With support from

Federal Ministry of Food and Agriculture

by decision of the German Bundestag

GFA CONSULTING GROUP
General Agent BMEL
Berlin Office

Sino-German Agricultural Centre, 2nd Phase

中德农业中心
Deutsch-Chinesisches Agrarzentrum

Study:

Digitalisation in Agriculture in Germany and China

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May 2019

Supplemented in December 2020 by Dr. Martin Schneider (IAK)

Implementer Partner

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iamo Leibniz Institute of Agricultural Development in Transition Economies

Disclaimer:

This study is published under the responsibility of the Sino-German Agricultural Centre (DCZ), which is funded by the German Federal Ministry of Food and Agriculture (BMEL). Any opinions, conclusions, suggestions or recommendations expressed therein are the property of the authors and do not necessarily reflect the views of BMEL.

Published by:

Sino-German Agricultural Centre (DCZ)

Content

List of abbreviations

AEF	Agricultural Industry Electronics Foundation
ATB	Leibniz Institute for Agricultural Engineering and Bioeconomy
BCS	Body condition score
GDP	Gross domestic product
BMBF	Federal Ministry of Education and Research
BMEL	Federal Ministry of Food and Agriculture
BMVI	Federal Ministry of Transport and Digital Infrastructure
BMWi	Federal Ministry for Economic Affairs and Energy
CAAC	Civil Aviation Administration of China
CAS	Chinese Academy of Sciences
CGTN	China Global Television Network
DCZ	Sino-German Agricultural Centre
DESI	Digital Economy and Society Index
DESTATIS	Federal Statistical Office
DLG	German Agricultural Society
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GIS	Geoinformation systems
GPS	Global Positioning System
ha	Hectare
IDW	Science Information Service
ICT	Information and communication technologies
IoT	Internet of Things
IT	Information technology
AI	Artificial intelligence
KPMG	Auditing and Consulting Firm
KTBL	Board of Trustees for Technology and Construction in Agriculture
MAP	Modern Agricultural Platform
MARA	Ministry of Agriculture and Rural Affairs
Mbps	Megabits per second
MIIT	Ministry of Industry and Information Technology
OECD	Organisation for Economic Cooperation and Development
PwC	PricewaterhouseCoopers GmbH
RMB	Renminbi; currency of the People's Republic of China
VIT	United Livestock Information Systems

1. Introduction

The demands on agricultural production have grown considerably in recent decades. In Germany, one farmer was still feeding 10 people in 1949, but by 2016 this figure had risen to 135 and is expected to continue to rise. On the one hand, the global area of arable land[1] per person more than halved between 1961 and 2016, from 1.44 ha per person to 0.65 ha per person. This is mainly due to the steady increase in the world's population and the simultaneous reduction in arable land due to land consumption, soil erosion and degradation (FAO 2019). On the other hand, demand is continuously increasing due to changing consumption patterns and consumption of feed in animal husbandry. Global grain production has already fallen short of annual consumption three times since 2010, partly as a result of increasing weather extremes (FAO 2019b). In order to ensure global food security despite rising demand, declining arable land and crop fluctuations caused by climate change, it is necessary to increase efficiency in agricultural production and processing. So far, productivity gains have mainly been achieved through economies of scale and increased use of inputs such as chemical fertilisers, pesticides and artificial irrigation.

Globally, however, sustainability concerns dictate the exploration of options for increasing the efficiency of agricultural production and avoiding crop losses. The digitalisation of agriculture is seen as a way to increase the productivity of agricultural production with sustainable use of resources and to make it more resilient to weather extremes. By using digital technology, not only individual steps in production, distribution or trade can be optimised, but the entire value chain can be optimised (BMEL 2017).

In principle, a distinction can be made between two development stages in the use of digital technologies in agriculture: precision farming and smart farming (PwC 2016). The differences between these two levels and the main underlying technologies are outlined below.

The term **precision farming** covers applications that provide the farmer with improved information to support business decisions. Internal and external **sensors** provide continuous access to important production parameters. In arable farming, it is mainly soil sensors and sensors on or in agricultural machinery that collect information about nutrients in the soil, water availability and storage capacity, plant health and growth stage. This data enables precise planning and implementation of soil preparation, sowing rate, fertilisation, irrigation, harvesting and storage. Furthermore, weather stations provide access to temperature, precipitation, humidity and other climate data (DLG 2018). In livestock farming, sensors in the barn or on the animal collect an abundance of information. The data collected includes animal identity, parameters such as height, weight, BCS, condition, animal activity (step count, lying time, lameness, neck-head movements), milk production (milk, milk quantity, cell counts, ingredients, udder health), physiological parameters (rumen pH, body temperature) and feed intake (concentrate and basal feed intake, water intake, feeding behaviour, chewing time) (Kunisch et al. 2017: 25). Additional sensors in the barn can check and optimise the functionality of the equipment (milking system, feeding, ventilation). Modern technology can also help to initiate optimal processes in the detection of oestrus and birth times (BMEL 2017: 13). In summary, sensor technology in animal production enables accurate monitoring and needs-based care of animals to increase efficiency while improving animal welfare and health (Taenzer 2016).

[1] The FAO definition of *agricultural area* includes arable land, permanent crops and permanent grassland.

Satellites or drones provide **remote sensing data** with ever higher resolution, for example optical information on plant growth. On the one hand, **satellite technology** provides optical information, radar data and location technology. This technology enables site-specific potential maps, which serve as a basis for heterogeneous tillage in crop production. It is subsequently possible to sow, fertilise and apply plant protection products on a site-specific basis, making crop production more accurate, cost-effective, needs-based and ecologically harmless (Speckle 2016). Optical data and radar data also opens up the possibility of yield estimation and weather risk management (Kuhn et al. 2018). **GPS guidance technology** continues to enable the precise and driverless use of agricultural machinery. The goal here, too, is the precise and demand-oriented use of resources, including the application of fertilisers and pesticides, which is relevant for resource and consumer protection. The precision of resource use is made possible by linking satellite data and tractors equipped with GPS receivers, correction signals and steering aids (BMEL 2017). **Drones**, on the other hand, provide optical information like satellites, but with greater flexibility in terms of time and location, as well as higher resolution due to lower flight altitudes. Areas of application also include the documentation and mapping of land areas, site-specific cultivation, but beyond that also the application of beneficial insects and pesticides as well as the protection of wildlife from meadow mowing and the detection of wildlife damage (Reger et al. 2018).

In both agriculture and animal husbandry, **robotics** reduces the need for human labour for repetitive work processes. The robotics are generally coupled to various of the sensory elements listed above. In arable farming, driverless robotics can replace traditional agricultural machinery. Research is also being conducted here into the use of alliances of small and medium-sized robots for flexible, soil-conserving and efficient tillage and application of production inputs (e.g. Echord 2019). In animal production, milking robots, slat cleaners, ventilation systems or automatic feeders are used in particular. In addition to the actual milking process, milking systems record the amount of milk produced by each individual cow, but also analyse the animal's state of health based on the milk ingredients. On the one hand, milking systems can increase milking performance while saving time. Furthermore, the data obtained on animal health enables the early detection of diseases and thus needs-based health care and lower treatment costs (BMEL 2017: 13, agrarheute 2018).

The information collected in precision farming thus serves primarily as a decision-making aid for farmers, either as raw data processed in applications for end-user devices such as smartphones and tablets, or as a data basis for the use of human-controlled or programmed agricultural machinery technology. Although impressive in their depth, the collection of many of these variables and the use of robotics are of course not new developments. What is actually new is the second level of digitalisation in agriculture, described by the term **smart farming**, the networking of various data, its evaluation and semi-autonomous use by downstream digital applications (PwC 2016).

The first step of smart farming is the transfer of information from analogue to digital storage and its networking in **clouds**. In contrast to storage media that physically remain in the possession of the user, the storage space here is created by the interconnection of several non-local servers. This form of data storage enables the storage and collection of large amounts of data from different sources, i.e. **big data**. Such data sets are the prerequisite for training artificial intelligences using **machine learning** in a second step. This involves the continuous and autonomous improvement of algorithms for data analysis and prediction of events and outcomes of business decisions. In other words, an artificial system is "trained" to make certain decisions based on large amounts of data. The aim of this process is to enable at least semi-autonomous decision-making by agricultural machinery and robotics. The third step involves not only the semi-autonomous use of individual units, but also real-time communication between sensors, satellites, agricultural machinery and end-user devices such as computers, tablets and smartphones, also known as the **Internet of Things** (IoT).

There are many areas of application for these networked technologies. In arable farming, for example, agricultural machinery can apply resources precisely to the crop, based on the previously created yield maps and by means of speed-dependent control of the implements (BMEL 2017). In animal production, developments such as the comprehensive survey of animal welfare and assistance systems for intelligent animal husbandry offer autonomy of sub-processes as well as comprehensive quality assurance across the entire value chain (Bergfeld 2019).

In the following, this report focuses first on a presentation of the spread of the use of these applications, opportunities and risks from the farmers' point of view, as well as corresponding market opportunities in Germany and in China. Subsequently, the legal framework in connection with digitalisation for both countries will be examined. Finally, possible synergies between Germany and China are discussed.

2. Situation analysis: State of digitalisation in Germany and China

2.1. Germany

Players

The agricultural sector in Germany currently employs about 940,100 workers in about 266,700 farms, of which 19,900 are organic farms. The utilised arable land at the end of 2017 was around 18.2 million ha (DESTATIS 2019). The net output value of German agricultural production in 2016 was approximately I$ 33 billion[2] (FAO 2019).

Germany is currently in 14th place, just above the EU average, as measured by the Digital Economy and Society Index (DESI) (European Commission 2018). Nevertheless, Germany also has a scene of young start-ups and established companies that develop and market digital innovation in the field of agriculture. Given the dynamics of the sector, a list of market players can by no means claim to be exhaustive, which is why the following list should only be seen as an excerpt.

On the one hand, important companies are concentrated in the area of agricultural machinery technology, more precisely the production and distribution of digital hardware solutions, so-called **smart products**. BayWa AG, CLAAS KGaA mbH, Amazone and the Grimme Group are worth mentioning in this context. Other important players are companies from the seed industry, the chemical industry or fertiliser manufacturers, including KWS Saat SE, BASF SE, Bayer AG, K&S Aktiengruppe or Döhler GmbH. These companies are working on digital hardware and software solutions for the efficient deployment of operating resources. Lastly, there are representatives of the wholesale and retail trade, including Metro AG or the EDEKA group, which are predominantly concerned with digital solutions for logistics, quality assurance and traceability (see also Appendix 1).

Many of the large corporations in the agricultural machinery and equipment sector are also operators of digital platforms for farm management. CLAAS, for example, sells digital agricultural machinery technology, but also offers a digital platform, 365farmnet, which uses the data from the agricultural machinery to provide a digital farmland database. This type of digital service is based, on the one hand, on farm data fed in directly by the farmer, but also on information collected automatically by agricultural machinery and robotics; such services are also referred to as **smart services**. BayWa and Yara also operate digital platforms to support farmers' decision-making in addition to their core business with agricultural machinery, fertilisers and seeds. While *FarmFacts (BayWa)* is a rebranding of the sales subsidiary **Land-Data Eurosoft**, *trecker* (Yara) is originally the development of a Berlin-based start-up (Gründerszene 2018). Like 365farmnet, *trecker* offers a digital acreage file based on satellite data and farmer input for documentation, work planning and with advice on how to reduce costs. *FarmFacts* (also: *NEXT Farming*) offers various agricultural software solutions for work planning, data management, crop data, order planning, herd management or weather information. A special feature of these providers is that software solutions are often marketed together with the matching hardware solutions (NEXT Farming 2019).

Furthermore, the industry consists of a large number of smaller start-ups that offer innovative components or complete solutions for arable farming and animal husbandry. For example, within the framework of the Bundesverband Deutsche Startups e.V., the AgTech platform brings together 25

[2] International $

start-ups from the field of agricultural technology to network and promote cooperation between start-ups, farmers and established companies (Bundesverband Deutsche Startups e.V. 2019). Start-ups and research groups are supported by a variety of funders, incubators and accelerators. Relevant institutions are listed in Appendix 1; a comprehensive description and discussion of the funding network can also be found in BMWi (2018).

Innovations in the field of digital agriculture are supported and advanced by the work of a large number of public research institutions, including institutes of the major research communities and university research institutions. Worth highlighting here is a recently launched research project by a consortium led by the Leibniz Centre for Agricultural Landscape Research (ZALF) entitled "Agricultural System of the Future: DAKIS - Digital Agricultural Knowledge and Information System", which aims to develop a comprehensive information and management system (IDW 2019). A presentation of the most important players can be found in Appendix 2.

Plant production

Digitalisation enables the collection, storage, linking and evaluation of data, some of which was previously unavailable or unrelated. For example, information on nutrients in the soil, water availability and retention, plant health and growth stage is brought together to accurately carry out soil preparation, sowing rates, fertilisation, irrigation, harvesting and storage. It can in this way help to optimise and improve decisions made by the farmer. Data comparisons between companies are also possible, as is networking with suppliers, customers and service providers. The end result could be more economical production (DLG 2018).

Modern technologies allow GPS-supported sub-area analysis by means of yield maps and, if necessary, also the use of aerial photographs from previous years. Combined with GPS technology, site-specific potential maps are created that serve as a basis for heterogeneous soil cultivation in crop production. It is subsequently possible to sow, fertilise and apply plant protection products on a site-specific basis, making crop production more accurate, cost-effective, needs-based and ecologically harmless (Speckle 2016). This effect is complemented by technologies (drones and ground-based sensors) that measure vegetation status and the need for fertiliser, irrigation or crop protection and enable crop-specific management by means of communication between digital units.

The precision of resource use is made possible by data obtained via satellites and tractors equipped with GPS receivers, correction signal and steering aids. Depending on the generated yield maps and by means of speed-dependent control of the attachments, the machines use the resources precisely (BMEL 2017).

As a result, farmers can make their decisions regarding the use of resources and timing more appropriate to the situation. The hope associated with this is to reduce resource use while increasing yields. At the same time, this enables greater transparency about agricultural activities for the community.

Animal production

Automated and digital systems as well as autonomous components are also very common in animal production. Thousands of milking robots, slat cleaners, ventilation systems and automatic feeders are already in use in Germany. With new purchases of milking systems, a majority of the equipment is now automated, which is not surprising since the KTBL has determined that automated systems increase milk yields by 7%. Not only is milking carried out, but at the same time the milk quantity of each individual cow is automatically recorded and the cow's state of health is analysed on the basis of the milk constituents. In addition to the higher milk volume (= higher turnover), treatment costs for sick animals can therefore be reduced (= lower expenditure), as diseases are detected earlier (BMEL 2017).

Additional sensors in the stall can check and control the functionality of the equipment (milking system, feeding, ventilation) as well as register animal-specific data on movement, feed intake, etc. The individual animal is thus better recorded and stands out from the herd earlier in the event of a disease. Modern technology can also help to initiate optimal processes in the detection of oestrus and birth times (BMEL 2017).

A wide range of sensors (in the ear, on the neck, in the rumen, on the foot or in the stall) collect a variety of information about the animals (Kunisch et al. 2017):

- Animal identity
- Height, weight, BCS, condition
- Activity
    - Step count
    - Laytime
    - Lameness
    - Neck-head movements
- Milk
    - Milk quantity
    - Cell counts
    - Ingredients
    - Udder health
- Physiological parameters
    - Rumen pH value
    - Body temperature
- Feed intake
    - Concentrate and basic feed intake
    - Water absorption
    - Feeding behaviour
    - Rumination time

Many of these variables are of course not new developments, such as electronic animal identification, automatic milking systems or the use of herd management programmes. Automatic data reconciliation with the National Control Association and the United Livestock Information Systems (VIT) has even been used for a long time. However, new opportunities for more efficient animal production and healthier animal husbandry are offered by developments such as the comprehensive survey of animal welfare, assistance systems for intelligent animal husbandry, autonomy of sub-processes and, beyond production and the producing farm, comprehensive quality assurance across the entire value chain (Bergfeld 2019).

Dissemination of digital technologies and development potential

While the preceding discussion provides an overview of currently market-ready technical applications, no comprehensive information is yet available on the sector-wide distribution of digital applications and services. However, some studies presented below provide information on technology distribution based on smaller samples.

The industry's acceptance of and attitude towards digitalisation can initially be described as positive. In the food industry, digitalisation is seen as an opportunity by an overwhelming majority of German farmers. While 66% of farmers had expressed a positive opinion in a Bitkom survey in 2016 (Rohleder and Krüsken 2016), in March 2019 84% of German farmers, when asked whether digitalisation was more of an opportunity or a risk, already saw it as an opportunity (Rohleder and Minhoff 2019). The representatives of the food industry surveyed in the Bitkom study hope that digitalisation will above all lead to increased production efficiency (98%), improved product quality and more sustainability (93%) and, among other things, more flexible work organisation (76%). At the same time, however, they see rising wage costs (76%), increasing competition (76%), rising consumer expectations (73%) and a shortage of skilled workers (73%), among other things, as the biggest challenges of digitalisation. Nevertheless, the fact that digitalisation has long been an integral part of agriculture is shown by the fact that 66% of farmers already use digital technology and a further 25% are planning to use it (Rohleder and Minhoff 2019).

In a survey of 401 farmers conducted by the Landwirtschaftliche Rentenbank in 2018, 80% of the participants rated the digitalisation of agriculture as useful or very useful. These digitalisation-oriented companies saw impacts of digitalisation in the areas of product traceability, documentation obligations, resource-conserving and environmentally-friendly production, working hours, physical strain and production costs. Among the farmers surveyed, planned and already made investments mainly concerned tractors with GPS (9% planned and 19% made investments) and land use registers (5% and 17% respectively). Less common were investments in sensors (4% and 5% respectively) and drones (2% and 3% respectively). Among the 38 farmers who used drones (representing 9% of respondents), the technology was used for wildlife rescue, crop and soil condition measurement, crop protection measures, yield and nutrient mapping, and crop monitoring. In livestock farming, planned and completed investments concern herd management (5% and 17% respectively), sensor technology (4% and 15% respectively) and milking robots (6% and 18% respectively) (Rentenbank 2019).

However, larger samples on the distribution of certain technologies are rare. A data set on the prevalence of automatic milking systems for the years 1997-2013 puts the nationwide prevalence of such systems in 2011 at 3% of dairy farms in Germany (Hunecke and Brümmer 2018).

In the *DLG Agrifuture Insights 2017*, more than 600 farmers continued to be surveyed on their attitudes to digitalisation in agriculture. According to the survey, German farmers hope that digitalisation will primarily provide support for profitability analysis, data transfer for applications, general decision-making support and documentation, all applications that are more closely related to precision farming. Applications for use in the context of smart farming, on the other hand, are still attracting less interest, especially the storage of data on clouds (DLG 2018).

Among 100 arable farmers surveyed in a PwC study, 97% admitted to using digital technologies in some form. However, only 20% of the farms were identified as technology leaders that actively integrated smart farming into their work processes and aligned and adapted them to daily updated information. 36% of farmers were classified as beginners who used digital technologies exclusively for information gathering. 29% of 100 companies surveyed said they had already invested in technologies. Another 25% planned further future digitalisation investments. In contrast, 29% of the companies are not planning any investments. About 60% of farmers with further investment plans expected stable follow-up investments. The most frequently used technologies were GPS technologies (58%), smart agricultural machines (45%) and agricultural apps, online platforms or other data services (39%). However, for most of the technologies offered, more than half of the respondents did not plan to use them. However, 44% of respondents stated that they did not feel sufficiently informed despite having studied the topic in detail (PwC 2016).

While many farms have a positive attitude towards digital technologies, uncertainty and scepticism can still be observed among the farmers surveyed. In particular, solutions that involve sharing farm data meet with the greatest scepticism among farmers. Across studies, surveyed farmers see a major risk in the area of data security (DLG 2018, PwC 2016). In fact, even in expert circles, data protection in digital applications has so far been classified as only selective (Martinez 2018). The analysis of the legal framework will therefore be dealt with in more detail in chapter 3. Other barriers include scepticism about the economic viability of the available technologies. Here, high acquisition costs meet with little experience of added value through the use of these applications (PwC 2016). Similar attitudes can also be found in the food industry (Rohleder and Minhoff 2019). A profitability analysis for the range of technologies presented is indeed pending.

Furthermore, deficits in individual skills in dealing with digital technologies can slow down the spread of these applications. Deficits can even be observed here among young people who can generally be classified as technology-oriented. In 2017, for example, in a survey of students of nutrition and agricultural sciences at Kiel University, they were unfamiliar with various relevant, including big data (unknown to 43% of participants), Industry 4.0 (68%), and Internet of Things (82%). Uncertainty was even higher with terms related to digital applications and buzzwords related to agriculture, such as GIS (geoinformation systems) (76% unknown) or FarmNet365, a common agricultural software, which was unknown to 81% of the students (Borchard 2017).

Networking

The collection of data on farms offers farmers new opportunities for networking knowledge and experience. This can be done within the farm in such a way that, for example, the breast time of cows can be determined more precisely, that fires in straw stores are prevented by measuring the temperature and, if the temperature increases, a signal is sent to the farmer, that more precise cost-benefit considerations are made possible for the use of resources, or that transport routes within the company are optimised. All this is made possible by collecting data (thermometers, GPS, etc.) and networking it in a cloud (Stauch 2018).

One obstacle to processing and using the data beyond the farm is often still the lack of uniform and open data formats (Taenzer 2016). Another urgent problem in rural areas is still the low network coverage and low transmission capacities in information and communication technology (Griepentrog 2018: 7). In many regions in eastern Germany and in some rural regions in the old federal states, the availability of broadband connections was still below 50% of households in April 2019 (Figure 1). When these challenges are overcome (and in many places in Germany they already have been), this will make communication of data beyond the farm possible. In the "Internet of Things" (IoT), devices and machines exchange data packets with each other and define themselves in the system so that the system can make its own decisions. This enables, for example, plant-specific cultivation in the field as described above (Kunisch et al. 2017).

Another condition for the processing and use of data beyond operations is the dissemination of uniform and open data formats. Here, too, there have been deficits so far. In particular, the exchange of data and the general compatibility between agricultural machinery and various data platforms could become a fundamental obstacle to the expansion of smart agriculture (Taenzer 2016): 2). With the AEF (Agricultural Industry Electronics Foundation), an international alliance of the agricultural technology industry is dedicated to ensuring interface compatibility (Hieronymus and Autermann 2017).

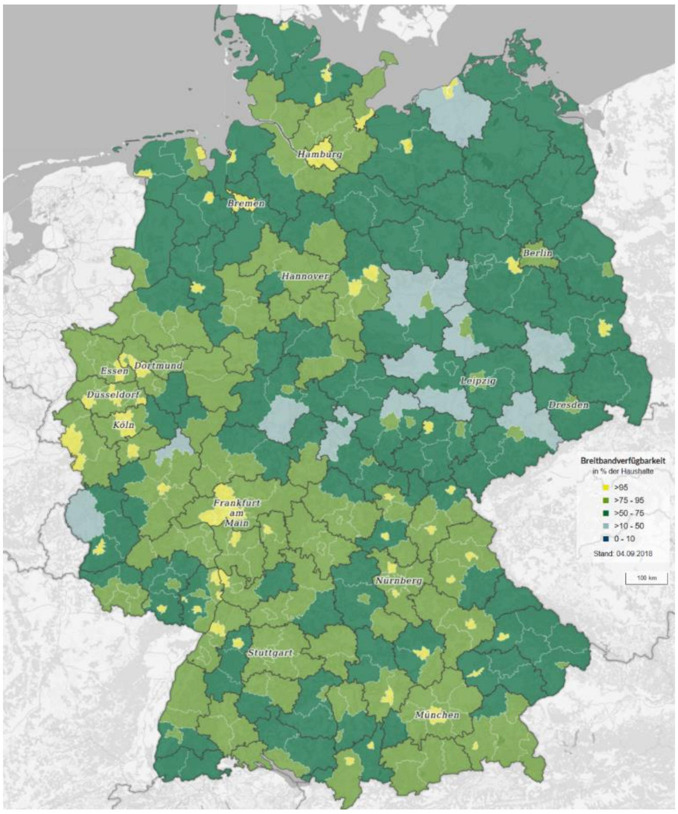

Figure 1:
Broadband availability (≥50MBit/s) in % of households
Source: BMVI 2019

The various studies give reason to conclude that digitalisation is progressing gradually, but is by no means being used to the same extent among all companies. The further diffusion of technologies will largely depend on whether new digital solutions are able to overcome existing financial, technical and intuitive reservations of users. The clarification of the legal framework and the removal of technical hurdles, such as broadband expansion and the creation of uniform interfaces, will continue to be decisive. Ultimately, the removal of these obstacles determines the economic viability of the solutions offered and thus their sustainable acceptance and application by farmers.

2.2. China

China sees the digitalisation of the country and its economy as part of the path to a new Chinese era. A new generation of digital technologies and industrial innovations, as well as the establishment of China's own national IT system, are intended to ensure China's sustainable progress in the economic, political, cultural, social and environmental spheres. To this end, a strategy was adopted to bring China into the digital age. Several goals of this strategy, such as the expansion of the broadband network, the establishment of big data centres, the establishment of the largest mobile network in the world and world leadership in the development and deployment of 5G networks, have already been achieved. Despite this advanced technologisation, terms in Chinese are unclear and undefined: "Smart farming", "digitalisation" and "networking" are vaguely separated from each other and often summarised by the term “informatisation”. This also complicates dealing with the issue of digitalisation in China (Deng 2019).

In addition, China has set up the Beidou positioning system (comparable to the US GPS) with the help of 200 of its own satellites, which is already fully functional. This communication network allows drones and other devices to be positioned with pinpoint accuracy and independently of international satellites (He 2018).

Digital technologies were not used in China’s agriculture for a long time, especially due to low labour wages and small farm sizes. The digitalisation of agriculture is meeting the need for huge increases in production in China: Among the 1.4 billion people, 200 million are farmers, representing 27% of the labour force. At the same time, however, agriculture generates only 7.9% of GDP. The nutrition of the entire population and the income of farmers must be ensured. The recognition of the need for greater climate action comes up against widespread global problems such as limited agricultural land, urbanisation, demand for higher quality products, climate change impacts, ecosystem degradation and, most importantly, an ageing population. In turn, digitalisation is associated with great hopes: modernisation of the country, elimination of hunger, improvement in the quality of food, protection of ecosystems and revitalisation of rural areas (He 2018). With a growing population and changing consumption patterns, food security is a growing challenge (Burggraf et al. 2015). Due to the ongoing intensification of agriculture, China, more than any other country in the world, is facing growing environmental problems such as degradation of land and other natural resources. In addition, rural society is ageing due to the ongoing rural exodus and demographic change, which is making rural labour increasingly scarce (He 2018). Digitalisation is therefore increasingly seen as an opportunity to modernise and sustainably increase the efficiency of agriculture and is promoted accordingly.

According to the understanding in China, digitalisation in agriculture offers the advantages above all of supporting planning and decision-making, facilitating the implementation of government services and enabling the entire food value chain to be traced back seamlessly - from production through storage, distribution, marketing and sales to consumption. In terms of technology, digitalisation offers systematised and more up-to-date data, better networking and closer data exchange, big data analysis, and weather and stress monitoring at state and provincial levels to make better decisions. In practical terms, however, it also includes online trading, food traceability, eco-monitoring, agricultural insurance, financing, credit and rural development (He 2018).

China’s comparative advantages in all these developments clearly lie in the area of data processing (He 2018):

- Scenario development regarding challenges and opportunities
- Purposeful and heavily subsidised national IT strategy across all administrative levels
- Comprehensive information infrastructure
- Extensive data sources
- Successful training in digital professions

Players

As in Germany, many of the key economic players are large companies that offer platform solutions in addition to their main activities in (agricultural) technology, the chemical industry or retail and wholesale. Unlike in Germany, however, a higher proportion of the players come from the telecommunications and IT sectors (see Appendix 3). The IT group *Alibaba* is particularly noteworthy in this regard. Through its online trading platforms *Taobao* and *TMall*, it promotes direct marketing, but also the tracing of food. And through its subsidiary *Alibaba Cloud*, the Group continues to be active in the development of big data platforms and artificial intelligence. Last year, the company launched *ET Agricultural Brain*, a smart farming platform for quality control, provenance analysis and food traceability. Another industry focus is drone technology. The market here is dominated by the manufacturer DJI, currently the world market leader in the field of civilian drones. An overview of currently active players in business and research is provided in Appendix 3.

The development activities are supported by various university and non-university research institutions. Appendix 4 also contains a presentation of the most important players. In addition to university research institutions, these include in particular research institutes of the *Chinese Academy of Sciences*. In addition, there are other university institutions, but also specialised research institutions, which are established directly under relevant ministries and perform specific tasks such as the analysis of soil samples.

For scenario development in particular, however, it is true that the scenarios become more accurate the larger their data basis is (He 2018). The collection of big data for decision support as well as its linking and processing for producers, traders, machine manufacturers and consumers, processing companies and political decision-makers for different needs will probably be one of the focal points of future activities. The aim is to merge and evaluate visual and digital data with environmental monitoring and the monitoring of the growth and condition of plants and animals in order to provide automated instructions for action to farmers via smartphone using artificial intelligence (Meissner 2018).

Examples of successful data collection and data processing already exist:

- *Geoglam-CropWatch*
  A satellite-based programme that tracks crop production and produces forecasts. The data is publicly available and is forwarded to FAO on a quarterly basis (He 2018).
- *Sinochem MAP (Modern Agricultural Platform)*
  Sinochem conducts business in the energy, chemical industry, agriculture, real estate and finance sectors. All activities and data touching on agriculture are brought together on the MAP, creating a knowledge and advisory platform for players in China's agricultural sector (Deng 2018).
- *Alibaba Smart Farming Platform*
  Smart farming platform that controls quality, origin, traceability of food and enables consumers (Alibaba Group 2019).
- *DJI (Da Jiang Innovations)*
  World market leader for drones, offers an agricultural management platform, a planning system for agricultural land and a spraying drone with "Radar Sensing System", which allows planning of drone operations in advance, controlling in real time and monitoring of drone flights (Meissner 2018).
- A precision farming solution based on Beidou satellite technology, spraying drones can be deployed fully autonomously and with centimetre accuracy, perform data correction and data analysis with artificial intelligence, and reflect the collected data back to Beidou for improvement (Meissner 2018).
- Yingzi is experimenting with facial recognition for pigs (Sternfeld 2018).

The focus of further development in China is expected to be on the further development of IoT, especially for the modernisation and intensification of animal husbandry. Another focus is on food traceability, food quality and food safety. The high demand for more transparency and better monitoring can be explained by past food scandals and the resulting high level of consumer sensitivity. Conventional monitoring mechanisms through inspections had so far not been able to restore consumer confidence in the safety of food (Kendall et al. 2019). Furthermore, the development of an open-source platform is planned, through which a standard for data exchange will be set, and research around artificial intelligence and the processing of big data will be further pursued. The main steps for the future will therefore be to strengthen and further develop the areas in which China is already a leader. In addition, solutions for increased digitalisation of smallholder agriculture are being pursued and a global exchange on digital solutions is being sought (He 2018).

The following are the main Chinese digital technology providers:

Soil analysis	Institute of Soil Science, Chinese Academy of Sciences http://www.soilrem.ac.cn/showsqzn.asp?id=327
	China Soil Pollution Status Inspection and Testing Laboratory Directory (National Ministry of Environment and Ecology, PRC) http://www.mee.gov.cn/gkml/hbb/bgth/201711/W020171129376594668833.pdf
Precision farming (application of resources and soil cultivation via GPS-controlled land vehicles)	MCFLY http://www.mcfly.com.cn/en/about.php (麦飞科技） MCFLY is a service provider for artificial intelligence and big data with a focus on smart agriculture
	PAS Submit http://www.passummit.com/
Systemic farm management approaches (Data-driven agriculture)	NB-Innovations 深圳市农博创新科技有限公司 http://www.nongbotech.cn Agricultural IoT equipment
Herd management and more precise feeding	Henan Zhonghe Modern Agricultural Industry Group Co., Ltd http://www.zhonghecn.cn/index.html Intelligent monitoring of sheep breeding and production
Digital solutions for agricultural advising and market information systems	Yimutian 一亩田http://www.ymt.com/ IT services for the entire agricultural value chain, including mobile IT offerings
Traceability	The traceability of agricultural products is carried out by the state; companies are not involved.

Dissemination and development potential

There are hardly any reliable figures on the spread of digitised technologies. Official bodies provide information on the dissemination of rural information services: According to government data, by mid-2018, 204,000 information centres had been set up across the country, through which a third of all Chinese municipalities had access to online trading platforms and farmer training services (Central Government of the People's Republic of China 2018). Online sales from rural areas increased by 39.1% in 2017, with agricultural products valued at RMB 300 billion. Successes from individual flagship projects can also be reported (Qu 2018). The Japanese drone manufacturer XAG puts the use of drones in agriculture at 5% of the total farm area. The users are mainly service companies that apply pesticides over their customers' fields; according to XAG statements this includes 1.2 million farmers so far (UAS Vision 2019). However, the authors of this study do not have more comprehensive data on the nationwide use of digital products and services.

The use of modern agricultural machinery and large agricultural equipment is limited for structural reasons. Some factors here are probably China's late entry into the use of digital technologies and the development lead of Western agricultural machinery manufacturers (Nie and Li 2017). The far more important reason, however, is certainly that digital farming is suitable for farms with large acreages or large numbers of animals, but is generally unprofitable for small-scale farming structures because of the high investment required. However, the majority of Chinese arable farms have so far been working on very small areas. Recent calculations indicate an average farm size of 0.78 ha for 2013. It is only in northern China, where there are a higher number of state farms for historical reasons, that the average farm size is 1.73 ha (OECD 2018). The most important users in China are therefore the following groups: (Liu 2019)

- Large state and private farms with an average cultivated area of 2,000 to 10,000 ha that already use modern and standardised cultivation methods, technology and large agricultural machinery.
- Large state-owned livestock production farms (pigs, dairy cows, beef cattle, laying hens, etc.), with high numbers of animals and which already work with standardised production methods, e.g. animal breeding, feeding, and epidemic control, etc.
- State "Modern Agricultural Demonstration Parks" in 26 provinces equipped with appropriate infrastructure and modern technologies.
- Large e-commerce companies, e.g. Alibaba, Jingdong and other e-commerce companies engaged in online marketing of agricultural products.
  Agricultural cooperatives and cooperative associations with large acreage and livestock numbers that have the financial capacity to use agricultural digital technology to manage the farms.

For the large number of small family farms, the market potential of costly sensors and agricultural technology is very low due to their low financial power and willingness to invest. At best, the use of such technologies becomes affordable through the use of sharing service providers. Service products, especially smartphone applications that provide decision support to farmers, have higher market potential.

Similar to Germany, there are various concerns on the part of farmers about the widespread implementation of digital technologies. Important factors here include a lack of investment capital (50%), financial risks of investments (35.3%), scepticism due to lack of experience (29.4%), lack of individual expertise in dealing with technologies (29.4%), lack of technical support (26.5%). However, unlike in Germany, data security plays only a very minor role (2.9%) (Kendall et al. 2017).

In 2014, fast broadband internet was only available to about 14% of the Chinese population, while 40% of internet users had less than 4 Mbps (Atkinson 2014: 3). According to official announcements, broadband speed has increased considerably since then and is classified as first-class in international comparison, an assessment that is received with scepticism even by national news agencies. Various rankings place China more in the international midfield in terms of upload and download speeds

(CGTN 2018). However, China plans to massively expand network coverage in the coming years: already by 2020, 98% of the municipalities are to have at least 4G internet access and enable digital administrative procedures. Further expansion with 5G is to follow swiftly thereafter (China Daily 2019).

3. Analysis of the legal framework

3.1. Germany

The most important need for legislative regulation is in the area of data security and data processing. A clear line must be drawn between protected data and data that can be used to share experiences. Hans Griepentrog gives the example of a farmer for whom a contractor does the threshing (Griepentrog 2018). The contractor uses a machine that is networked with the manufacturer's service and records impact and yield data. Griepentrog asks who owns the resulting data:

- The agricultural machinery manufacturer, as it uses the operating data for diagnosis and maintenance, and possibly for further development of the machines?
- The farmer, as it is his farm and business data?
- The combine harvester driver, whose personal data is protected by the right to self-determination regarding information?

When accounting, tax or financial advice and other external players are added to this process, it becomes clear that digitalisation can only develop its full benefits when the data obtained is collected, processed and shared, but at the same time data must also be protected. It is therefore necessary to clearly define which party has access to which data.

Survey results from Bitkom also show that further regulations are necessary here: When asked what the biggest obstacles to digitalisation in the food industry were, 70% answered "danger of spying on company data (data security)". When asked where policy-making is needed to support the digital food industry, 95% of respondents answered "Clear legal framework for data security" and 90% "Practicable data protection". In the perception of the respondents, further obstacles related above all to the lack of digital skills among employees and the lack of further training opportunities, as well as insufficient internet provision in terms of breadth and speed (Rohleder and Minhoff 2017). As the BMEL also notes, there are thus fundamental concerns among farmers with regard to data sovereignty and data security. In particular, manufacturers of operating resources could gain an advantage in terms of knowledge through the use of farm data from their agricultural software, which would subsequently put farmers in a worse negotiating position. Therefore, the Federal Ministry of Food and Agriculture also sees the need to counteract such possibilities in order to avoid unilateral disadvantages and dependencies (BMEL 2017).

Beyond new legal regulations, responsible handling of personal, business and sensor data by all players in the agricultural and food sector will also have to take place. Not everything can be regulated by a law. At the same time, sharing certain data is in the interest of making efficient use of the opportunities offered by digitalisation in agriculture. This includes, for example, the agricultural machinery industry, which can improve its service and future machines on the basis of the use of its machines and the data obtained from them and adapt them more to agricultural needs. On the other hand, an agricultural business only has an interest in handing over its data if it benefits from it. The machinery industry will probably have to approach farmers here, and the law will have to allow for a corresponding opening (BMEL 2017).

The advantages that farmers can derive from handing over their data include, for example, information resulting from the exchange of empirical values. In cloud or big data processing, positive and negative production experiences could be shared, resulting in mistakes not being repeated and the stakeholders involved being able to learn together. However, farmers must be able to benefit from this sharing of data; otherwise, data theft, data monopolies and, in extreme cases, even the closure of farms could occur (DLG 2018).

The General Data Protection Regulation, which came into force in May 2018, regulates the handling of personal data throughout Europe (European Union 2016). The data collected through digital applications, on the other hand, usually comprises mainly business and agronomic data. One recommendation of the DLG is therefore to extend future data protection to farm and business data, arguing that farm and machine data basically belong to the farmer. According to the DLG, authorisation, control and transparency should be guaranteed for every data transfer (DLG 2018). However, remote sensing data and other sensor data that does not occur at the farm level and is publicly available and usable is often included. One example is satellite data, which in principle can enable harvest estimates at the farm level. Public authorities sometimes oppose stricter data protection regulations for this reason, also because the collection and archiving of certain data is paid for out of tax revenues and should therefore be publicly accessible free of charge. This type of data includes in particular weather data, cadastral data, soil data and road networks (DLG 2018). Overall, there is a clear gap between legislation and economic realities created by the rapid progress of technical possibilities. The different arguments and interests mentioned above, also among the ranks of the legislators, however, make it difficult to create uniform regulation.

Another legal issue concerns the use of drones. Current legislation in Germany stipulates that the pilot or a person supporting them must have constant visual contact with the drone, i.e. the drone must not be controlled out of sight. This may be impossible when surveying large agricultural areas, for example, which is why a clear definition of the usability of drones in agriculture would be desirable. In order to fly outside the pilot's line of sight, permission must currently be applied for with the responsible state aviation authority (Reger et al. 2018). However, a joint initiative by Telekom and German air traffic control is now aiming to enable the use of drones beyond the pilot's sight. Concrete applications of the approach for agriculture are said to be possible, but are still under development (Connected Drones 2019).

Furthermore, the networking of machines, clouds and users must be designed in such a way that, on the one hand, quick exchange between the individual components is possible and, on the other hand, none of the units fail should the telecommunications system fail. The data should be stored and networked in a decentralised manner without a disconnection limiting the ability to work. However, the legal framework or national or even international standards are still being developed. Since 2018, the Ministry of Agriculture has been funding the *GeoBox* project of the German Aerospace Centre for the development and free availability of standardised data structures (BMEL 2018).

Furthermore, as described, the expansion of stable and high-performance internet coverage in rural areas is an important task (DLG 2018). In November 2016, the Act to Facilitate the Expansion of Digital High-Speed Networks (DigiNetzG) came into force. Among other things, all construction activities are required take into account the further need for broadband expansion through the co-laying of fibre optic cables. Furthermore, a central information office and a national dispute resolution body at the Federal Network Agency are supposed to ensure and support the practical implementation of measures (BMVI 2019b).

3.2. China

While the use of drones in China is not yet regulated by law, there is a very great need for regulation on data protection issues. Currently, the Chinese National Informatisation Strategy 2006-2020 and the Network Security Law of 2016 are key regulatory frameworks in this area (Liu 2019).

The 2006 **Informatisation Strategy** covers nine areas: (Atkinson 2014: 1f)

- Promoting digitalisation of the Chinese economy
- Dissemination of e-government
- Establishing an advanced internet culture
- Expansion of digitalisation in education, health care and public safety
- Expansion of communication infrastructure
- More efficient use of information and communication technologies (ICT)
- Strengthening China's global competitiveness
- Establishment of national IT security systems
- Improving IT and ICT user knowledge among the population

A core part of the strategy is the development of own ICT technologies and industries to make China independent of imports of these technologies.

The **13th Five-Year Rural and Agricultural Informatisation Development Plan** of 2016 outlined a digitalisation strategy for agriculture as well. For agriculture, this plan envisages an increase in the use of IoT, online trading and, above all, the improvement of internet coverage in rural areas. It also envisages the modernisation of the entire value chain from soil analysis and precision farming to digital agricultural extension, traceability and logistics (State Council of the People's Republic of China 2016). The political vision behind digitalisation is not only the modernisation of agriculture but also the substitution of foreign solutions with Chinese products. In the long term, the aim is to export Chinese products, primarily digital services. For this reason, internet and technology companies that work in rural areas or for agricultural products are subsidised (Meissner 2018: 13).

Similar to Europe, the legislators foresee a need for regulation in the handling of data. A new **cybersecurity law** came into force in June 2017 to regulate data protection issues. According to this law, personal information may only be collected with the consent of the person concerned. Stricter rules for companies regarding the handling of personal information have been introduced, in particular concerning the protection of collected and stored information from access by third parties (KPMG 2017). Among other things, regulations require continuous, verifiable precautions for cyber protection, regular training of employees and in-house IT specialists, as well as the provision of organisational emergency plans in the event of a hacker attack (Pattloch 2017). Just as in Germany, much of the data collected by agricultural machinery and software is not considered personal data and therefore does not fall under the regulations listed above.

Relevant for German companies for digital agriculture activities within China are in particular new regulations of the law regarding a state security audit for activities and products in areas classified as critical, including communications, energy, transport, water supply, finance, public utilities and e-government services. Almost all companies that are involved in data exchange in any way are therefore affected. For foreign companies or companies with foreign relations, one regulation is particularly relevant that obliges companies involved in "critical infrastructure" to store personal or "important" data locally in China and to transfer it abroad only after application and approval. Such requests trigger a security review of the data by Chinese authorities and external auditors (Pattloch 2017). In order to be able to examine the data, Chinese authorities are allowed to demand the disclosure of source codes and encryption techniques, among other things. Overall, however, the regulations are very vaguely formulated and leave room for interpretation (Theusner 2017).

The law is criticised for its potential restriction of freedom of speech, as it also obliges services, for example, to check and store the identity of users and, if necessary, to pass it on to authorities (Alsabah 2017). The Network Security Act thus poses a serious challenge for the export of networked agricultural technology to China. Data exchange with the manufacturer in Germany is associated with time delays and bureaucratic effort. It is also possible to spy on the trade secrets of agricultural machinery manufacturers.

The **use of light drones** is subject to registration with the Civil Aviation Authority (CAAC). Drones weighing 7 kg or more and commercial drones require licensing by the CAAC. Drones weighing 116 kg or more also require a pilot's licence and a certificate of operation. Furthermore, flights outside the pilot's line of sight, close to densely populated areas or in certain restricted zones are not permitted here either (CAAC 2015).

4. Opportunities and risks surrounding German-Chinese cooperation

4.1. Opportunities

Research

Cornelia Weltzien from the Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB) summarises her assessment of the potential for cooperation on digital agriculture in the short report for the DCZ as follows:

> "Based on the reports from the different research institutions, it can be said that the development of digital agriculture covers similar topics on both sides and that the stages of development in research are taking place among peers. In Germany, the development of machine and sensor technology is still somewhat ahead. The Chinese are very advanced in the mathematical-theoretical fields, especially in artificial intelligence and data analysis." (Weltzien 2018)

In line with this assessment, this report also states that existing differences in the research priorities of both countries should be used for exchange and the generation of synergies between Germany and China. The focus of Chinese agricultural research is on IoT, tracking of agricultural products and monitoring of agricultural resources, which means an advantage on the part of the Chinese in terms of knowledge can be expected in these areas in the future as well.

There is high demand on the Chinese side, especially for increasing abilities on the part of agricultural professionals. The gap between the skills associated with rural labour and the requirements of a digitalised agriculture is enormous. The Chinese are definitely interested in elements of dual training for farmers based on the German model. On the other hand, however, it should be noted that China's training system is already a bit ahead of the German system in terms of digital content in training. Dealing with digital technology, e-learning and e-services could be areas where Germany can benefit from China's experience (Weltzien 2018). The exchange of knowledge among peers is therefore also a possibility in the training sector.

Economy

Opportunities for economic cooperation and investment arise from the different fields of expertise of the two countries, as outlined in chapter 2. While Germany has strong players in agricultural machinery technology, logistics and the chemical industry, China scores particularly well in data processing, cloud services, telecommunications and drone technology. Challenges of digital agriculture, such as broadband expansion or the improvement of data interfaces, could be tackled efficiently in cooperation. China also has a large number of innovative start-ups with modern offerings and solutions. Exchanges between German companies and these start-ups could also prove profitable for both sides. The protection of patents and know-how on both sides would be important here (Weltzien 2018).

In China, digitalisation is limited by farm size, agricultural structures and low financial possibilities of producers. At the same time, software and machines are being developed in Germany that optimise established processes. This shows that both countries face different challenges and have to take different paths towards digitalisation. Exchanges between Germany and China concerning the opportunities offered by cooperatives and machinery rings could be useful at this point.

There are also already various partnerships and activities with German companies, which can provide conclusions about future developments and requirements. The following are some major investments and business activities of three German companies from the agricultural machinery technology, chemical industry and logistics sectors with the aforementioned focus in China.

BASF has a branch office in Shanghai and in 2015 achieved a combined turnover of around 5.5 billion euros in the People's Republic of China, Hong Kong and Taiwan (BASF 2015). One product already registered in China, for example, is the *AgCelence* product portfolio. In the area of brand protection, BASF continues to introduce tamper-proof labels with data codes. In October, BASF expanded a partnership with local start-up *Akzelerator Plug and Play*to drive digital innovation in China. The partnership is intended to give BASF access to start-ups working on artificial intelligence, big data, blockchains and smart sensors (BASF 2018).

The *CLAAS Group* has branches in Beijing and Shandong province. The site in Shandong resulted from an acquisition of the Chinese agricultural machinery producer *Shandong Jinyee Machinery Manufacture Co. Ltd. (Jinyee)*. China was one of the strongest markets for the company in terms of sales, with an expected growth rate of 6.2% (CLAAS 2018). The 2018 Annual Report saw a slight downturn in the agricultural machinery market, partly due to overcapacity and uncertainties regarding the expected tightening of emission standards. All in all, however, a lasting trend towards professionalisation in agriculture was observed (CLAAS 2018: 17).

Metro Group has been active in China since 1996 and currently operates over 95 locations with sales of €2.7 billion. While the group has been cooperating with *Alibaba* for years to strengthen its online retail capabilities, it appears that it is currently considering a partial sale of its offline retail presence to Alibaba (Reuters 2019).

4.2. Risks

However, some risks remain for German-Chinese economic cooperation. On the one hand, the Chinese Network Security Law poses a serious challenge for the export of networked agricultural technology to China. Depending on the implementation, data exchange with the manufacturer in Germany is only possible with a time delay and involves bureaucratic effort. Another uncertainty factor is the requirements listed above for foreign companies in areas of activity considered critical. Disclosure of source data, user data, storage of data on Chinese servers and going through a government clearing process are all severe market entry hurdles, especially for small businesses and SMEs without experience in the Chinese market. Despite joint declarations of intent, intellectual property protection still exists, as in all economic and many research areas. The *CLAAS Group* describes the Chinese subsidy policy and the unclear future of exhaust gas regulations as the greatest business uncertainties (CLAAS 2018), although the latter factor cannot be limited to China. Conversely, the debate about the participation of the Chinese company Huawei in the 5G network expansion in Germany shows fundamental security concerns in the field of telecommunications, which would also affect cooperation in the field of digital agriculture.

For scientific cooperation in the field of digital agriculture, general challenges of research cooperation with China apply. Some of these challenges have already been formulated in the BMBF's China strategy, including

> [...] the dynamic nature of developments in political, economic and social terms, the high complexity of responsibilities, the often low level of transparency in decision-making at the political level and the information that is sometimes difficult to access or inadequately provided (BMBF 2014: 4).

Scientific cooperation in the field of digital agriculture is also subject to possible difficulties in dealing with remote sensing data and data transmission technology that is generally classified as sensitive. In principle, the added value of scientific cooperation should be critically examined.

5. Conclusion: Recommendations for further activities of the DCZ

In view of the results of this study, the DCZ can contribute to the continuation and structured expansion of exchange between Germany and China at the political, economic and scientific levels. It has been shown that Germany has an advantage over China especially in mechanical engineering and in optimising agricultural production, while China has advantages in the areas of networking and IoT. Exchange can take place however as among peers especially in education and training.

The exchange can initially be continued by holding a workshop that brings together experts from politics, business and science as a platform for discussion. The core topics of such an exchange should include the challenges discussed above in introducing digitalisation into agriculture in the area of data security, economic efficiency, interface issues and capacity building. The targeted use of digital technologies for the protection and conservation of natural resources should also be discussed in order to link several important cross-cutting issues regarding German-Chinese dialogue concerning agriculture and economics

The present study should also be continued and deepened. Many issues such as the economic efficiency of digital applications and the degree of dissemination of applications can only be discussed with more comprehensive data sets. With the help of partners from the scientific community, a comprehensive collection of farm data would be the first step, as previous data is only based on small and partly unrepresentative samples. For issues such as risks and problems related to exchanges between German and Chinese companies, intensive discussions with German and Chinese providers of digital agricultural machinery and services should be sought, for example within the framework of an online survey in the DCZ network.

The DCZ can initiate exchange programmes for scientists and bring together interested institutions from both countries. It is important that not only Chinese scientists come to Germany, but that the exchange takes place mutually in order to better understand the framework conditions on the other side. The Saxon Teaching and Experimental Farm in Köllitsch with its test field for 5G-networked arable farming, which is unique in Germany, can serve for such an exchange and possible delegation visits.

The DCZ can also serve as a platform for establishing contacts between German and Chinese counterparts. In the long term, contacts can be established that may lead to a technological exchange in the future. The DCZ can provide flanking support and advise on questions regarding patent protection and related legislation.

6. Study supplement, December 2020 (Author: Dr. Martin Schneider)

The present study is supplemented in the following by current study results from the year 2020. All statements refer exclusively to the German market.

In 2020, two different studies on the digitalisation of agriculture in Germany were published. A study entitled “Digitalisation in Agriculture 2020” was conducted by BITKOM, the German Farmers’ Association and Rentenbank (Rohleder et al., 2020). A total of 500 decision-makers on farms were surveyed for this purpose. The second study “Farmers’ Survey 2020 - Digital Agriculture Bavaria” refers exclusively to the federal state of Bavaria (Gabriel and Gandorfer, 2020). A total of 2,390 stakeholders on farms were surveyed here.

The BITKOM study paints a very positive picture of digitalisation and the practical relevance it has achieved so far. For example, 93% of respondents are in favour of digital technologies helping to reduce the use of fertilisers, pesticides and other resources. Also, 64% of respondents are convinced that digital technologies will lead to cost savings in the long run. Eight out of ten of the farms surveyed stated that they already use digital technologies, with 91% of farms in the size category of 100 ha or more already using digital technologies. When asked about the digital technologies used, GPS-controlled agricultural machinery together with automatic feeders or intelligent feeding systems (only for finishing farms) are in first place. 40% of the farms surveyed use farm and herd management systems. 28% say they use sensor technology in crop production and animal husbandry. Only 11 percent of the companies use drones. The authors of the study also asked the respondents which issues they thought policy-makers should address. The nationwide expansion of mobile telephony and broadband (95% of respondents) was in first place. And the user-friendly and free provision of geo, resource and weather data was mentioned (86%) in second place. This was closely followed by the desire to promote digital literacy in education and training (86%). With regard to the provision of a state data platform, a feasibility study on "State Digital Data Platforms for Agriculture" commissioned by the Federal Ministry of Agriculture and Food has been prepared in the meantime (Bartels et al., 2020). It recommends the rapid, iterative development of such a platform. The authors conclude that this platform should include the following modules:

- Data and information reference
- Reporting and documentation
- Agricultural applications
- Universal data platform
- Administrative area

The recommendation continues to be made that such a platform should overcome previous federal boundaries within the Federal Republic of Germany.

In contrast to the BITKOM study, the second study on digitalisation in Bavaria comes to a somewhat sobering conclusion: The study shows that only 21% of the farms surveyed use a digital land use planning index. Automatic steering systems are only used on 17% of farms here. Site-specific management in terms of site-specific nitrogen fertilisation and plant protection is only practised by 5-6% of the farms surveyed. A further 13-16% of farms are planning to purchase the necessary technology within the next 5 years. The study identifies the following as reasons for the low market penetration of digital technologies:

- Market penetration for many technologies is a cost issue.
- Questionable economic viability of the technologies is a major obstacle.
- Potential users' concerns about security

The study also shows that private business consultants currently have little influence on the decision of businesses to use digital technologies.

The interaction of the two studies shows how heterogeneous the use of digital technologies is in Germany at the present time. Overall, many farms in Germany need to start digitising their processes.

In order to accelerate this process and to develop further necessary foundations, the BMEL has set up 14 experimental fields in Germany, which are investigating digitalisation in agriculture at different locations on various technical topics. The project was launched between September 2019 and March 2020. In the coming period, the first findings and recommendations from this work are expected to be put into practice. Concrete recommendations for the use or configuration of digital tools formulated from actual practices are one expectation of the work in these experimental fields. Feedback for the developers of digital tools, especially on networking among themselves, is also expected.

From an advisory perspective, the offerings related to digital tools should be evaluated according to the following criteria:

- How easy is it to integrate digital tools into existing farm environments? Are the user interfaces as simple as possible?
- How high is the degree of automatic networking between the individual digital tools?

- To what extent are the positive effects of using digital tools quantifiable compared to the status quo – without digitalisation?
- How stable/available are the digital tools?
- What is the level of data security?

Attention must also be paid to training all users well (not only decision-makers) in the use of digital tools.

Within the work of the DCZ, the knowledge platform **smart-agriculture.org** was established in 2020. It includes various contents on the state of digitalisation in Germany, with a brief look across the border to France. Different points of view are presented there: those of politics, industry, research and, last but not least, those of the users.

This platform could be further used by the DCZ in the future to address obstacles to digitalisation in agriculture in Germany and China and to identify possible solutions or approaches in both countries. This could show the different levels of action of politics, industry or application development and education. This in turn could accelerate mutual learning and reduce barriers.

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Appendicies

Appendix 1: Economic players / business-related players Germany

Player	Description
Private companies:	
Amazone	Agricultural machinery technology
BayWa AG	Conglomerate with an agricultural division. FarmFacts agricultural software
KWS Seed SE	Plant breeding and biotechnology; world's fourth-largest seed producer by sales from agricultural crops
Döhler GmbH	Leading global manufacturer of food additives
EDEKA Group	One of the leading food retailers in Germany with store-brand production
Metro AG	Listed group of wholesale and retail food companies
CLAAS KGaA mbH	International Group Agricultural Machinery Technology - Intelligent agricultural machinery technology - Arable land index 365farmnet
K&S Aktiengruppe	Manufacturer and supplier of standard and special fertilisers, mineral products
Grimme Group	Manufacturer of agricultural machinery technology in the field of potato, beet and vegetable technology
Bayer AG	Conglomerate with focus on chemical and pharmaceutical industry
BASF SE	Chemical group with agriculture division
Yara International	Manufacturer and supplier of fertilisers, urea, nitrates and ammonia. Arable land index tracker
agrando	Agricultural services start-up: Platform for communication, information procurement, processing and administration in agricultural trade
agrirouter	Data exchange platform for farmers and contractors with which machines and agricultural software can be connected across manufacturers (start-up)
agrar2b	Trading system for agricultural inputs (start-up)
ag.supply	Online shop for farmers and contractors
agrora	Online marketplace for agricultural commodities
Accelerators:	
AgroInnovation Lab (BayWa/RWA)	Founded by BayWa and RWA as an innovation platform for the exchange of ideas and the promotion of partnerships. Support for start-ups.
Seedhouse	Promotion of start-ups in the food and agricultural sector
SmartHectar	Promotion of start-ups in food production and water management

Schmiede.One	Promotion of start-ups, in the agricultural sector, focus on indoor crop production, AI, services

Investors:	
Atlantic Labs/ Atlantic Food Labs	Investment in start-ups that serve food trends
Munich Venture Partners	Investments in companies with a broad portfolio, including the agricultural sector
Target Partners	Investments in companies with a broad portfolio, including the agricultural sector
HTGF	Invests venture capital in technology companies that implement promising research results in an entrepreneurial way
UnternehmerTUM	Support in the development of products, services and business models
Public funding:	
Exist	BMWi funding programme; the aim is to improve the start-up climate at universities and non-university research institutions
DiP Agrar	BMEL funding programme; the aim is to improve the innovative strength of German agriculture in terms of sustainable management
Other organisations/platforms:	
BitKom	Industry association of the German information and telecommunications sector
NGIN Food	Magazine and platform for founders from the food sector

Source: Bösel 2019, own research.

Appendix 2: Research Institutions for Digitalisation Germany

Institution	Area of responsibility
Teaching and Research Farm Köllitsch	Opened a test field for 5G networking in arable farming in June 2019, the only one of its kind in Germany
Thünen Institute for Agricultural Technology	The Institute was significantly involved in the position paper on digital policy prepared for the BMEL; Precision plant cultivation, the use of fully or semi-autonomous machines, and the design of sensor-based monitoring systems for e.g. recording soil condition or emissions; Assessment of technology impacts and possible risks of digitalisation
Leibniz Institute of Agricultural Engineering and Bioeconomy (ATB)	Research focus animal husbandry • Optimised milking • Animal welfare and husbandry practices • Stable climate and emissions Research focus on plant cultivation • Soil fertility • Precision crop protection • Precision horticulture • Automation and process development

Institution	Area of responsibility
Leibniz Centre for Agricultural Landscape Research (ZALF)	Development of a concept as a basis for integrated intelligent management of agricultural landscapes
Leibniz Institute of Agricultural Development in Transition Economies (IAMO)	• Behavioural economic approaches Innovation adaptation • Implementation of digital innovations in the field of risk management • Yield estimate • Land planning • Climate impact assessment
Fraunhofer Institute for Optronics, System Technologies and Image Exploitation (IOSB)	Research into multisensory systems; Generation and automated evaluation of aerial and satellite images; Information data management for the development of database systems, e.g. for the collection of environmental data
Institutes of the University of Hohenheim: • Agricultural Engineering • Phytomedicine • Farm Management • Crop Sciences	Projects on precision agriculture, smart farming and the use of robots in agriculture; Evaluation and development of site-specific sensor-based perception and application technologies for weed management; Benefits of precision farming technologies for mechanical weed control in sugar beet, soybeans and maize; Comparison of precision hoeing with conventional mechanical weed control; Intelligent optical sensor for site-specific herbicide application; Application of precision agriculture in crop production; Design modelling and evaluation of improved cropping strategies and multi-level interactions in mixed cropping systems in the North China Plain
TU Munich, Weihenstephan Science Centre for Nutrition, Land Use	Precision farming in grasslands; Automation of feeding systems for dairy cattle; Stall 4.0 (Integrated Dairy Farming); Modelling of agricultural transport logistics; Simulation of agricultural crop chains
TU Dresden, Institute of Natural Materials Technology	Agricultural technology of the future - machine concepts and visions; Automation - Robots for orchards and vineyards for use of plant protection products; Participation in the EU project UNIFARM
TU Berlin, Institute of Machine Design and System Technology	Development of an open system for documentation and process monitoring of agricultural machinery especially for precision agriculture
University of East Westphalia-Lippe	First Bachelor's programme for Precision Farming in Germany

Appendix 3: Economic Players in Digital Agriculture in China

Institution	Tasks / Website
Beijing Aerospace TITAN Technology co. LTD.	Geoinformation systems. Part of Beijing Aerospace Wanyuan Science & Technology Co., Ltd., a conglomerate with divisions in military electronics, intelligent system integration, industrial equipment and circular economy http://www.spacewanyuan.com/en/about

Institution	Tasks / Website
Hubei Forbon Technology Co., LTD.	http://m.forbon.com Fertiliser testing and distribution
ync365.com	http://www.ync365.com Largest online agricultural trade in China
Vimao Corps	http://www.befe100.com
Sinoso Science and Technology Inc.	http://www.cocon.com.cn
GAGO Inc.	http://www.gagogroup.com Development and support of big data databases
Farm Friend Inc.	http://www.farmfriend.cn
Yuyan Technology Inc.	http://www.ssiot.com/solutions/detials/2/67.aspx Recognition software developer
Talent Cloud Information Technology co., Ltd.	http://www.tcloudit.com Technical services in smart agriculture from production to sales
Zoomlion Heavy Industry Science & Technology Co., Ltd.	http://www.zoomlion.com Agricultural machinery manufacturers with advisory services on optimal machine utilisation
YTO Group Co., Ltd	http://www.yituo.com.cn Agricultural machinery manufacturer
Lovol Heavy Industry Co., Ltd.	http://en.lovol.com.cn/# Agricultural machinery manufacturer
Shandong Guofeng Machinery Co., Ltd.	http://www.guofengjixie.com Agricultural machinery manufacturer
MCFLY (麦飞科技）	Service provider for artificial intelligence and big data with a focus on smart agriculture http://www.mcfly.com.cn/en/about.php
PAS Submit	Precision farming (application of resources and soil cultivation via GPS-controlled land vehicles) http://www.passummit.com/
NB-Innovations 深圳市农博创新科技有限公司	Agricultural IoT equipment http://www.nongbotech.cn
Henan Zhonghe Modern Agricultural Industry Group Co., Ltd.	Intelligent monitoring of sheep breeding and production http://www.zhonghecn.cn/index.html
Yimutian 一亩田	IT services for the entire agricultural value chain, including mobile IT offerings http://www.ymt.com/
Sinochem MAP (Modern Agricultural Platform)	Group in the energy, chemical industry, agriculture, real estate and finance sectors MAP: Knowledge and advisory platform for players in the Chinese agricultural sector

Institution	Tasks / Website
Alibaba	E-commerce - Taobao: Online trading platform in the food sector - TMall: Online trading platform in the food sector - Ele.me: Delivery service - ET Agricultural Brain: Smart farming platform for quality control, origin analysis and traceability of food, based on Alibaba Cloud
DJI (Da Jiang Innovations)	World market leader for civilian drones, "complete solutions" agricultural management • Spray drone with "Radar Sensing System", which enables drone operations to be planned in advance, controlled in real time and the flight to be monitored. • Agricultural management platform, a planning system for agricultural land https://www.dji.com/de/agriculture-solution/info#downloads
Precision farming solution	Based on Beidou satellite technology, spraying drones can be used fully autonomously and with centimetre precision. Data correction and data analysis with AI and mirroring of collected data back to Beidou to improve satellite data.
Yingzi	Animal identification in pig breeding

Appendix 4: Institutions for Digitalisation of Agriculture in China

Institution	Tasks / Website
Chinese Academy of Agricultural Engineering	http://www.caae.com.cn/
China Soil Pollution Status Inspection and Testing Laboratory Directory (National Ministry of Environment and Ecology, PRC)	Soil analysis http://www.mee.gov.cn/gkml/hbb/bgth/201711/W020171129376594668833.pdf
Institute of Soil Science, CAS	Soil analysis http://www.soilrem.ac.cn/showsqzn.asp?id=327
Beijing Academy of Agriculture and Forestry Science	http://www.baafs.net.cn
Chinese Academy of Agricultural Mechanization Sciences	http://www.caams.org.cn
Chinese Society for Agricultural Machinery	http://www.agro-csam.org/xhhd/gjjl/zyxw/djgz/index.shtml

Institution	Tasks / Website
College of Environmental and Resource Sciences (CERS), Zhejiang University	http://www.cers.zju.edu.cn/chinese/
The Xinjiang Production and Construction Corps	http://www.xjbt.gov.cn
Heilongjiang Farms & Land Reclamation Administration	http://www.hljnk.gov.cn
Institute of Remote Sensing and Digital Earth, CAS	http://english.radi.cas.cn/
Institute of Geographic Science and Natural Resources Research, CAS	http://www.igsnrr.ac.cn
Remote Sensing Application Institute of Sichuan Province	http://www.chinawestagr.com/ygyjs/

Appendix 5: Digital Agriculture Demonstration Projects of the Ministry of Agriculture and Rural Affairs of the PRC

Project title	Pilot location	Institution
Digital farming		
National Digital Agriculture Demonstration Project	Beijing, Heilongjiang, Sichuan	Institute of Agricultural Resources and Regional Planning, CAAS
High Quality Cotton Digital Agriculture Pilot Project	Xinjiang	Xinjiang Agriculture Reclamation Corporation
Digital Rice Production Pilot Project	Fujin City, Heilongjiang	Jinma Agricultural Co., Ltd. Heilongjiang
Digital Organic Rice Production Demonstration Project	Wuchang City, Heilongjiang	Jinfutai Agricultural Co., Ltd, Wuchang City, Heilongjiang
High Quality Rice Digital Cultivation Project	Ningbo City, Zhejiang	Crop Machinery Cooperatives, Ningbo City
Digital horticulture		
Digital Value-Chain of Orange Plantations Demonstration Project in Chongqing	Zhong County, Chongqing	Jincheng Agriculture Co., Ltd. Chongqing Municipality
Digital Horticulture Pilot Project in Henan Province	Xinzheng City, Henan	Mubenliang Innovative Agriculture Co., Ltd. Henan Province
Digitalized Engineering Horticulture Demonstration Project	Jinzhong City, Shanxi Province	Juxinweiye Agricultural Development Co., Ltd., Shanxi Province
Digitalized Engineering Horticulture Demonstration Project in Qinghai	Huzhu County, Qinghai	Kaifeng Agri. Co., Ltd., Qinghai
Digitalization of Modern Agricultural Demonstration Park	Baiji City, Hanzhong City, Shaanxi	Qifeng Fruit Plantation Co., Ltd., Shaanxi Province
Digitalized Engineering Horticulture Demonstration Project	Zhangye City	Lühan Agri. Production Co., Ltd., Gansu Province
Digital livestock		
Digitalized Special Livestock Breeding Project	Baishan City	Jinqishen Organic Agriculture Co., Ltd., Jilin Province
Digitalized and Smart Laying Hen Production Project	Pinggu District, Beijing	Huadu Yukou Poultry Production Co., Ltd., Beijing
Full Digitalized Smart Laying Hen Production Pilot Project	Wuhan City	Hongnong Agricultural and Animal Husbandry Co., Ltd. Wuhan Municipality
Digital Agriculture Demonstration Project	Heyuan City, Guangdong	Dongrui Food Group, Guangdong

Project title	Pilot location	Institution
Digitalized Livestock and Poultry Production Demonstration Project	Fuzhou City, Fujian	Xingyuan Agri. and Livestock Technology Co., Ltd. Fujian Province
Digitalized Swine Production Pilot Project	Changzhou City, Jiangsu	Fenghua Animal Husbandry Co., Ltd., Jiangsu Province
Digitalized Swine Production Pilot Project	Zhoushan City, Zhejiang	Dinghai Huasheng Animal Husbandry Co., Ltd., Zhejiang Province
Digitised fish farming and fishing		
Digital Aquaculture and Fishery Demonstration Project	Binzhou City, Shandong	Haicheng Ecological Technology Group, Shandong Province
Digital Fishery Production by Use of Recycled Water	Natong City	Nantong Longyang Aquaculture Co., Ltd., Jiangsu