter and a low pH. Even though soybean oligosaccharides can be extracted from wastewater by reverse osmosis and nanofiltration, so far, the utilisation of soybean wastewater has not been industrialised.

1.5. Potential of China-grown Soybean for Reduction of Imports

In response to the increasing demand for soybeans in China, imports have annually grown over the past two decades. In order to reduce the dependence on soybean imports in the future, the national soybean production is enhanced. Firstly, the cultivation area for soybeans is extended to 140 mu in 2020 with further expansions to 149 million mu in 2025 and 149.9 million mu in 2028 according to the "Soybean Revitalisation Plan". Secondly, China seeks to increase domestic soybean yield per unit area as the average yield in China currently amounts to 1787.4 kg/ha, whereas the US, Brazil and Argentina have achieved an average yield of 2945.7 kg/ha. This can be achieved by improving soybean breeding, planting techniques and pest management. In 2019, soybean variety Henong 71 set a new record for China's soybean yield with 447.47 kg/mu. The research focus of planting techniques lies on soybean planting in narrow lines, but also considers alternatives such as intercropping, interplanting, three-row cultivation and isometric hill-seeding. Furthermore, in the provinces Jilin and Liaoning significant increases in soybean yield per unit area could be achieved by means of a crop rotation system. In order to increase the overall competitiveness of Chinese soybeans, besides increasing the amount of domestically grown soybeans, additional factors such as soybean quality with regard to protein and oil content as well and price management should be taken into account. However, as the imported soybean breeds with a high oil yield are genetically modified, it is necessary to balance quality standards and public interests.

1.6. The Economic Potential of Soybean Production of Medium-sized Family Farms and Producer Groups/Village Level Economic Cooperatives

China's soybean industry value chain can be roughly divided into production, processing, trade and consumption. In response to a constant boom in all these sectors but in the soybean production the focus lies on increasing yield per unit area. The current self-sufficiency rate for soybean production only amounts to 18.13% (2018) which is seen as a threat to China's grain and oil supply as well as its economic security and social stability. The State Council issued an opinion on supporting the development of leading enterprises of agricultural industrialisation and new agricultural operation entities, mainly include family farms, large professional households, agricultural cooperatives and leading enterprises. Since 2016, the new agricultural management system ushered in a new period of development and resulted in 130 000 new agricultural organisations. In the current institutional environment and in the practice of the state, there are three agricultural operation modes: the "old", administrative mode, the laissez-fair market-oriented mode and the new concept of professional cooperatives. The **administrative mode** derives the long-term strategy that the state operates and plans national grain planting in defined "main production areas" in order to ensure food security. In this system the state has set up a huge institutional system for the collection, processing, storage and sale of grain, while the small-scale farmer only delivers the harvest to the grain management office. In order to encourage grain production, the state stabilises grain prices by means of subsidies and fiscal transfer payments. When China's grain price exceeded the international market price, international competition and food safety became more important. With regard to soybean production, food security would require the use of 400 million mu of arable land for soybean production which is could hardly be achieved. Instead the long-term strategy of the country is to meet domestic demands for soybean as animal feed by importing more efficient and cheaper genetically modified soybeans and use available arable land for producing high value-added agricultural products. At the same time, China continues to produce natural soybeans to enter the international market of soybeans as a high-value health food. The production of these refined and high value-added agricultural products offers a high economic potential to medium-sized rural economic organisations in China without competing on the primary soybean market. The **laissez-fair market economy** in China operates in a different institutional environment. Here state intervention is limited to giving support to "large leading enterprises" and "large households" which are meant to enhance China's competitiveness on the international market. However, most agricultural producers are small-scale farms and receive no subsidies, whereas many producers suffer from price fluctuation and the imbalance of supply and demand on the market. The production mode of "**professional cooperatives**" was proposed in the Document No.1 by the Central Committee and the State Council. The aim is to unite "producers and operators of similar agricultural products and providers and users of similar agricultural production and operation services" within a democratically managed organisation. In practice, it has happened that investors have undermined cooperatives with false entities to benefit from state subsidies. Furthermore, it is criticised that cooperatives operate separately from rural village communities. This separation could be addressed by implementing the "East Asian model" of the semi-governmental Comprehensive Agricultural Association which aims at supporting small-scale farmers in operational and community activities and safeguarding their political interests.

In order to enhance efficiency in soybean production, the organisational form of production and processing units as well as circulation facilities must be improved. The distance between soybean planting areas and processing units has been identified as the major challenge in efficient soybean circulation. The main soybean production area is in the northeast, whereas most processing facilities are located along the southeast coast and in the south, while railway transportation capacities are limited. The recent emergence of new circulation entities such as soybean cooperatives, brokers and rural grain industrialisation management enterprises enhances communication and exchange between family farms and cooperatives. Following the example of the American soybean industry, soybean value-adding processing industry could be integrated in soybean production groups. Furthermore, the internet enables family farms and cooperatives to make decentralised online sales and benefit from the economic potential of selling on the high-end market. In respond to a growing demand for "natural" and "green" products, non-genetically modified soybeans produced by medium-sized family farms and producer groups have a considerable economic potential.

Chapter 2: Status Quo Soybean Production in Germany

2.1. Soybean Market in Germany

Domestic soybean production at a relevant scale is a relatively new phenomenon in Germany which can be seen by the fact that size of soybean growing area and corresponding yields are only reported since 2016. In 2019 soybeans were grown on 29000 ha in Germany with an average yield per ha of 2.91 t and a total harvest of 84000 t. The main growing regions are in southern Germany: in Bavaria (15500 ha) and Baden-Wuerttemberg (7600 ha) (2).

As domestic production of oilseeds cannot meet the demand for protein feedstuff, the existing "protein gap" is currently closed by large imports. Due to its optimal amino acid structures, so far soybean meal is the most important protein feedstuff in Germany which is especially difficult to substitute in pig and poultry feeding (3). In 2017/18 Germany imported 3.5 million tons of soybean and 922000 tons of soybean meal. With regard to soybean oil Germany is a net exporter with a negative import value of 209000 t. In 2018 most important trading partners for soybeans were the USA (62%) and Brazil (27%) (Figure 1). In Germany soybeans are mainly processed to soybean oil and soybean meal with a small proportion of whole soybeans which are used in compound feed production (4). In 2017/18 8.35 million tons of oil cakes and extraction meals were used as animal feed, out of which 3.47 million tons originated from soybean meal (4).

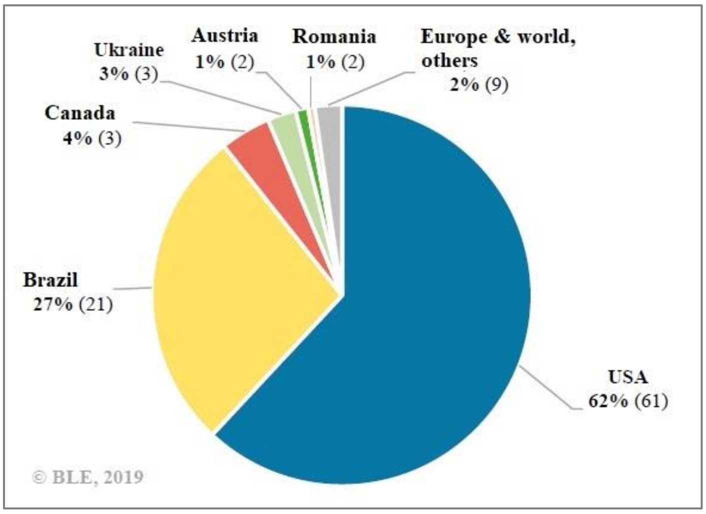

Figure 1: Soybean imports to Germany in 2018 in %. Values in brackets display imports in 2017.
Source: (4), p.28, translated from German.

As a result of the "*Protein Plants Strategy"* by the German Federal Ministry of Food and Agriculture (BMEL) and in the light of an increasing awareness for the relevance of products free of genetically modified organisms (GMO), soybean production in Germany is expanding. Furthermore, it is expected that higher average temperatures due to climate change will lead to better growing conditions for soybeans in Europe (4). On the other hand, an increasing rejection of GMO products among consumers in Germany leads to a rising demand for GMO-free products, including animal products that guarantee GMO-free feeding. This development as well as the temporarily lower costs of rapeseed by-products led a decline in the use of soybean meal and soy cake since 2009/10 by 14.4%, while rapeseed meal production increased by 37.0%. In 2017/18 amounts of rapeseed meal exceeded the amounts of soybean meal for the first time (4) (Figure 2). However, GMO-free soy meal obtains higher prices and therefore European and German producers see a large market potential (4).

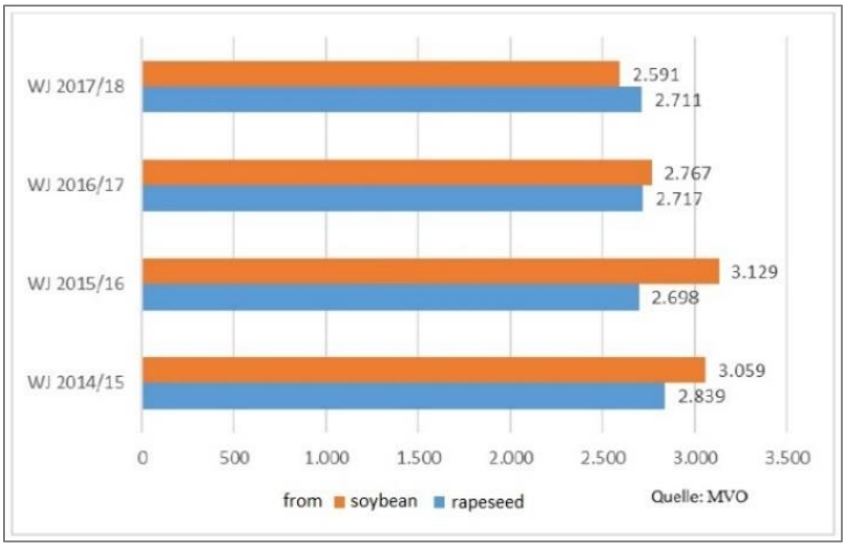

Figure 2: Processed by-products from soybean and rapeseed in 1000 tons between 2014/15 and 2017/18.
Source: (3), p.18, translated from German.

So far, Brazil is the only producing country out of Europe that can supply GMO-free and certified soybeans, whereas, as a result of current European law, all soybeans grown in Europe are GMO-free (3). Besides the controversial debate on health impacts of GMO as imported feed, GMO soybeans also have a strong impact on climate change. Especially in Brazil, the production of soy for export is an important driver for the deforestation of primary forests. As Brazil is the second most important exporter of soybeans to Germany, domestic demand for soy as an animal feed indirectly contributes to the ongoing deforestation (5). With the Amsterdam Declaration in 2015, the German government together with other European countries declared their will to support the private sector's goal to eliminate deforestation from agricultural supply chains by 2020. Unfortunately, in 2019 Brazilian farmers demonstrated by illegal slashing and burning of large amounts of primary forest their unwillingness to contribute to this agreement. Especially the production scale of pork for export raises demands for imported soy feed. From top-ten swine-exporting countries, European countries reach a proportion of 57 %, seven EU countries range under the "world top ten" led by Germany (Figure 3). Consequently, the objective of eliminating

#	Country	Exports (in Mio. €)	Global Market Share
1	Germany	4216	15,8 %
2	USA	4052	15,2 %
3	Spain	3602	13,5 %
4	Denmark	2427	9,1 %
5	Canada	2234	8,4 %
6	Netherlands	1921	7,2 %
7	Brazil	1297	4,9 %
8	Belgium	1277	4,8 %
9	Poland	940	3,5 %
10	France	824	3,1 %

Figure 3: Top 10 pork exporting countries in 2017
Source: (30)

deforestation from agricultural supply chains puts additional pressure on Germany to increase the production of protein plants, especially soybeans.

2.2. Political Framework

In response to an increasing demand for GMO-free protein feedstuffs and in order to capitalise on the environmental benefits of an integration of legumes in local cultivation systems, the BMEL implemented the *"Protein Plants Strategy"* in 2012. The strategy promotes the cultivation of indigenous protein plants such as peas, field beans, sweet lupines and also soybeans (6). In order to implement corresponding measures within the framework of the European Common Agricultural Policy (CAP) and as an investment in research and demonstration projects between 2014 and 2020, the German government provides 27 million Euro of funding (4). Within the CAP, the financial support of agri-environment measures (AECM) can apply to the cultivation of legumes on at least 10% of an agricultural holding with a special focus on grain legumes. Since 2013 the Bavarian State Research Center for Agriculture (LfL) coordinates the S*oy-Network* of more than 100 demonstration farms which apply recent research findings to their soybean cultivation practice. The dialogue platform "*Forum for more sustainable protein feedstuff*" facilitates the exchange of knowledge and ideas between relevant stakeholders.

With a strong focus on soybean promotion and in response to the 2030 Agenda by the United Nations General Assembly for a sustainable development, 14 European states signed the so-called *European Soy Declaration* in 2017, followed by five more countries until 2019 (7). The declaration contains the commitment to promote and expand sustainable cultivation of soybeans and other legumes.

Main stakeholders specifically for the promotion of soybean production are the *German Soy Promotion Group* (Deutscher Sojaförderring) which was founded in 1980 by soybean producers and the *Danube Soy Organisation* with a focus on the promotion of sustainable soybean cultivation across several European countries along the Danube river. Besides these two organisations with a clear focus on soybeans, there are several other associations with relevance to soybean production and processing: The *Union for the Promotion of Oil and Protein Plants* (UFOP) was founded by the German Farmers' Association (Deutscher Bauernverband) and the German Plant Breeders' Association (Bundesverband Deutscher Pflanzenzüchter e.V.) and has the more generic objective of representing producers as well as the processing and marketing industries for domestic oil and protein plants. Specifically, oilseed processing enterprises are brought together by the *Association of the Oilseed Crushing and Oil Refining Industry in Germany* (OVID). Under the objective of strengthening regional economies the *Federal Association of Decentralized Oil Mills and Vegetable Oil Technology* (BDOel e.V.) unites decentral oil mills and stakeholders from science and politics. At a larger scale the *German Association of Wholesale Traders in Oils, Fats and Oil Raw Materials* (Grofor) represents and connects traders, producers, consumers, agents and service sector enterprises from all over Europe. A list of the relevant stakeholders for the promotion of soybeans and oil and protein plants in Germany can be found in appendix A.

2.3. Value Chain of Soybean in Germany

2.3.1 Soybean Production in Germany

According to the German Soy Promotion Group, about 780000 ha of arable land in Germany would be suitable for soybean cultivation, with a potential harvest of 2 million tons of soybeans (8). Currently, only 84 000 tons of soybeans are produced on 29000 ha (2). In consideration of temperature, global radiation, precipitation and soil value, the Julius-Kühn-Institute generated a map of potential growing regions with a classification system from "very good", i.e. very suitable for soybean production, to "unsatisfactory", i.e. not suitable (see Figure 4).

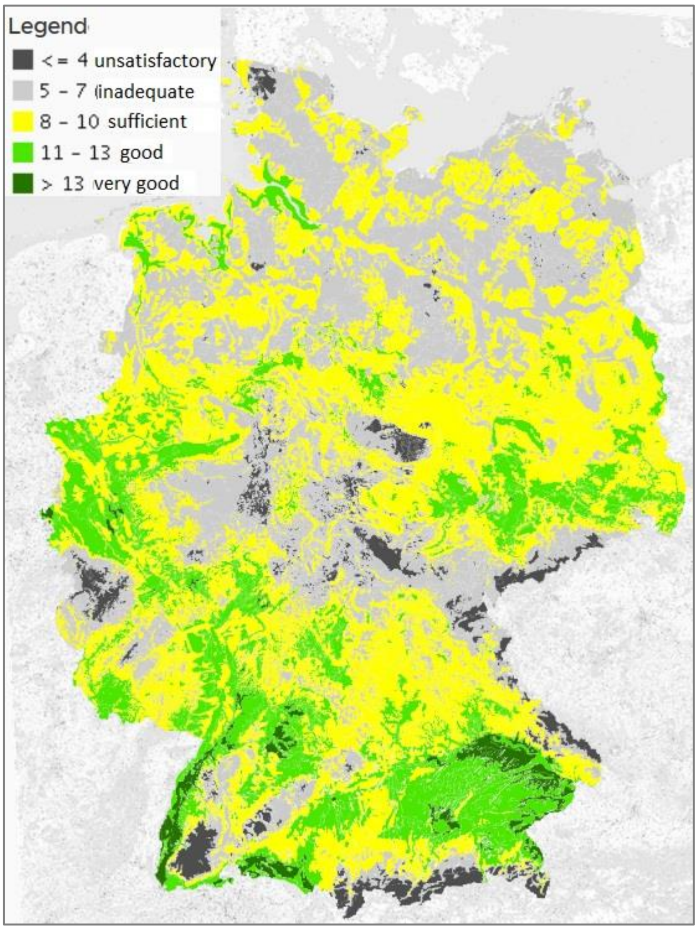

Figure 4: Suitable regions for soybean cultivation in Germany. Source: (28), translated from German.

In the process of identifying suitable soybean cultivation regions, location-specific Crop Heat Units (CHU) were calculated and modified according to the specific requirements of soybeans: night temperatures above 4.4°C and day temperatures above 10°C and below 30°C; sufficient amounts of rainfall in July and August and good soil quality (9). The map (Figure 4) also allows an informed choice of the most suitable varieties to be grown in a specific location. Following the American system of maturity groups, it is recommended to grow varieties with the value 00 in the most suitable areas (dark green), 00 to 000 value varieties in the second category (bright green) and 000 varieties in those areas with medium suitability for soybean cultivation (yellow). Besides a warmer climate, water availability is the second limiting factor for soybeans grown in Germany with direct implications for soybean yield and quality (9). Field experiments with soybean varieties Merlin and Sultana (both MG 000) in Northeast Germany have shown that irrigation can increase yields in dry years by 41%. However, same evidence for soybean varieties for human consumption are still missing (10).

Based on extensive variety trials, the German Soy Promotion group annually publishes a list of available and promising soybean varieties and seed suppliers for both conventional and organic agricultural production. Currently, 19 suppliers offer more than 50 different soybean varieties from 000 and 00 MG. In general a distinction can be made between two different growth types: the indeterminate type which continues to grow after temporary disruptions e.g. by water stress, whereas the semi-determinate type stops growing as soon as its specific demand of heat and water is met.

Consequently, the first type is adapted for dry regions, whereas the latter type is more suitable for wet regions (11). In order to optimise the plants nitrogen fixation and beneficially impact yield and protein-contents, it is essential to inoculate seeds with *Bradyrhizobium japonicum.* Inoculation is either offered by seed producers or can be carried out by the farmer within 48 h before sowing.

Depending on the type of variety and on the farming system, row distances in soybean production vary from 12.5 cm (like for cereals) to 75 cm (normally used for maize). In order to apply mechanical weed control, row distances over 25 cm are necessary. In general, the same machinery used for oilseed rape, cereals and other legumes can also be used in soybean cultivation. In organic agricultural systems, for 000 varieties 65-70 seeds are used per m² and for 00 varieties 55-60, aiming for 50 plants per m² (12). In conventional farming systems seed densities are lower as there are fewer losses by mechanical weeding which is used in organic cultivation (13). Field experiments with different weed control methods in organic soybean cultivation have shown that cover crops like rye and barley can successfully suppress weeds, whereas reduced tillage combined with hoeing resulted in highest yields (14). If soybeans are used in human food production, most food manufacturing companies have specific requirements for soybean breeds and quality. For instance, tofu production requires soybeans with a minimum protein content of >450 g/kg (15). For this reason, soybeans for food production are normally grown under contract farming conditions, for instance for the German tofu company Taifun (16).

2.3.2 Soybean Processing Industry in Germany

In Germany farmers can sell their untreated soybeans either directly to a food manufacturer, normally within contract farming, or to a primary distributer. In the value chain for animal food production, soybeans go through a thermal, hydrothermal or combined process with heat and pressure to remove antinutrients. The toasted, full-fat soybeans can be further processed to reduce the fat content, resulting in soya cakes which can be used as animal feeding in organic production (17). In order to produce extraction soybean meal an additional extraction process with hexane is required. The resulting soybean meal must not be used in organic production but is the main protein feedstuff used in conventional animal husbandry (18).

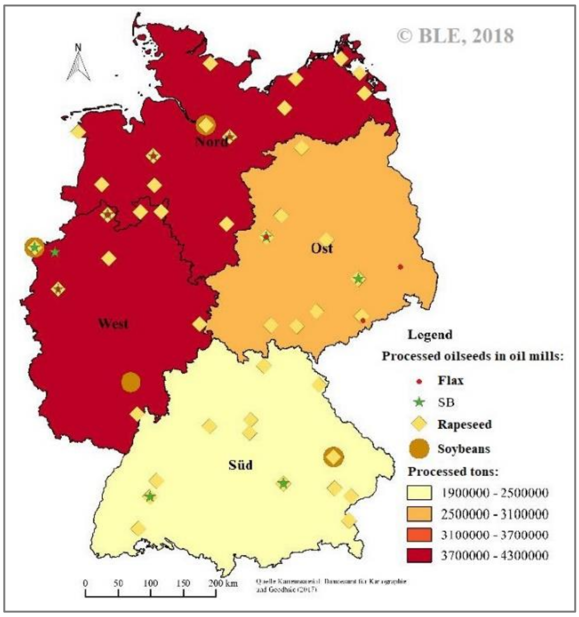

Figure 5: Oilseed processing by regions, 2017 in t
Source: (4), p.15, translated from German.

For the soybeans value chain for human consumption, a minimum soybean size of 5 mm is required. After a cleaning process, soybeans are dried to achieve a moisture content of only 11-14%. During storage of soybeans and in all processing steps it is important to prevent contamination with GMO-soybeans. Furthermore, soybeans from organic and conventional production must be clearly separated. The main soybean food product for human consumption in Germany are tofu and soy milk (19). Due to the focus on imports of protein plants, most processing industries and wholesalers are located close to large international harbours. As a result of company takeovers and fusions few companies hold a big market share. The map in Figure 5 shows the current distribution of the 53 main oil mills in Germany. Largest amounts of oilseeds are still processed in the north-eastern parts of the country.

The German Soy Promotion Group provides an annually renewed list of suppliers for all available soybean varieties in organic and conventional cultivation systems (20). Furthermore, they provide lists of soybean processing companies who buy untreated soybeans directly from the farmer (21), as well as lists of German enterprises who process soybeans for human consumption (22) and for animal feed (23).

2.4. Research on Soybeans in Germany: Breeding and Cultivation Systems

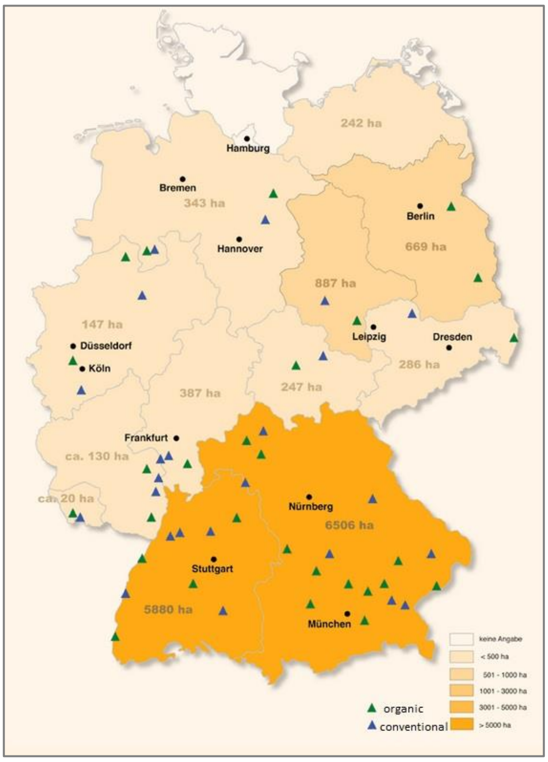

Figure 6: Flagship projects of the Soy-Network in Germany
Source: (29), translated from German

Within the soy-network 50 demonstration farms were chosen as flagship projects. These farms provide a field cultivated with soybean which is used as a demonstration site to communicate state-of-the-art knowledge on soybeans to interested visitors. These flagship projects are distributed over Germany and entail organic and conventional farms (Figure 6). The main research project of the soy-network aimed at the "Expansion of soybean cultivation in Germany through adaptation by breeding and optimisation of crop production", evaluated results from 146 demonstration farms and published a final report in 2018 (24). The involved research institutes are listed in appendix B. Besides the Soy-Network, the LfL is also involved in a Sino-European research and innovation project on soybean breeding, which started in January 2018 and is coordinated by Donau Soja (25). Leibniz Centre for Agricultural Landscape Research (ZALF) currently also conducts several research projects related to soybeans with a strong focus on sustainability and impacts of climate change.

2.5. Ecological and Economic Potential of Soybean Production in Germany

As it is also acknowledged by the Protein Plant Strategy, legumes have several positive ecological effects, specifically on soils, such as contribution to humus formation, increases in earthworm populations, improved soil fertility, increased water retention capacity or soil loosening through deeper root penetration. Furthermore, their ability to extract nitrogen from the air and to make it plant available, reduces the amount of chemical fertiliser application and corresponding CO_2

emissions. The integration of legumes in dense crop rotations can diversify cultivation systems, enhance agrobiodiversity and provide additional resources for bees (6). Besides cool growing conditions and the soybean variety's maturity characteristics yields and quality of German soybeans are most affected by the abundance of nitrogen-fixing bacteria. Only in symbiosis with certain rhizobia strains, soybeans form root nodules that enable the provision of plant available nitrogen from the atmosphere in exchange for energy from plant photosynthesis. In practice, a successful nodulation requires the inoculation of seeds with the appropriate rhizobia culture as these bacteria are not native in European soils and different soybean varieties are not compatible with all rhizobia strains. Field trials with different Bradyrhizobium japonicum inoculants and different soybean varieties under German growing conditions showed that interactions between these factors significantly affect protein content (15). Furthermore, grain yield, protein content and protein yield could be increased by up to 57%, 26% and 99%, respectively. As a result of this trial, biodoz Rhizofilm, Force 48 and NPPL Hi-Stick are recommended as inoculants. However, as only soybean variety Protina in combination with Biodoz Rhizofilm resulted in sufficient protein contents for tofu production, it is recommended to conduct further field experiments to test the effectiveness of Bradyrhizobium inoculants with different soybean varieties – ideally before commercialisation, as it is practiced in France. As soybean plants form less nodules at a high N content in the soil, N fertilisation can have adverse effects on nodulation as well as protein contents and yields (15). However, this effect does not necessarily apply to the use of recycled organic manure which was found to have a positive effect on certain rhizobia strains (26).

With regard to the economic potential of soybeans, their positive effect on the subsequent crop and their implications for a reduced use of nitrogen fertiliser lead to a good competitiveness with other grain legumes, barley or oats (13). The evaluation report of the soy-network project with several exemplary value chains for soybean production in Germany also estimate that domestic soybean production can compete with other domestically grown crops. However, it is important to distinguish between organic and conventional farming systems: for more than 50% of the participating organic farms soybeans turned out to be more profitable than field beans, grain peas, winter wheat and partly also grain maize, whereas in average less than 50% of the conventional businesses could achieve higher profits with soybeans than with other crops. Furthermore, the study concludes that domestic and GMO-free soybeans are more suitable for direct marketing in the context of a regional value chain for the production of meat or dairy products than for replacing imports of soybean meal. Limiting factors for an expansion of soybean cultivation are the concentration of processing industries in the south and falling prices which make growing of domestic soybeans in many areas unprofitable. Even though the market for soy products for human consumption is still rather small, there is a lot potential for direct marketing of locally grown soybeans to replace the imported soybeans most producers use so far (24).

Chapter 3: Outlook and Potential of Sino-German Cooperation

In both countries, China and Germany, soybean production is on the rise. However, due to different environmental conditions and limited resources of arable land, there is a considerable difference of scale of soybean production. Furthermore, purpose and uses of soybeans differ: in China the main objective is the production of soybean oil with soy cake as by-product, whereas in Germany the focus lies on the production of soybean meal due to a high demand from the animal feed industry with soybean oil is often seen as a by-product (19). The different prevailing areas of soybean use in both countries also result from different, underlying drivers for the promotion of soybean production. In China soybean production is expanded under the objective of achieving a higher self-sufficiency in high-quality products for human consumption and feed production in order to become less dependent from imports, especially from the USA. As one of the world's top ten pork exporting countries Germany is facing constant pressure from civil society as well as environmental organizations to improve the quality of imported feed supply and substitute imports by domestic soybean production. Furthermore, according to the Amsterdam Declaration the German government is supposed to reach the target of eliminating deforestation from agricultural supply chains by 2020.

3.1 Breeding Activities in China and Germany

Scientists in both countries have a similar focus in their breeding activities. First of all, soy varieties should be adapted to upcoming changes in climate and growing conditions in different agricultural zones. Generally, it is expected that increasing temperatures will on one side improve growing conditions for soybeans in Europe. On the other side, shortages in rainfall will have a negative impact. Although an increase of CO_2 may stimulate photosynthesis of plants and increase their biomass, water-deficiency caused by increased temperatures and droughts could have a negative impact on soybean production. Breeders in both countries search for climate-adapted varieties.

In order to contribute to an increased national production, also yield per ha plays a major role in the breeding discipline. Varieties suitable for dense planting are favoured and recommended in China. Germany differentiates between two major groups, whereas the indeterminate types are more suitable to dry or water deficient areas and expected shortages in natural rain fall.

Quality plays another important role in both countries - foremost for China's traditional soy products like soy sauce or tofu. Especially the green soybeans are rich in essential nutrients, vitamins and protein for human consumption.

Inoculation with node evoking bacteria's like Bradyrhizobium japonicum plays an important role in Germany's breeding and production because of its effect on nitrogen fixation capability, yield and protein content. Trials in Germany show that composted manure could have the same result in nodule formulation. The present study on Chinese soybean value chains by Li Yumei (27), summarised in chapter 1, does not provide insights whether inoculation is practiced in soybean production in China.

Both countries struggle with the use of GMO-soy either in their own soybean production or imports of GMO-soybeans. Consumers in both countries refuse genetically modified organisms in their daily food intake or in food chains. The majority of German consumers – especially eco-consumers – demand GMO-free soybeans also with regard to imported animal feed.

3.2 Productivity

In general, low productivity in China's agriculture has several factors. The main identified factor is the small size of farms (in average 0,4 ha per farm) and inefficient cultivation systems managed by individual farmers; mono-cropping systems have been identified as another major driver of decreasing yields in soybean production over the years. Obviously, China aims to shift from previous monoculture systems to a more sustainable cultivation system avoiding inefficient (over) use of agro-chemicals and inappropriate cultivation techniques (27). Farmers are encouraged to apply crop rotation instead of longstanding mono-cropping schemes. Besides cultivation factors, also the limited access of farmers to storages or other infrastructure leads to remarkable post-harvest losses. Forming medium-sized family farms and producer groups on village level like "village level economic cooperatives" will contribute to better productivity, reduced losses and reduction of production costs in farming. Current research in China shows that grain yield depends on four components where the number of pods per plants plays a major role. In consequence, in research great attention will be paid in future on high-yielding soybean varieties.

Compared with China, Germany's production system distinguishes between "conventional" and "organic" farming systems. Weed control is an essential factor in organic soybean cultivation with impact on crop quality and yield and trials with cover crops already have shown promising results. In the light of upcoming stricter European plant protection regulations, it could be expected that positive experiences from organic farming will be applied in conventional soybean farming systems.

Actually, a comparison of productivity between the two countries is not possible as accurate figures are not available.

3.3 Value Adding Procedures /Soybean Processing

According to a Chinese investigation (27) in May 2012, a major problem in Chinas soybean industry lies in geographic distances between production and processing areas, lack of appropriate storages followed by outdated technologies in processing - mainly its energy supply systems.

Besides these challenges, it must be recognized that China maintains a huge range of soy products as well as soybean by-product with a wide variety of different processing steps. Problems in the Chinese processing industry are mainly caused by lack of energy in rural respective soybean production areas and outdated machinery. Although so many new enterprises entered the processing industry in the last ten years, investments in modern or innovative equipment did not meet the demand due to risk aversion of entrepreneurs and lack of financial services. In consequence, China faces high production costs and low product quality with a weak competitiveness on international markets.

The underlying study from Prof. Li described very detailed the different soybean processing steps in China but did not inform about the structure of the value chain stakeholders, like farmer associations or unions. Assumingly, interaction, cooperation and communication between the different stakeholders have an impact on quality and productivity of the soybean processing industry.

In Germany, the information flow between science and producers is well organized. Since the rise of soybean production, different actors from production side like the farmer associations, breeders, millers, oilseed processing enterprises and scientific institutes are engaged in strengthening the whole German soybean value chain. Perhaps one link in the soybean value chain is underrepresented in this and the underlying study: the human end-consumer of soybean products. Due to the history and the long tradition in human consumption, China's cuisine offers a richness of delicate "standing alone" vegetarian soybean dishes whereas in Germany often soybean products are marketed simply as a "substitute of meat", even among the vegetarian community of consumers.

3.4 Political Framework

Since 2012, with the introduction of the *Protein Plant Strategy* and the *European Soy Declaration* in 2017, soybean production increased in Europe. Soybean farmers in Germany tend to add value on farm and developed regional marketing strategies, differently supported by the specific federal governments.

Figure 7: "Bauernmeile Munich"
Source: Tränkner, K. (2019)

Regionalism as a new consumer trend is supported by governmental institutions like the previously mentioned LfL (Figure 7). According to the study on the Chinese soybean market (27), Chinese farmers and processors demand for political support in order to decrease production costs.

When China entered the World Trade Organization (WTO) in 2001, the domestic soybean planting area and soybean production decreased significantly while imports increased, mainly from USA. Imports increased from 13.94 million tons in 2001 to 95.542 million tons in 2017. Between 2016 and 2018 production again increased. This happened mainly due to a national policy, promoting crop rotation and a guided reduction of corn planting areas. Trade tensions between the USA and China in

2018 and the dramatic outbreak of African swine fever led to falling imports of soybean. Nevertheless, China's self-sufficiency rate in soybeans is lower than 20 percent, in 2018 only 18,13%. The ongoing trade tensions unveiled China's strong dependency on soybean imports. In consequence, China introduced the national soybean revitalization plan. According to this plan, foremost the production area will be extended introducing high-yield soybean varieties where breeding plays a crucial role followed by improvements in plant protection and cultivation methods.

Document No.1, released in January 2020, highlights again the importance of increasing Chinese soybean production and increasing self-sufficiency with a series of measures; for example, investments in infrastructure like roads, electricity supply, transportation systems, storages and processing plants in growing areas and - most important - subsidies for soybean producers. A so-called red line will ensure sowing areas for soybeans and generally protect arable land from construction or other uses. Finally, the support of large-scale farms and farmer cooperatives are on the agricultural policy agenda.

3.5 Possible Topics for Further Investigations

Having a focus on the strengths of both countries to identify areas of synergies or common interests following potential topics could be stimulating for further investigation or cooperation:

- ➢ Chinas rich genetic resources and long history of soybean cultivation in three different growing zones - the cultivation systems and choice of soybean breeds in China could provide relevant knowledge and experience to German farmers whereas Chinese farmers could benefit from existing model farms in Germany.
- ➢ Cooperation between Chinese and German soybean breeders and processors
- ➢ German and Chinese research on resistance and tolerance in plant production under the light of climate change
- ➢ Bilateral research on inoculation efficacy
- How is China dealing with inoculation of seed? Is inoculation necessary? Are research papers available about Chinese soil life (micro fauna and micro flora) in soy growing areas?
- ➢ Agriculture and processing technology exchange (e.g. harvester, dryer etc.)
- Bilateral establishment of demo-farm(s) in Chinese production areas (MARA and BMEL in cooperation with Danube Soy Association)
- Farmer to Farmer / processor to processor exchange study tours in the context of “family farming systems” and “moderate scale farming operations in China and Germany with a focus on integrated processing of soy in production areas (or a study tour for key-experts / actors in soy value chains)
- Are German models of demo farms and processing facilities in growing areas transferable to Chinese soybean growing areas?
- ➢ What are consumer expectations regarding GMO-free soybean products and meat?
- ➢ How does China deal with risks in GMO-soy production for animal feed concerning the leap of genetic transmission to soybeans for human consumption? The release of genetically modified organism always bears risks of irregular transmission of genetic information to other crops.

Considerations of a necessary follow-up study have been made when designing this study. Doing so, it could be sage to include German value chain actors at the very beginning for conceptualisation of an in-depth study.

As a starting point for a closer bilateral cooperation, DCZ could host a “Soybean Symposium” in Beijing after the Corona pandemic that includes value chain actors, participants from science (CAU, CAAS, ZALF, Thünen Institute), agribusiness and politics. DCZ considers promoting a closer cooperation with the “Sino-German Crop Production and Agrotechnology Demonstration Park” (DCALDP) on this topic.

Appendix A

Table 1: Relevant stakeholders for the promotion of soybeans and oil and protein plants

Association name (EN)	Association name (GER)	Members	Website
Relevant stakeholders: promotion of soybeans			
German Soy Promotion Group	Deutscher Sojaförderring	Mainly soybean producers	https://www.sojafoerderring.de/
Donau Soja Organisation	Donau Soja	Producers, stakeholders from research, trade, processing industries, politics, NGOs	https://www.donausoja.org/de/ueber-uns/ueber-uns/kernziele/
Relevant stakeholders: promotion of oil and protein plants			
Union for the Promotion of Oil and Protein plants	Union zur Förderung von Öl- und Proteinpflanzen e.V., UFOP	Producers, processing and marketing companies who are working with domestic oil and protein plants	https://www.ufop.de/english/ufop-association/
Association of the Oilseed Crushing and Oil Refining Industry in Germany	Verband der Ölsaatenverarbeitenden Industrie in Deutschland, OVID	Enterprises of oilseed crushing and oil refining industries in Germany	https://www.ovid-verband.de/
Federal Association of Decentralized Oil Mills and Vegetable Oil Technology	Bundesverband Dezentraler Ölmühlen und Pflanzenöltechnik e.V., BDOel e.V.	Decentral oil mills, technical companies, agents from science, politics	https://www.bdoel.de/
German Association of Wholesale Traders in Oils, Fats and Oil Raw Materials	Deutscher Verband des Großhandels mit Ölen, Fetten und Ölrohstoffen e.V., Grofor	More than 150 firms, traders, producers, consumers, agents, service sector enterprises	https://www.grofor.de/en/

Appendix B

Table 2: Relevant research institutions working on breeding and cultivation systems for soybeans in Germany

Institute Name (EN)	Institute Name (GER)
Research Institute of Organic Agriculture (FiBL)	Forschungsinstitut für biologischen Landbau Deutschland e.V.
University of Hohenheim, State Seed Breeding Centre	Universität Hohenheim, Landessaatzuchtanstalt (720)
University of Applied Sciences Osnabrück, Faculty of Agricultural Sciences and Landscape Architecture	Hochschule Osnabrück, Fakultät Agrarwissenschaften und Landschaftsarchitektur
University Kassel, Faculty Organic Farming and Cropping Systems	Universität Kassel, Fachgebiet Ökologischer Land- und Pflanzenbau
Georg-August-University Göttingen, Department of Plant Breeding	Georg-August-Universität Göttingen, Abteilung Pflanzenzüchtung
Life Food GmbH – Taifun Tofu Products	Life Food GmbH – Taifun Tofuprodukte
Julius Kühn Institute, Institute for Resistance Research and Stress Tolerance	Julius Kühn-Institut, Institut für Resistenzforschung und Stresstoleranz
Agricultural Technology Center Augustenberg (LTZ)	Landwirtschaftliches Technologiezentrum Augustenberg, Außenstelle Mühlheim
Leibniz Centre for Agricultural Landscape Research (ZALF)	Leibniz-Zentrum für Agrarlandforschung (ZALF) e.V.

References

1. The State Council Information Office of the People's Republic of China. Full Text: Food Security in China. *http://english.scio.gov.cn/2019-10/14/content_75300394_2.htm (Accessed: 20.03.2020).* 2019.

2. Statistisches Bundesamt (Destatis). Land- und Forstwirtschaft, Fischerei. Wachstum und Ernte. Feldfrüchte 2019. 2020. Vol. Fachserie 3 Reihe 3.2.1.

3. Bundesanstalt für Landwirtschaft und Ernährung (BLE). Bericht zur Markt- und Versorgunslage Futtermittel 2019. 2019.

4. —. Bericht zur Markt- und Versorgungslage. Ölsaaten, Öle und Fette - 2019. 2019.

5. Hargita, Y., Hinkes, C. and Bick, U. Entwaldungsfreie Agrarrohstoffe - Analyse relevanter Soja-Zertifizierungssysteme für Futtermittel. s.l. : Johann Heinrich von Thünen-Institut, 2018.

6. Bundesministerium für Ernährung und Landwirtschaft (BMEL) & Bundesanstalt für Landwirtschaft und Ernährung (BLE). Ackerbohne, Erbse & Co. Die Eiweißpflanzenstrategie des Bundesministeriums für Ernährung und Landwirtschaft zur Förderung des Leguminosenanbaus in Deutschland. 2016.

7. European Soya Declaration - Enhancing soya and other legumes cultivation. 2017.

8. Deutscher Sojaförderring. Anbaueignung der Regionen in Deutschland. *https://www.sojafoerderring.de/anbauratgeber/sojaklima-in-deutschland/karte-anbaueignung-deutschland/ (Accessed: 26.02.2020).*

9. Roßberg, D. und Recknagel, J. Untersuchungen zur Anbaueignung von Sojabohnen in Deutschland. *Journal für Kulturpflanzen.* 69, 2017, Vol. 4.

10. Reckling, M., Bachinger, J. und Bellingrath-Kimura, S.D. Potenziale des Sojabohnenanbaus in Nord-Ostdeutschland: Einfluss von Beregnung und Sojasorte auf Ertrag, N2-Fixierung und Vorfruchtwirkung. *Tagungsband. Soja-Tagung 2017, 06-07.12.2017, Rastatt.* 2017.

11. Recknagel, J. Die Bohne gibt den Ton an. *agrarheute.* 02, 2019.

12. Kögel, A. Der Standort bestimmt die Sojasorte. *bioland.* 01, 2018.

13. Fogelberg, F. and Recknagel, J. Developing Soy Production in Central and Northern Europe. [book auth.] D., Stoddard, F.L. and Watson, C.A. Murphy-Bokern. *Legumes in Cropping Systems.* 2017.

14. Weber, J.F., Kunz, C., Peteinatos, G.G., Zikeli, S. and Gerhards, R. Weed Control Using Conventional Tillage, Reduced Tillage, No-Tillage, and Cover Crops in Organic Soybean. *agriculture.* 7, 2017, Vol. 43.

15. Zimmer, S., Messmer, M., Haase, T., Piepho, H-P., Mindermann, A., Schulz, H., Habekuß, A., Ordon, F., Wilbois, K.-P. and Heß, J. Effects of soybean variety and Bradyrhizobium strains on yield, proteincontent and biological nitrogen fixation under cool growingconditions in Germany. *European Journal of Agronomy.* 2016, Vol. 72.

16. Tainfun-Tofu GmbH. Partnerschaftlicher Vertragsanbau. *https://www.taifun-tofu.de/de/partnerschaftlicher-vertragsanbau (accessed 26.02.2020).*

17. Landesvereinigung für den ökologischen Landbau in Bayern e.V. (LVÖ). Praxisleitfaden. Bio-Soja. Qualität vom Feld bis zum Futtertrog.

18. Landwirtschaftliches Technologiezentrum Augustenberg (LTZ). Wertschöpfung durch heimische Sojabohnen. Leitfaden für Anbau und Verwertung von gentechnikfreien Futtersojabohnen aus konventionellem Anbau. 2018.

19. Forschungsinstitut für biologischen Landbau (FiBL) and Donau Soja. Biosoja aus Europa. Empfehlungen für den Anbau und den Handel von biologischer Soja in Europa. 2016. Vol. 5.

20. Deutscher Sojaförderring. Übersicht der lieferbaren Sojasorten und Bezugsquellen 2020 . *https://www.sojafoerderring.de/wp-content/uploads/2020/01/Sojasorten-und-Bezugsquellen-2020.pdf (Accessed: 06.03.2020).*

21. —. Ersterfasser - Partner für Landwirte . *https://www.sojafoerderring.de/nach-der-ernte/ersterfasser-partner-fuer-landwirte/ (Accessed: 06.03.2020).*

22. —. Hersteller von Lebensmitteln aus Soja. *https://www.sojafoerderring.de/nach-der-ernte/soja-verarbeitung/hersteller/ (Accessed: 06.03.2020).*

23. —. Aufbereitungsanlagen in Deutschland. *https://www.sojafoerderring.de/nach-der-ernte/verarbeitung-zu-futtermitteln/aufbereitungsanlagen-in-deutschland/ (Accessed: 06.03.2020).*

24. Weiher, N., Tschigg, S., Schätzl, R., Wolf, L., Gain, A., Pfeiffer, T., Mayus, M. and Miersch, M. Schlussbericht zum Thema "Modellhaftes Demonstrationsnetzwerk zur Ausweitung und Verbesserung des Anbaus und der Verwertung von Sojabohnen in Deutschland". 2018.

25. Bavarian State Research Center for Agriculture (LfL). Sojazüchtung - Forschungspakt zur Zusammenarbeit zwischen China und Europa. *https://www.lfl.bayern.de/ipz/oelfruechte/185635/index.php (Accessed: 23.02.2020).*

26. Yan, J., Han, X., Chen, W., Wang, E., Zou, W. and Zhang, Z. Long-Term Fertilization Strategies on Soil Productivity and Rhizobial Diversity in Chinese Mollisol. *Pedosphere.* 2017.

27. Li, Yumei. Investigation on the Value Chain of Soybean in China – from Breeding, Planting to Processing. s.l. : DCZ, 2020.

28. Geoportal Julius-Kühn-Institut. Anbaueignung für Sojabohnen. *http://geoportal.julius-kuehn.de/#/map/public/5e1f0476e9208e35a71e24a7 (Accessed: 26.02.2020).*

29. Deutscher Sojaförderring. Leuchtturmbetriebe im Soja-Netzwerk. *https://www.sojafoerderring.de/aktuell/leuchtturmbetriebe/ (Accessed: 26.02.2020).*

30. International Trade Center (ITC). List of exporters for the selected product: Meat of swine, fresh, chilled or frozen, 2017. *International Trade Statistics: http://www.intracen.org/itc/market-info-tools/statistics-export-product-country/ (Accessed: 06.03.2020).*