How can we make sense of smart technologies for sustainable agriculture? – A discussion paper

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Abstract: *This paper discusses the challenges of assessing the benefits and risks of new digital technologies, so-called 'smart technologies' for sustainable agri-food systems. It builds on the results of a literature review that was embedded in a wider study on future options for (sustainable) farming systems in Germany. Following the concepts of Actor-Network-Theory, we can conceive of smart technologies in agriculture as networks that can only be understood in their entirety when considering the relationships with all actors involved: technology developers, users (farmers, consumers and others), data analysts, legal regulators, policy makers, and potential others. Furthermore, interaction of the technology and its implementers with nature, such as plants, entire landscapes, and animals, need to be taken into consideration. As a consequence, we have to deal with a highly complex system when assessing the technology – at a time where many of the relevant questions have not been sufficiently researched yet. Building on the FAO's SAFA guidelines, the paper outlines criteria against which smart technologies could be assessed for their potential to contribute to a sustainable development of agri-food systems. These include aspects of governance, ecology, economy and social issues. We draw some tentative conclusions on the required framework conditions for implementation of digital technology, in particular from the perspective of sustainable agriculture. These are aimed at fuelling further discussion about the potentials and risks of the technology.*

Keywords: *digitization; smart technology; sustainable agriculture; assessment criteria*

Conceptualizing digitization in agriculture

Generally speaking, the term digitization encompasses the conversion of analogue information into digital data. On the other hand, it includes the automation of processes and business models by networking digital technology, information and people (Federal Ministry of Food and Agriculture, 2017). In agriculture, GPS control systems, sensors, robotics and automation, as well as drones are used in particular; if different systems are networked on the farm and additional data is integrated, this is referred to as "Agriculture 4.0". In addition, technologies (such as blockchain technology (Tian, 2016)) and software programs are being developed to integrate the entire value chain, thus creating complete transparency from the use of resources for a product through its processing and transport to its purchase in the supermarket. For this purpose, so-called "Agri-Business Collaboration and Data Exchange Facility (an ABCDEF)" is required (Poppe et al., 2015).

A further classification of digital technologies in agriculture can be made according to application areas. Rohleder and Krüsken (2016) subdivide digital technologies in agriculture according to applications in livestock farming (e. g. milking robots, automatic feeding, health monitoring), plant production (e. g. precision agriculture, field robots, drones), the supply industry (manufacturing and use of agricultural machinery), and the food industry (especially data integration via the value-added chain and production processes).

All these applications produce large amounts of data that can be linked ("Internet of Things"), which leads to so-called "big data", often stored in a "cloud". Big Data is generally understood to mean methods and technologies that enable the collection, storage and analysis of large data volumes of differently structured data (Federal Ministry of Food and Agriculture, 2017). Comprehensive farm management systems have been developed by various agritech companies, as well as enterprises working on seeds and crop protection. A highly developed example is the Monsanto subsidiary "TheClimateCorporation", which links impact specific weather data, plant available nitrogen and other crop specific information and on this basis gives partial crop specific recommendations for variety selection and seed density as well as nitrogen fertilization (de Witte et al., 2016).

In this paper the terms "digital technologies in agriculture","agriculture 4.0","smart farming" and "precision agriculture (PA)" are used synonymously.

The large amounts of data and the wide range of applications result in a complex picture of this still quite new technology(s). Actor-Network theory (ANT) addresses this complex system of human-technology-environment. In line with ANT, we consider smart technology in agriculture as co-constructed between those who develop technology, those who apply it, the legal and political actions of the state, as well as those actants to which the technology is applied, i.e. soil, plants, and animals (see Figure 1). People, machines, and the "objects" of observation (plants, soil, animals) are linked by means of data collection, storage and analysis; furthermore, policies and legal regulations from the state interfer in the network. In the way the technologies are developed and implemented gives them a strong position of acting, in the sense that they produce data which people can (and partly must) use, but even more as they already process data applying algorithms that influence the possible ways of further adoption and implementation.

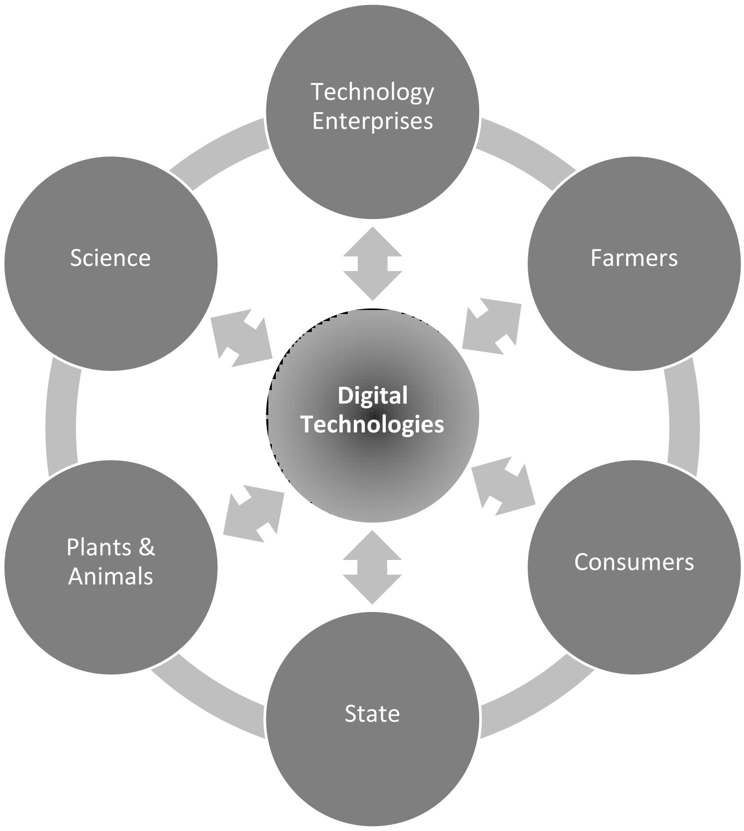

Figure 1: Digitization in agriculture as a complex network between humans, technology and the environment

For a critical examination of the possibilities and limitations of the use of digital technologies in agriculture, it is therefore necessary to consider the entire system involved in the development, use and control of this technology. The complex system of human-technology-environment-policy will be strongly affected through digitization of agriculture (Hostiou et al., 2017).

Conceiving of digital technologies in agriculture as such a complex network renders an array of questions to be addressed when trying to make sense of the technology and its applications. This paper focuses on the opportunities and limitations of digital technologies to contribute to improving the sustainability of agriculture. To structure the questions to be addressed for assessing the technology in this sense, we chose the comprehensive SAFA

(Sustainability Assessment of Food and Agriculture systems) guidelines from the FAO, which cover economic viability, ecological impacts, new social structures (e. g. working environments), and last but not least, questions of governance (FAO, 2014). These criteria do not represent ready-to-use set of indicators - rather, questions are formulated that shed light on different sustainability areas. Applying ANT makes it clear that the questions must be answered specifically for each technology in relation to its application. Due to the still insufficient level of knowledge about the detailed effects of the technologies, generalisable statements and an integrative sustainability assessment are difficult, and have so far only been attempted in very few cases (Rösch et al., 2005). The present discussion paper aims to make a further contribution here.

Concerns regarding the evaluation of smart technologies for sustainable agriculture

Based on the SAFA guidelines of the FAO (FAO, 2014), we consider the four sustainability areas of governance, ecology, economy and social affairs. For each of these areas, SAFA defines topics that are to be taken into account in a sustainability assessment. We adapt those topics to the specific problems of digitization in agriculture.

Governance

Ethical and legal considerations play an important role in the area of governance, as well as questions of transparency and participation.

At present, the political and legal control of digitization (not only) in agriculture is lagging behind technical developments. Politicians have a special and urgently needed role to play in creating the legal framework for the ethical and sustainable use of digital technologies (Bittner et al., 2016, Walter et al., 2017). In this context, farmers' organizations often refer to the fear of a "transparent farmer or farm". However, there seems to be more unease about the transparency of the financial situation of a farm than about the disclosure of decisions in farm management, such as the use of fertilisers and pesticides (de Witte et al., 2016, Rösch et al., 2005). The collected and combined data from agricultural holdings could be used by third parties to the detriment of agriculture if, for example, manufacturers of inputs use the knowledge advantage to gain economic advantages or increase their dependency on individual companies in the upstream industry (Federal Ministry of Food and Agriculture, 2017b). Such interdependencies are already evident in the United States, where farmers have signed contracts with Monsanto's subsidiary "Climate Corporation" to supply the company with comprehensive field and crop-specific data on about one-third of its agricultural land. Monsanto can completely bypass farmers to collect and evaluate a very large amount of data (Carbonell, 2017). Companies such as John Deere, General Motors and the above-mentioned Climate Corporation have signed a contract prohibiting farmers from intervening in the software of their tractors to carry out repairs to the machines themselves (Carbonell, 2017; Wiens, 2015). In the application area of integrated value-added chains, there is also the risk that software development will be driven by companies in particular, and that farmers will ultimately become franchise entrepreneurs on behalf of globally active agricultural companies (Poppe et al., 2015).

With regard to the issue of transparency as regards data exploitation, it helps to take into account three groups of people or companies: 1. those who provide data (farmers), 2. those who have the means to collect data, and 3. those who have the ability and expertise to analyse it (currently mainly agribusinesses). Data providers often do not have access to their data and are neither capable nor have the technical means to analyse it. In addition, a lot of usable information is created by analyzing the entire data set ("Big Data"), which results in a "Big Data Gap" between people and their data (Andrejevic, 2014). This raises the question of the role of the state as a public actor, which could evaluate agricultural data via a publicly funded open-source programme or a publicly accessible system (Carbonell, 2017; Poppe et al., 2015). In this case, all relevant stakeholders, in particular farmers, would have to be effectively involved in order to ensure that their requirements are sufficiently taken into account (König et al., 2012). So far, the beneficiaries of Big Data seem to be the large companies in the upstream industry. New companies such as google or SAP, which have not been active in agriculture so far, will also feature here (Roland Berger Strategy Consultants GmbH, 2015). In response to this strong position of large agricultural companies, projects have recently been developed that regulate privacy and access to agricultural data between the parties involved. A prominent example is the Open Ag Data Alliance http://openag.io/ (Bittner, Heil et al., 2016). The question of networking and interaction between different systems and thus the counteraction of monopolization tendencies is not least concerned with the question of technical interface design in order to make systems from different manufacturers compatible with each other. A critical aspect also regards data security and the possible vulnerability of electronically networked systems to hacker attacks or technical failures that could seriously disrupt the entire course of operations (Federal Ministry of Food and Agriculture, 2017b).

Another important aspect of governance is the question of research funding. Up to now, the technical development of PA applications has been driven very strongly by the industry, which has developed a new business field. The focus of the research was therefore on technologies and application areas that promised the most profit for companies. Up to now, it has focused primarily on large farms and the use of mineral fertilizers and pesticides (Bechar and Vigneault, 2016; Carbonell, 2017).

One possible application of digital technology is the improvement or monitoring of agri-environmental policies. This would require that private, company-related data be combined with public data, such as weather data, to create a specific environmental situation (Antle et al., 2015). Antle et al. (2015) propose private-public partnerships for this purpose. The important question here is the sovereignty of data and the exploitation of company-specific data. However, there are currently no concrete examples of applications that have been implemented.

In the field of governance, these considerations on different application scenarios and data use in agriculture 4.0 give rise to the following questions for the evaluation of digital technologies with regard to their significance for sustainable agriculture:

- What decision-making mechanisms are there to define which data is to be evaluated or with which underlying question the data is to be evaluated?
    - Who has access to the data?
    - Are data anonymized?
    - Will public institutions be included in the data analysis?
- Who decides on the direction of further technological developments?
- How are public institutions involved in research and development of the technology (machinery and software)?
- What protection does the technology/their application offer against hacker attacks and disruptions that could interfere with the operation?
- Can data on the provision of public goods in agriculture be collected and analysed?
- How transparent are the rights and obligations of the respective users/processors?

Ecology

In general, it is difficult to estimate the environmental impacts of the use of specific techniques in agriculture due to the complex interactions between agricultural measures and measurable environmental effects, including the ecological impacts of the use of digital technologies. In addition, there are still few studies available and the available data are site-specific and therefore do not allow generally valid conclusions (Möckel, 2015). Furthermore, it is difficult to make absolute statements regarding the environmental impact of a technology use; a relative improvement depends on the alternatives with which it is compared (e. g. with a rather extensive or rather intensive cultivation) (Rösch and Dusseldorp, 2007; Rösch et al., 2005). Finally, comprehensive studies on the environmental effects of the different digital technologies are missing so far.

Against this background, it is possible to make some statements about trends, but it is not surprising that different studies come to very different conclusions regarding the environmental impacts of the use of different technologies. For example, in a trial operation in Germany, nitrogen fertilization in the case of partial area-specific fertilization decreased by about 7% (at a 6% increase in yields), while in a model calculation in the USA, an operation with a combination of different digital technologies applied only 1.1% less nitrogen (Rösch et al., 2005; Schieffer and Dillon, 2015). Apart from the difficult forecasts of the effective saving of nitrogen fertilizers, it is uncertain to what extent an overall situation can actually be improved by PA applications. For instance, in Germany there are high nitrogen balances due to poor nitrogen utilisation efficiency of the manure produced in high-density livestock regions. However, no practical PA procedures have been developed so far for the application of these fertilisers; instead, mineral fertilisers have been the focus of technical development (Rösch et al., 2005).

Furthermore, a reduction in fuel and seed consumption can be assumed, but reliable data are also lacking here (Rösch et al., 2005). Rösch et al. (2005) see the greatest potential for improving the environmental impact of agriculture in reducing herbicide use, where a reduction of up to 90% has been observed due to the use of digitization methods. In their model calculation, however, Schieffer and Dillon (2015) conclude that herbicide use in their model farms would only decrease by about 10% without simultaneous policy measures (for the discussion of interactions not only have a direct positive influence on humans and the environment, but also contribute to a reduction of the risk of resistance formation - although this is hardly discussed at present). Similarly, it has not been investigated to what extent PA techniques can also provide services in species and biotope protection if, for example, small-scale sensitive areas are excluded from the application of plant protection products. Similarly, there are still very few studies on, for example, mechanical weed management (Rösch et al., 2005).

In animal husbandry, milking crobotics is probably the most widespread digital technology currently in use. For farmers, it is above all a labour saving measure, and it is controversial whether it has a positive influence on animal health (Lassen et al., 2015). Sensor technology is increasingly being used in animal husbandry, such as the monitoring of animal behaviour in order to draw conclusions about the health of animals, or the direct detection of problematic behaviour, such as feather pecking in chickens or tail biting in pigs. Such early detection procedures can be used to promptly eliminate problems with minor surgery before they become clinical (Dawkins, 2017). There is therefore the potential to reduce the burden on the environment and food with antibiotics or other groups of veterinary medicines (Nasirahmadi et al., 2016).

There is also no consideration or evaluation of the potential benefits of such technologies on a landscape level. Big Data's research and analysis could provide new insights into the large-scale effects of pesticides on the environment or the impacts of different agricultural practices on biodiversity. However, companies working with Big Data have not addressed such questions so far. Thus, there is a connection here with the ethical questions formulated above concerning data sovereignty, the interests of data analysts and the relationship between private and public interests (Carbonell, 2017).

In conclusion, we can say that digital technologies offer some possibilities for reducing the environmental impact of agriculture, but these are (currently) limited or have not been researched enough (Rösch et al., 2005). There are two reasons for this: firstly, technical development has so far not considered a number of environmentally relevant effects; secondly, the technology is not yet available (for large-scale use) and therefore could not be tested for its environmental impact. It should also be borne in mind that some desirable environmental impacts can already be achieved today, and often at a lower cost, with established techniques such as conservation tillage or organic farming. So an improvement of the environmental situation could also be reached by further development of these systems. Furthermore, some sustainability deficits can only be remedied to a limited extent by means of technical solutions, as the example of regional nitrogen surpluses from livestock farming shows. In addition, the trend towards ever larger farms with monocultures, which is supported by the use of PA, is problematic in terms of assessing the impacts on biodiversity (Bittner et al., 2016). Finally, the risk of a rebound effect is relevant (Schieffer and Dillon, 2015). If the efficiency of e.g. nitrogen fertilizer application increases, the overall costs decrease, and more nitrogen can potentially be applied to increas yields.

These considerations give rise to the following questions in the field of ecology for the evaluation of a possible contribution of digital technologies to sustainable agriculture. By "environment" we mean animal welfare, among other things.

- What are/can be achieved with the technology?
  - At what level are effects to be expected? Single farm or landscape level?
- Are the expected ecological impacts in line with the sustainability goals?
  - Are the environmental problems relevant to the respective region/region in Germany addressed?
  - Does the state of the art meet the requirements with regard to sustainability (e. g. problems with agricultural fertilizers versus technology for the use of mineral fertilizers)?
  - o What are the effects of the use of technology on animal welfare?
- Can the same environmental effects be achieved with other (simpler or less expensive) techniques and management methods?
- Is a rebound effect to be expected?
- Are new digital approaches and policy instruments coordinated?

Economy

Depending on the technology and its area of application or location, the costs for the technology can vary considerably. They consist of the investment costs for the devices, costs for data acquisition, for data management and consulting systems, as well as for application and navigation technology. Comprehensive calculations on the cost-effectiveness of digital technologies in agriculture are not available. This is partly due to the fact that the technology is still under development and is therefore rarely used in practical applications (de Witte et al., 2016). On the other hand, this is due to difficult and exact quantification of the technology's effects, such as possible positive effects on the quality of harvested products or possible negative effects such as increased management costs, and potential synergy effects through multiple use of data and devices (Rösch et al., 2005). The economic considerations are therefore often only based on model calculations or simplified considerations and are not necessarily generalizable.

The majority of research and development in the field of digital technologies is focused on individual operations or plots. The focus is in particular on increasing management efficiency, whether through savings in means of production (plant protection, mineral fertilizers) or working time. Implementation of the technology in the medium to long term seems possible, provided that the farmer benefits from economic advantages, be it through cost savings, productivity increases, quality improvements, reduction of uncertainty and fluctuation of production, or by reducing work classified as dangerous (Bechar and Vigneault, 2016; Jensen et al., 2012). Bechar and Vigneault (2016) note, however, that the economic benefits are so far often lacking and that technology is still often inefficient.

The greatest economic benefit is achieved on large farms, as the fixed costs of an investment in the new technologies per area unit are lower. This applies to almost all applications in crop production and animal husbandry. Since most digital applications have so far been developed for large farms (Ball et al., 2015), and it is there where the technology is most widely spread, there is little data on a possible economically effective use in smaller farms (Carbonell, 2017). For such farms, the shared use of machinery together with other farms could make the technology economically interesting (Kutter et al., 2011).

In addition, many technologies such as the variable rate application of fertilizers or pesticides, are of particular economic interest where fields are highly heterogeneous (Balafoutis et al., 2017). Indirectly, this indicates that the technologies are economically more sensible for large farms and large areas, where their full potential can be exploited. Rösch et al. (2005) conclude that PA applications are more likely to reach the economic viability threshold "the larger the operating area and the more heterogeneous the conditions on the field are" (Rösch et al., 2005, p.123).

From these considerations, the following questions arise in the field of economics for the evaluation of a possible contribution of digital technologies to sustainable agriculture.

- What is the area threshold from which the technology become economically efficient?
- Is the technology suitable for shared use?
- What are the consequential costs (e. g. prices for data acquisition, management and evaluation or consulting systems, linking with other devices, additional devices and software (application and navigation technology), equipment)?
- What are the benefits (e. g. through savings in operating resources)?
    - Can this benefit be achieved more cost-effectively with other technologies?
- Can external positive and negative effects of the technology (current and future) be included in the economic efficiency calculation?

Social

Looking at the agricultural sector as a whole, some of the most advanced digital technologies currently available tend to lead to larger farms. Cost-intensive technologies are only economically viable if they are used on large areas. This supports structural change towards larger farms, provided that the machines are not shared between farms. With regard to the single farm/farmers, three areas of change can be identified: knowledge requirements, relationships between humans, soil and animals, and as a result of this, the occupational profile of a "farmer".

Change in knowledge requirements

First of all, the use of new technologies requires a large investment in training and further education, if only to acquire technical knowledge. In addition to purely technical knowledge, however, digitization in agriculture requires extensive training in the handling of data, especially with regard to legal contracts for the use of data by third parties. Only with sound knowledge in this area farmers could avoid becoming unintentionally dependent on companies (Manning, 2015). It is therefore a question of new ways in which farmers deal with new players in the agro-food industry, such as IT service providers and software developers, who have not been relevant for them in the past. Business relations with the upstream industry will become closer, and without publicly accessible data management systems in the value chain, the impact of upstream industry on farm management will increase (Poppe et al., 2015). In addition, the use of digital technologies for management decisions in individual branches and in the entire management system can lead to losing previously existing knowledge, since the cognitive processing of information is delegated to machines or algorithms (Jago et al., 2013; McBratney et al., 2005). The tacit knowledge acquired over the years can thus no longer be used and runs the risk of being forgotten (Heijting et al., 2011; Rösch and Dusseldorp, 2007). An increasing use of shared machinery (e. g. machine rings) may lead to a decline of crop and site-specific knowledge when a farmer cultivates his or her own fields less and less often, but outsources important work (soil cultivation, fertilization, plant protection). The new demands on technical knowledge, together with the diminishing importance of traditional implicit knowledge, can also lead to conflicts between generations, which can make cooperation between young and old and in particular farm handover more difficult (Federal Ministry of Food and Agriculture 2017b). On the other hand, the use of digital technologies, such as sensors for monitoring animal behaviour, can also replace the lost knowledge of older generations (Götz, 2017). In addition, farmers using digital technologies also indicated that they would get to know their production sites better and thus gain greater certainty when making decisions (Rösch et al., 2005).

Changes in the relationship between humans and animals

One aspect of digital technology in animal husbandry is the development of the relationship between humans and animals. Increased use of technology in animal husbandry, such as automatized milking and feeding, reduces the time a farmer spends interacting directly with his animals. This leads on the one hand to animals becoming less accustomed to humans, or even to experiencing the interaction with humans only in stressful situations (such as castration, claw care etc.). This in turn can increase the stress of the animals as a whole. In order to avoid such a development, farmers should use some of the time saved by technology to establish a positive contact with their animals, for example by passing quietly through the herd (Hostiou et al., 2017). In this context, the fact that farmers increasingly see their animals as part of an industrial process, rather than as animals with complex characteristics in a herd, is also a problematic issue (Cornou, 2009).

Another aspect that has not yet been studied is the impact of digital technologies on the relationship between consumers and agriculture. In many places, an increasing alienation of consumers from agricultural production is observed (Wiskerke, 2009), and this alienation is associated with unsustainable patterns of consumption (e. g. no consideration of the seasonality of products in purchasing, a lack of knowledge about production aspects leading to poorly informed purchasing decisions). With regard to the digitization of agriculture, the question arises as to whether this alienation will increase or decrease. On the one hand, technologies offer easier traceability of products so that information on a particular product can be easily retrieved via the Internet, for example, in the shop (Poppe et al. 2015); on the other hand, it is conceivable that the increasing technologicalisation of the entire value-added chain could contribute to the perception of foodstuffs as being technologically produced, as uniform as possible (and thus freely interchangeable). Yet, a model of innovative direct marketing developed in France and combining digital technology with analogous experience should be mentioned here. The business model "La ruche qui dit oui" ("The beehive that says yes"); offers consumers the opportunity to order products within a defined radius directly from various farmers, and then pick up and pay for the products centrally one day a week. On this "Market Day", producers and consumers come together as if on a weekly market, so that efficient digital technology is combined with social experience.

Change in the occupational profile of a "farmer"

In sum, the changed relationships of farmers on their farms and in the value chain, as well as the new demands on knowledge, lead to a changed working environment and job description.

The use of digital technologies in various branches of industry can make work considerably easier if, for example, mechanical weed control is carried out by robots or if feeding and milking takes less time due to the use of robotics (Hostiou et al., 2017; Jago et al., 2013; Pérez-Ruíz et al., 2014). Often, the greater flexibility in the organization of work is particularly appreciated, even if overall working time does not necessarily decrease (Schewe and Stuart, 2015). However, the effects of these technologies on the working environment and everyday working life are further reaching, and in some cases controversial (Hostiou et al., 2017). Part of the time saved has to be used for other work, such as the maintenance of the new technology, management and data evaluation. The high information density, for example, when milking robots continuously send alerts to farmers' mobile phones, can lead to stress (Hostiou et al., 2017; Schewe and Stuart, 2015). In principle, digital technology seems to be used by young, well-educated farmers with a large acreage or when farms share machinery (Lencses et al., 2014; Paustian and Theuvsen, 2017). On the other hand, jobs will be reduced for unskilled workers, especially through the use of robots. The need for training and further education of farmers will increase and new jobs will be created in the field of digital services for agriculture. It is mentioned in various places that the job description of a "high-tech agricultural manager" could possibly be attractive for young people and thus have a positive effect on the employment situation in rural areas (Federal Ministry of Food and Agriculture, 2017b; Rösch et al., 2005).

From these considerations, the following questions arise in the field of social issues for the evaluation of a possible contribution of digital technologies to sustainable agriculture.

- What are the farmers' requirements for knowledge and training with regard to the technology?
- How does the technology affect the farmer's workload?
    - Will work be safer?

    - Is work made easier/labour saved?
    - What are the requirements (higher or lower complexity of the work)?
    - How does the use of technology affect working time and the distribution of work among different activities?
- What effects are to be expected on the relationship between farmer and environment; farmer and animal; between people?
- Does the technology meet the demands of its users?
    - With regard to practical application, desired saving of labour, and other aspects

Input to a discussion on required framework conditions for digital technologies from the perspective of sustainable agriculture

As mentioned above, due to the complex interactions between the technology, its developers, users and regulators, it is not possible to formulate simple requirements for its development and deployment. Moreover, the data available in the different impact areas - ecology, economy, social affairs and governance – is currently inadequate for making final assessments. Rather, we are asking the question of what a sensible use of digital technologies in agriculture could look like, and in particular what framework conditions must be in place.

The public sector plays a leading role in setting the framework conditions, in particular in what regards research & development, the organization of data analysis, and legal aspects. The participation of the state should be designed in such a way that the development of new technologies is aligned with the sustainability objectives of agriculture and that the potential for the provision of public goods (e. g. erosion protection, integration of ecological priority areas, mixed crops) is also taken into account. In addition, the state must create structures to ensure that farmers have access to all their farm data, including the control of their machines, in order to remain more independent of high-tech companies. Similarly, data analysis and consultation based on this should be done by the public sector or in private-public partnership. Open source programs are to be promoted.

Vocational training should focus on the use of digital technology; here, cooperation between the public sector and agricultural organizations would benefitial. The demand on high-tech knowledge will increase, and in particular the demands on sovereign handling of (partly sensitive) data. This also includes an awareness of possible dependencies on technology and agrochemical enterprises, and the knowledge of (organizational and legal) structures to avoid this. In addition, training and further education should teach how the new technology can be combined in a wise and meaningful way with existing experiental knowledge in order to be able to use the existing knowledge reservoir on the farm. This changed job description has to be taken into account and alternative employment opportunities for unskilled workers who have been able to work in agriculture up to now must be considered.

Finally, it should be noted that the widespread use of digital technologies in agriculture will make agricultural reality even more distant from the image consumers have of agriculture. In the interests of transparency and an integrative understanding of the food system, both agricultural organizations and the public sector should put some effort into informing and educating consumers accordingly.

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