

Digitalisation in agriculture

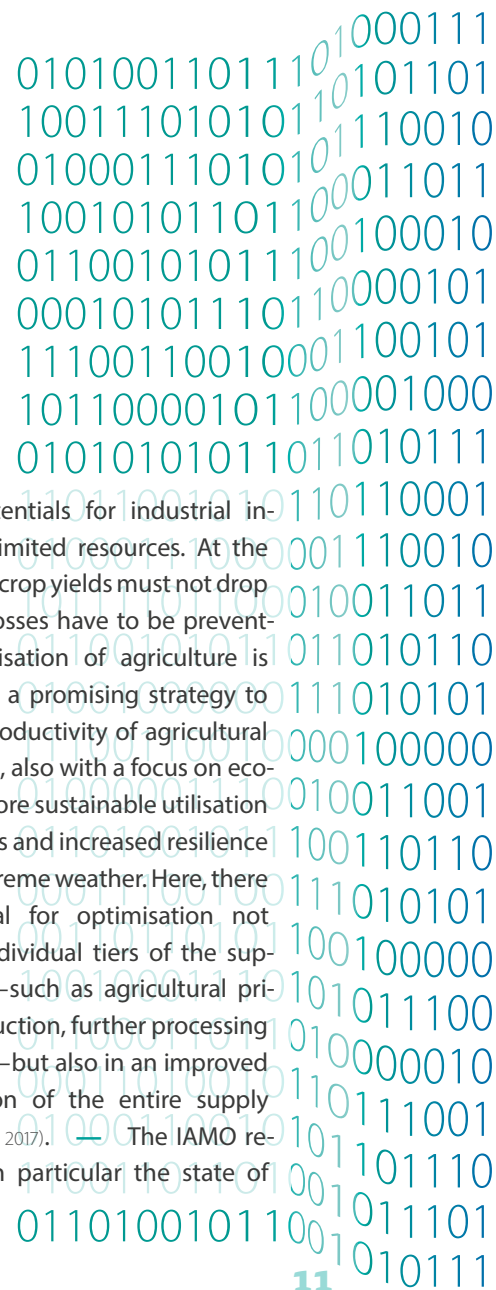
Opportunities, obstacles and risks for transition economies

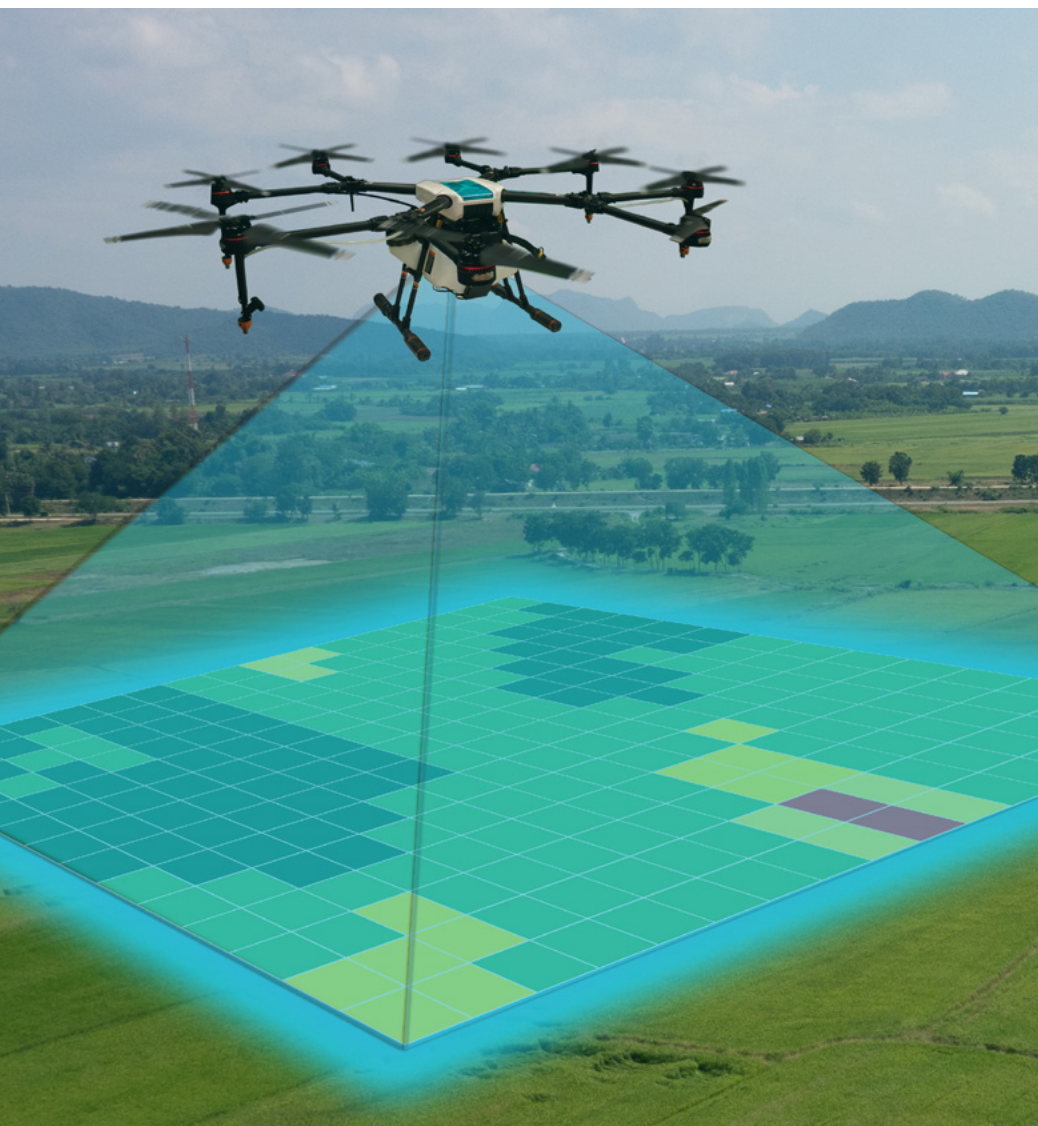
— Growing pressure on supply chains in agriculture and food industries —

In the past decades, structural transitions, environmental issues and intense international competition have increased pressure on farmers worldwide. A true challenge is the steady growth of the world population with simultaneous diminishing of area suitable for agriculture caused by increased construction, soil erosion and soil degradation (FAO 2019). However, the demand for agricultural goods continues to grow due to ever-changing consumer trends and increased feed consumption for livestock. Crop losses caused by extreme weather events have resulted

in worldwide grain production falling below annual consumption already for the third time in a row (FAO 2019b). Under these critical circumstances, it has become a necessity to secure a sufficient supply of food worldwide by considerably increasing the efficiency in agricultural production and processing. — In particular in transition economies of Eurasia with their enormous agriculture potential, significant increases in crop yields could be achieved already through a more efficient use of production resources such as chemical fertiliser, pesticides and artificial irrigation. Worldwide, not only costs but also ecological sustainability aspects address the need to research

saving potentials for industrial inputs and limited resources. At the same time, crop yields must not drop and crop losses have to be prevented. Digitalisation of agriculture is considered a promising strategy to increase productivity of agricultural production, also with a focus on ecologically more sustainable utilisation of resources and increased resilience against extreme weather. Here, there is potential for optimisation, not only for individual tiers of the supply chain—such as agricultural primary production, further processing and trade—but also in an improved coordination of the entire supply chain (BMEL 2017). — The IAMO researches in particular the state of





digitalisation and the implementation of new techniques and technologies at all levels of the agricultural commodity chains. It also deals intensely with the challenges of digitalisation for politics and society.

— State of Technology ¹ —

In general, there are two development stages of digital technology use in agriculture: Precision Farming and Smart Farming. **Precision Farming** is used to describe applications (apps), which provide farmers with improved information supporting them with entrepreneurial decisions. Internal and external facility **sensors** provide access to important production parameters. In arable farming, soil sensors and sensors on or in agricultural machinery collect information on nutrients in the soil, water availability and storage capacity, plant health and growth stages. These data make it possible to precisely plan and implement soil preparation, sowing rate, fertilisation, irrigation, harvest and storage.

¹ This chapter is based on a study conducted on behalf of BMEL (KUHN et al. 2019).

Weather stations continue to provide access to temperature, precipitation, humidity and other climate data. With livestock, sensors in stalls or placed on the animal collect data such as size, weight, animal activity, milk production, physiological parameters and feed intake. In summary, sensory devices make it possible to precisely monitor and feed/care for the livestock according to their needs. The aim is an efficient increase of yield and simultaneous improvement of the well-being and health of the animals. — Satellites or drones provide **remote sensing data** with higher resolution, for example optical information about plant growth. **Satellites** provide optical information, radar data and site technologies. The satellite technology enables the creation of high-resolution potential maps enabling heterogeneous soil preparation as well as sowing, fertilisation and crop dusting. Optical and radar data provide further information for yield estimation and weather risk management. **Control systems** based on Global Navigation Satellite Systems

(GNSS) allows for precise and automated use of agricultural machinery. Need-based deployment of equipment is the intended goal here. Linking satellite data and tractors, which are equipped with GNSS receivers, correction signals and steering assistance ensures precision of equipment use. **Drones**, on the other hand, provide optical information similar to satellites, however are more flexible with regard to time and location and have higher resolutions due to their low flying trajectories. Areas of application also include documentation, site-specific processing, but also the spreading of beneficial organisms and pesticides as well as protection of wildlife from meadow mowing and the detection of damage caused by game. — In crop farming, as well as in livestock farming, **robotics** reduce the need for manual labour in repetitive work processes, usually in combination with the above-mentioned sensory elements. The goal in arable farming is to use automated agricultural machinery, but also combine small and medium-sized robots for flexible,

sustainable and efficient soil preparation and the output of production resources. Milking robots, column cleaners, ventilation systems or feeding systems are commonly applied in livestock production. In addition to the actual milking process, milking systems record the quantity of milk of each individual cow, analyse the milk ingredients, but also the state of health of the animal. The goal here is to increase milk production and to detect diseases at an early stage. — The information collected in Precision Farming serves therefore predominantly as a decision aid for farmers. Irrespective of the fact that they are impressive in their scope and diversity, the collection of many of these parameters and the use of robotics is of course not a new development. Actually new is the second stage of digitalisation in agriculture, described by the term **Smart Farming**. Smart Farming includes the combining of different data, their analysis and partial autonomous use through downstream digital applications. The first step to Smart Farming is the transfer of

information from analogue to digital storage, as well as their connecting in **clouds**. Unlike storage media that physically remains with the user, here, the storage space is created by the joining of several remote servers. This form of data storage makes it possible to file and collect large quantities of data from varying sources, also known as **Big Data**. This data forms the preconditions for training artificial intelligence via **Machine Learning** in the second stage. The term describes continuous and autonomous improvement of algorithms for data analysis and prediction of events and results of entrepreneurial decisions. In other words, an artificial system is trained to learn certain decision processes using large amounts of data. The goal is to enable at least partially autonomous decision-making of agricultural machinery and robotics. A third, further step not only includes partially autonomous deployment of individual units, but also real-time communication between sensor technology, satellites, agricultural machinery and end user devices such as com-

puters, tablets, and smart phones, which is also known as the **Internet of Things** (IoT). — According to estimations, approximately 75 billion digital devices could be in use by 2025 (IOTA 2019). New technologies must therefore be able to utilize enormous amounts of data from different types of IoTs. The **Distributed Ledger Technology** (DLT) allows for safe and immediate connection between IoT devices. With this technology, databases are manageable not only by a central authority but also by several decentralised bodies. Changes in data made by participants are automatically adopted by all other participants. The DLT therefore offers transparency with regard to actions, inalterability of records (i.e. transactions) and ensures trust between all supply chain participants. **Blockchain** is the most well-known DLT type. In addition to increased transparency and data integrity, the DLT could improve, among others, access of small farmers to financial markets. For example, operating information can be recorded on the relevant DLT and

used by the financial institute to assess a client's credit standing. This is especially relevant for regions in which a large informal sector, information asymmetries and a low degree of documentation of assets prevents the recognition of formal securities and thus an undersupply with credit. A similar concept could provide small farms with the opportunity to use intelligent agreements (i.e. digital agreements) and automated payment systems. The **tokens** or **cryptocurrencies** used here are based on block-chain technology, which document the transactions in a decentralized manner and thus prevents manipulations.

Implementation and challenges

Increased use of digital technologies and their development potential

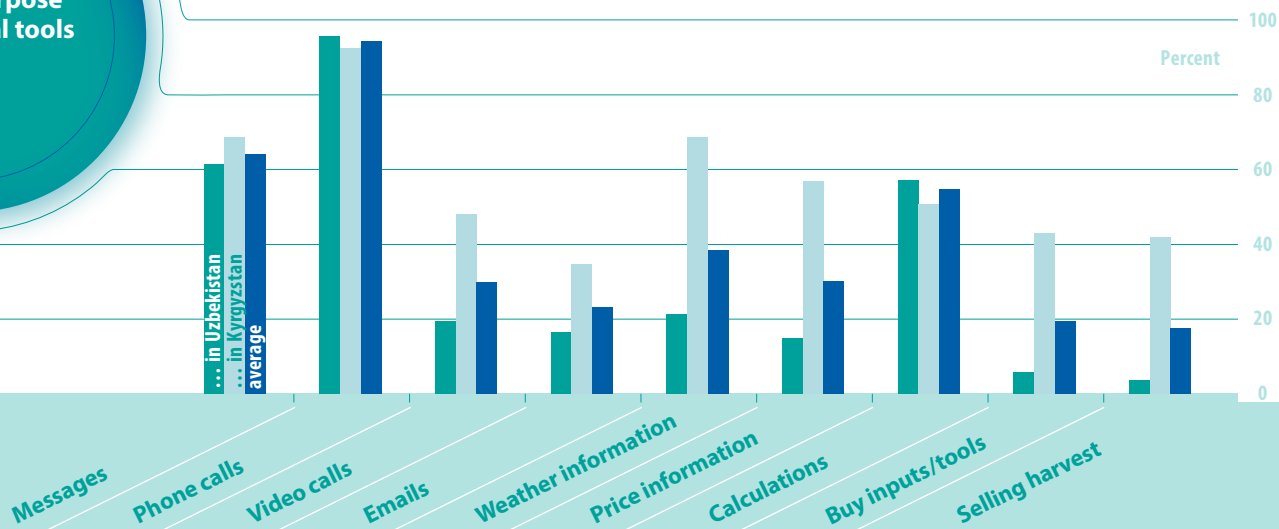
Many of the technologies mentioned are already available on the market worldwide. For example, in 2016, there were already 561 Android applications in agriculture (COSTOPOULOU et al. 2016). In German speaking countries alone at

least three industry giants (BayWa, Yara and CLAAS) offer field indexes or farm management software. A number of start-ups offer software solutions for agricultural trade, input management and data exchange platforms, support through so-called accelerators, industry-specific investors and public funding channels. There are several relevant initiatives also in transition economies, for example, the comprehensive agricultural software by the Ministry of Agriculture of Kazakhstan or the ET Agricultural Brain of Alibaba Cloud (the Cloud computing branch of the Chinese Alibaba Group). — Due to different socio-economic conditions, agricultural structures and political frameworks, there are varying potentials for the use of the above-mentioned technologies in Eurasian transition economies. The application of digital technology in agricultural machineries appears to be in particular beneficial to large farms with professional management and good access to credit. Another decisive factor seems to be standardised production procedures

at an already high level of technology input. For small farms, also in less developed economies, the use of low-cost apps and platforms can be beneficial. The use of digital agricultural machinery and sensory systems would be possible for these smaller farms in particular via service providers. — Meanwhile, empirical data on the actual use of digital technologies in transition economies is scarce. Studies in industrial countries (USA, Great Britain, Denmark, Australia) measure application rates of precision agriculture at 23–59% in the US, 22% in Great Britain, 77% in Australia and 23% in Denmark (LOWENBERG-DEBOER and ERICKSON 2019). The limited data for transition economies indicate a much lower use of digitalisation in that region. According to Ustinovich et al. (2019), in Russia only 10% of farmland is processed with the help of digital technologies. Farm level data on the use of GPS-controlled tractors, which was collected by the authors of this report, show an application rate of 18% in Russia and 4.5% in Kazakhstan. For China, the Japanese

drone manufacturer XAG reported the use of drones in agriculture at 5% of the entire farm area. Users are predominantly service providers who spread pesticides over the fields of their customers, according to XAG to date 1.2 million farmers (UAS VISION 2019). — Although intensive use of digital technologies in the recreational area can also be observed in transition economies, available data show that only few relevant applications have made their way into everyday business of the regional agricultural and food industry. For example, in the countries of Southeastern Europe digital tools are mainly used to access government information, email correspondence and general agricultural information, rather than direct transactions such as the purchasing production resources, online trade or e-banking (FACE 2017). A similar picture can be observed for farmers in Central Asia. In scope of their farming activity, they use digital tools mainly for checking news, conducting calls and calculations. Additional uses include access to weather information (39%),

1— What purpose do digital tools serve for farmers?



price information (30%), video calls (30%) or e-mails (23%). Less than a fifth of the farmers use digital tools to purchase production resources or to sell crops. [Figure 1](#)

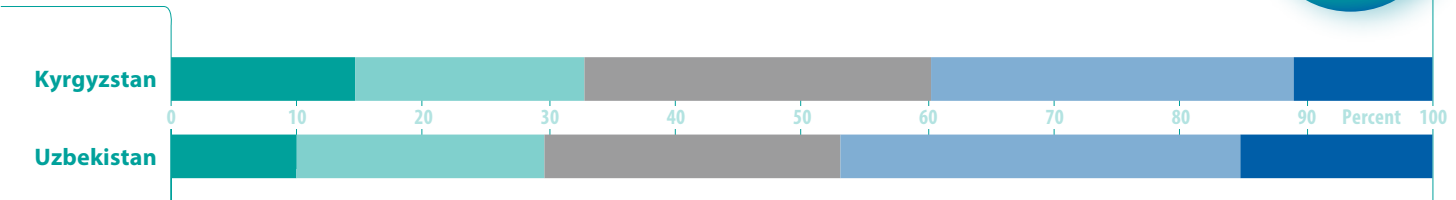
Implementation factors

Various factors are considered impediments for faster implementation in both transition economies and industrial countries. Some empirical evidence is offered by farm level data: In one survey, Chinese farmers reported the lack of investment cap-

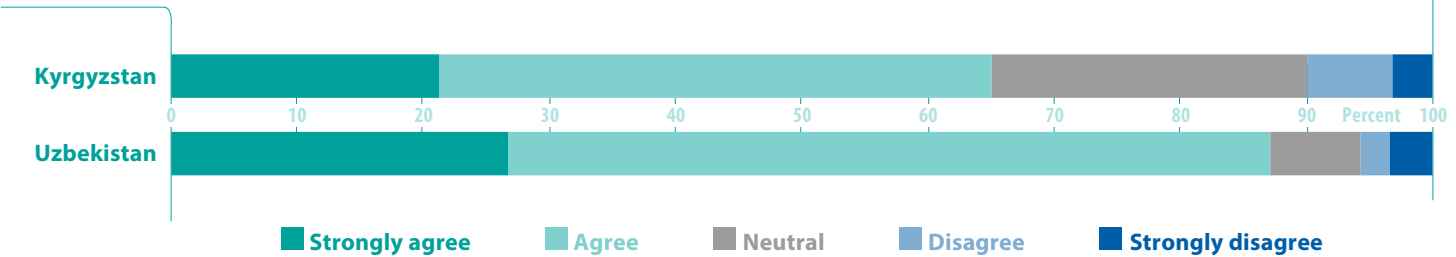
ital (50%), financial risks of investments (35.3%), scepticism due to a lack of experience (29.4%), the lack of individual technological skills (29.4%), and a lack of technical support (26.5%) to be obstacles to digitalisation. Other than in industrialized countries, data security played a lesser role (2.9%) (KENDALL et al. 2017). Surveys of IAMO scientists in Uzbekistan showed high implementation and operating costs, complicated utilization and general preference

for personal interaction (each 15%) as main hindrance to digitalisation. Concerns over profitability were expressed only by 6% of the interviewees. Russian farmers named high implementation costs (94%), the lack of specialists (84%), insufficient expertise of the farm head (75%), a lack of technical infrastructure (66%), insufficient trust in the effectiveness of the technology (53%), and a fear of theft of the installed sensory devices and robotics (41%) as the main deter-

I have no other access to this information



This information can give me operational advantages



rence (KOSHKAROV and KOSHKAROVA 2019). Surveys performed by the authors of the presented article among farmers in Kazakhstan and Russia showed insufficient need (77%), high costs (27%) and the lack of know-how (22%) as main obstacles. A lack of reliability (5%) and the non-existence of compatible systems (4%) was only rarely indicated as the cause, however. In the following, some of these factors will be discussed in detail. The most relevant aspect is the

economic benefit of digital technologies. In general, digital technologies are considered to have a high potential for increasing yield or applying resources more efficiently. There could be an economic benefit especially in countries with large adjoining agricultural areas. Ustinovich et al. (2019) estimate that the use of digital technologies could reduce crop loss in certain types of grains by up to 40%. A detailed calculation for the production of grain shows

that digital technologies could lower the average costs of production by approximately 6580 RUB/t to 5066 RUB/t, a cost reduction of approximately 23%. The greatest cost reductions could be achieved in the utilisation of chemical systems for the production of fertilizer, the use of mineral fertilizer and mineral oil material, as well as the use of fixed assets and labour costs (USTINOVICH et al. 2019). Meanwhile, the Kazakh government estimates that digital tech-

nologies could lead to an increase in agricultural productivity by 25–50% and a reduction of production costs by 10–20% in future (THE ASTANA TIMES 2019). Decisive for the implementation of new technologies is, however, not the externally estimated or subsequently measured economic benefit, but rather the individual perception of the farmers. A study among grain producers in Kyrgyzstan and Uzbekistan showed significant differences in perception with regard to the utilisation of digital tools for one's own production. Farmers in Uzbekistan, for example, view online information on average as being more relevant for their agricultural production than farmers in Kyrgyzstan; presumably also because they can identify fewer alternative sources of data. [Figure 2](#) In Russia and Kazakhstan, even 77% of the farmers were of the opinion that GPS-controlled agricultural machinery was of no benefit for them. — An additional [basic hindrance](#) is the lack of [know-how](#) of the farmers with regard to digital technologies. In the DESI ranking (digital and economic

social index of the EU Commission) Eastern European countries (with the exception of the Baltic States) are ranked below the EU average. [Figure 3](#) According to the rate of internet use in the entire population, an important general indicator for digitalisation, Central Asian countries are ranking in the lower third, while the People's Republic of China is ranking average. The Russian Federation, on the other hand, is in the top third of the scale, even before the US (ITU 2017). Still, there is a difference between urban and rural populations. As determined by the International Telecommunication Union (ICT), the number of IT skilled users in rural regions was on average 11% below of those surveyed in the city (ICT 2018). According to the World Bank, internet utilisation rates in the various transition economies fluctuated between 21% and 88%. Some Central Asian countries are ranking particularly poor as not even a fourth of the population is using the internet (WELTBANK 2019). In consequence, the search for trained employees for the introduction and operation of new technologies is dif-

ficult. — In addition, the [technical networking](#) of machines, clouds and users must be designed so that, on the one hand, there is a quick exchange between individual components and, on the other hand, no units have downtime if there is a fault in the telecommunication system. This is especially important for countries where fluctuations in the electricity supply are common. Data needs to be stored de-centrally and networked while withstanding an interference with work flows should the energy supply be interrupted. The related legal framework as well as national or even international standards are still in developmental stages, however. In this respect, the German Federal Ministry of Food and Agriculture has been supporting the project [GeoBox](#) of the German aerospace centre for the development and provision of free uniform data structures since 2018 (BMEL 2018). There are similar national initiatives known also from larger transition economies at various stages of advancement. Coordination of the many activities involved represent

an important task of the future. — An additional condition for the processing and use of data beyond one's own business is the distribution of **uniform and open data formats**. Difficulties in data exchange and the general compatibility between agricultural machinery and different data platforms constitutes a fundamental hindrance for the quick spread of Smart Agriculture. With the Agricultural Industry Electronics Foundation (AEF), an international alliance of the agricultural industry is dedicated to the securing of interface compatibility. Hungary and Slovenia are the only two transition economies currently taking part in this alliance. — Additional, urgent issues in rural regions include low **network coverage** and the few transmission capacities in information and communication technology. Whereas many countries already achieved nearly 100% coverage with 3G technology, only two-thirds of the population have access to 3G technology in Kyrgyzstan. Coverage with 4G technology amounts to 19% in the Commonwealth of Independent States (CIS), which is significantly below the worldwide average of 43% (GSMA 2019). Rough estimates show that there is a wide gap between existing and required technology. With an incurring data amount of ca. 50 MB per ha maize, 2G translated into an overall upload time of 40 minutes, 3G into 1–3 minutes, 4G into 4–16 seconds and 5G into 0.01 seconds. [refer to Table 1, p.20](#)

Also the question of **Data Safety and Data Processing** is gaining increasing relevance with increasing spread of digitalisation. In transition economies, there are currently few concerns with regard to data rights and further

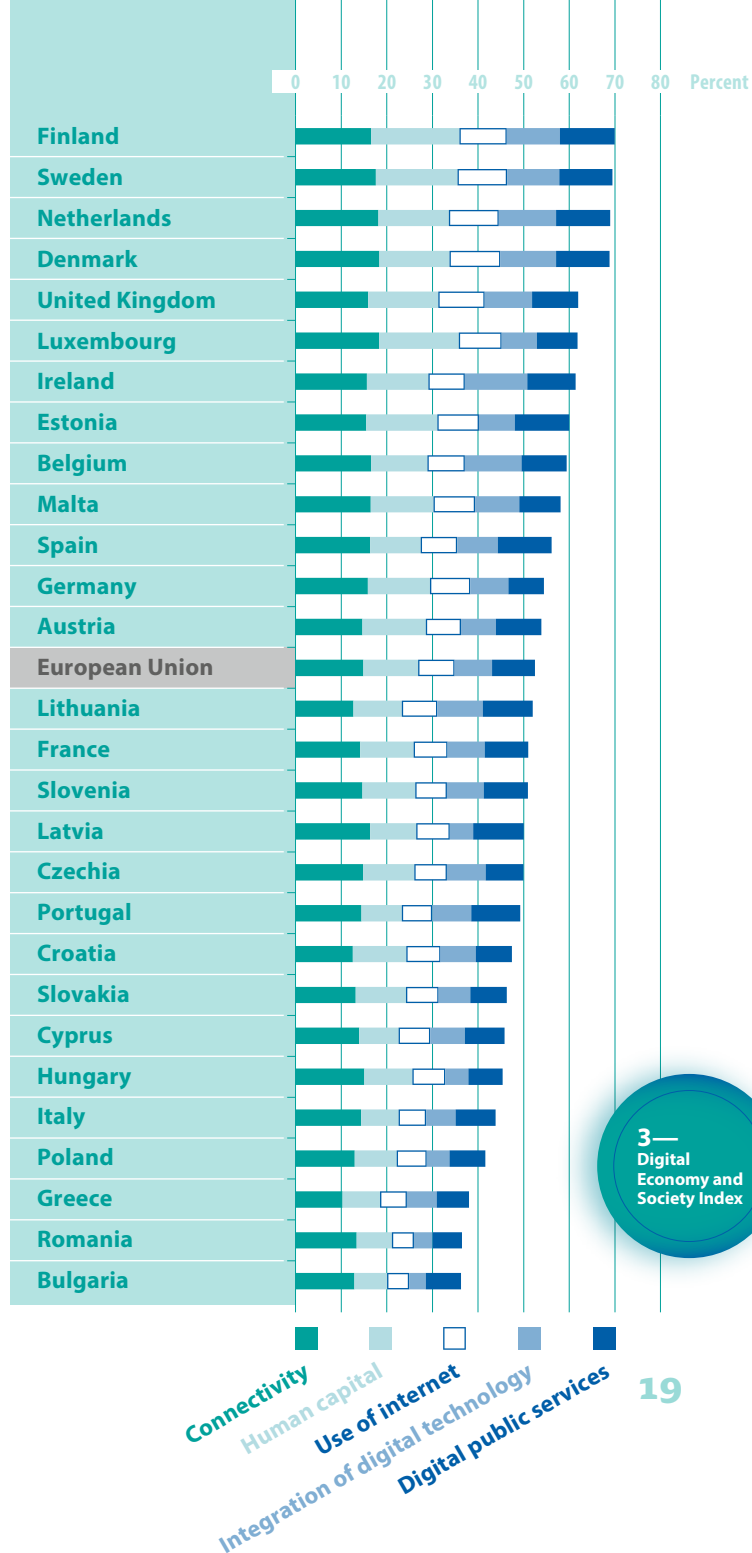


Table 1 — Calculation of the duration of transfer of remote sensing data per hectare

Technology	Technology Detail	Max. Down-load Speed	Max. Upload Speed	Real Down-load Speed	Real Upload Speed	Time to upload data for 1 ha maze (≅ ca. 50 Mbit data)	
		Mbit/s	Mbit/s	Mbit/s	Mbit/s	Seconds	Minutes
2G	GPRS	0.1	0.02	<0.1	>0.02	>2428	>40
	EDGE	0.3	0.06	0.1	0.02	2428	40
3G	3G (Basic)	0.3	0.06	0.1	0.02	2428	40
	HSPA	7.2	1.44	1.5	0.3	162	3
	HSPA+	21	4.2	4	0.8	61	1
	DC-HSPA+	42	8.4	8	1.6	30	1
4G	LTE Category 4	150	30	15	3	16	0
4G+	LTE-Advanced Cat6	300	60	30	6	8	0
	LTE-Advanced Cat9	450	90	60	12	4	0
	LTE-Advanced Cat12	600	120	24	4.8	10	0
	LTE-Advanced Cat16	979	195.8	39.16	7.832	6	0
5G	5G	1000–10000	2000–5000	10000	5000	0.010	0

Source for transfer speeds: tigermobiles.com. Source for data volume: Mark & Griffin (2016)

processing. Among farmers in China, data safety only played a minor role as a hindrance to implementation (2.9%) (KENDALL et al. 2017). Meanwhile, data from industrial countries shows an increase in awareness in

agricultural and food science operations and companies with regard to transfer of data to third parties. As a result, 70% of those surveyed in the German food industry were concerned about data safety

with regard to industrial espionage (ROHLEDER and MINHOFF 2019). Herein, we have to differentiate between personal data of the farmers, financial operating data, sensor data and remote sensing data. Differences also

pertain to the legal framework, copyright, access rights and the potential benefit for the general population. Conflicts of interest are especially likely with regard to financial data and operating data. These data influence in particular economically relevant areas such as access to credit, access to other financial benefits or the market power of producers towards suppliers of production resources and purchasers.

— Outlook —

The previous discussion on hindrances of adaptation of digital technologies in transition economies has touched many basic questions and challenges, in particular with regard to cost efficiency, reliability and data safety. Even if there are internationally different perceptions, the basic focus topics are similar in all countries surveyed. In addition to education and a suitable legal framework, it is especially important to adapt the digitalisation to the concrete demand and to consider the operational circumstances. Significant concern exists with relevant questions, for instance:

— How do digitalisation processes influence workplaces in agriculture and in rural areas?

— Which new requirements does the agricultural education system face?

— What skills will farmers need in the future and how can the increased skill requirements be dealt with, in particular considering the already existing lack of qualified labour in rural areas?

— Who owns the collected data?

— How can we protect the operational data of farmers while at the same time offering consumers a transparent supply chain?

Since most digital technologies are still at an early stage of implementation, their actual impact on agriculture and food industry can hardly be assessed in its entirety. The lack of sufficient information about the benefit of certain technologies and the potentially high costs of technology adoption are some of the greatest obstacles for broader acceptance and prevent a speedy spread of various new technologies. The acceptance of digital technologies and re-

spective skills acquired by farmers of course constitute a central topic. Providers of new technologies do provide trainings in order to acquaint farmers with their implementation, however so far only to limited extent. In light of the increased spread of digital technologies, the curriculum at all levels of agricultural education should be adapted to the new conditions. This need for modernisation of curricula is certainly not limited to transition economies. — As mentioned, the new technologies greatly depend on large amounts of data, which are collected by technology providers. In particular, large agricultural and food companies, especially input and machinery providers, try to collect and to network large amounts of data in order to better understand and monitor their market and to increase their market share and profits. This ‘insatiable need for data’ also plays a role in the currently ongoing large-scale mergers of companies in the agricultural and food sectors, which have led to concentration processes in certain segments such as in seed production

and agricultural machinery. In addition to insufficient data, the lack of consensus about the property rights to certain types of data and/or legal insecurity pose a second obstacle for the speedy digitalisation of agriculture and food industry. For one, we must take into account the position of technology providers who offer the tools for data collection, such as all types of sensors on tractors and harvesting machines or data about the consumption behaviour collected via digital platforms. At the same time, providers of data platforms are asserting their rights to processed and optically edited data. In addition, the farmer has ownership over personal data and surely will request control over operational data, which is being automatically collected. Different legal views and lack of regulation with regard to data ownership leads to significant legal complications and conflicts. Thus, there is a growing need for national data protection provisions such as international standards, which can be updated simultaneously with the technical advancements and actu-

al implementation. In addition, the governments should create stricter regulations to ensure a competitive market, by preventing monopoly-type market conglomerates that lead to higher costs of technology utilisation and the emergence of a digital gap. — In order to provide a broad basis of technological development and acceptance, but also quicker adjustment to legal frameworks and national agricultural policies, private as well as public sectors should combine their digitalisation efforts within the scope of a public-private partnership. Instead of lagging behind fast market developments, the legislative body could be involved in technological developments early and thus have access to the latest technologies and know-how as well as have the opportunity to adapt regulatory requirements to innovative technology in a timely manner. Numerous examples in the past have shown good results of public-private partnerships, in particular when improving consulting services for farmers, e-government or the

efficient provision of state funds to promote digitalisation.

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— Sources and credits —

S. 12 Drones in use in the agricultural sector © Monopoly919 - stock.adobe.com

Figure 1 Data for use of digital tools by farmers © Own presentation. Data: Bobojonov & Kuhn (2019)

Figure 2 Study among grain producers in Kyrgyzstan and Uzbekistan regarding perception of digital tools © Own presentation. Data: Bobojonov & Kuhn (2019)

Figure 3 Digital Economy and Society Index of the EU Commission © Own presentation. Data: <https://digital-agenda-data.eu/datasets/desi/indicators>