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The opportunities and risks of digitalisation in agriculture

Stefanie Reith, Jürgen Frisch, Martin Kunisch

Like in other sectors, numerous digital technologies are already being employed in agriculture and significantly influence working practices. This is referred to as Work 4.0. The aim of this paper is to characterise work systems in agriculture and to show the extent to which the content and conditions of work are changing as a result of digitalisation processes as well as the effects on people working in agriculture. Based on this, we will provide an up-to-date overview of the opportunities and potential resulting from the digital shift. In addition, conflicting priorities and risks will be analysed. Work systems are changing owing to the enhanced quality of information generated by big data. The increase in information and the connectivity of systems – both in the barn and on the fields – have expanded the scope of action. Work processes can increasingly be implemented digitally. Workers are required to take on more planning and monitoring tasks and to reflect on production processes. Supporting and autonomous systems can assist with the execution of tasks and supplement or replace individuals in various functions. The new work structures are, in particular, characterised by flexibilization processes, the dissolution of boundaries, new forms of collaboration and the growing relevance of knowledge work. The volume of (real-time) data and the diversity of information require working persons to possess additional skills, abilities and competencies. The key challenges of implementing digital solutions include the growing complexity of systems, IT security and readiness to invest. This means that staff competences and qualifications must be constantly updated to meet the demands of the digital shift.

Keywords
Digitalisation, Work 4.0, Work System, Big Data, Agriculture 4.0

"Work" is the conscious and purposeful (physical or mental) activity performed by human beings in order to meet needs (Schlick 2010). Auernhammer (1986) describes it as an ongoing cycle of perception, decision-making and implementation of information. In agriculture, work is the most important, but also the scarcest, production factor (Schick 2012).

Work is driven by two distinct objectives. In terms of objects, work aims to produce goods, information and services. The goal is to create an optimal relationship between labour input and output in order to increase labour productivity (the "productivity aspect"). In the subject-related sense, the goal of work is related to personality-oriented aspects. It is defined as the effort that provides persons with a special sense of purpose and the opportunity for self-actualisation (the "humanity aspect") (Schlick et al. 2010). The prerequisite is that the conditions under which people perform work are harmless, feasible and tolerable and do not have any adverse effects. In addition, it is important that socially adequate standards are met regarding the content, task, environment and remuneration of

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work (Schlick 2010). The definition shows that in particular human objectives (motivation, personal development, health protection) are key factors studied in occupational science.

Increasing mechanisation can be observed in all areas of agriculture (crop production, animal husbandry, farm management). Technological progress has always influenced the organisation of work, and digitalisation can also be seen as a significant driver of change processes in the world of work – both in everyday life and business. An important parameter determining the use of technical aids is the extent to which a work process can be modified through automation or digitalisation. The trends and challenges associated with digitalisation are manifold. While new technologies can help make work more compatible with human needs, they can also induce situations leading to physical and psychological stress, which need to be evaluated (Sendler 2016). This article provides insights into the importance of work for people and their role in work systems from the perspective of occupational science. It also shows how the increasing use of digital and mobile technology is changing the content of work and job profiles as well as the opportunities and risks associated with using the wealth of data produced by technologies in agriculture.

Work systems

In a work system, people interact with other people and with technical aids in such a way that a given input yields an output (Auernhammer 1986) through the use of the appropriate aids. From the perspective of occupational science, therefore, a work task in a work system is completed as a result of humans and work equipment interacting with the subject of the work. According to REFA (1971), the human being or the person engaged in the work is the active and most important element in the work system. In all forms of human work, the human being is the starting point and objective of all considerations, together with his or her individual and social relationships with the other elements of the work system (Figure 1). When work systems are (fundamentally) redesigned, for example, as a result of digitalisation processes, the requirements of human work must be taken into account (Schlick et al. 2010).

The size of work systems can vary. Depending on the purpose under consideration, a very minor task can already be represented as a work system – the smallest work system is the individual workplace (a micro work system). Alternatively, an entire company can form a work system (a macro work system). The decisive factor is the wording of the work task and, with it, the amount of detail required in the analysis (Auernhammer 1986, REFA 1971).

The following system elements form the description of work systems:

- The work task: the purpose of the work system
- The work flow: the spatial and temporal sequence of interaction between the worker, on the one hand, and the work equipment and the work subject, on the other hand, in order to change the latter in accordance with the work task
- Input: the work subjects, people, information and the energy required to perform the work task
- The working person: the person performing the work
- The work equipment: tools, machines, devices, furniture, facilities and information technology used in the work system
- The work subject: substances, goods, energies and living beings that are changed in the work system

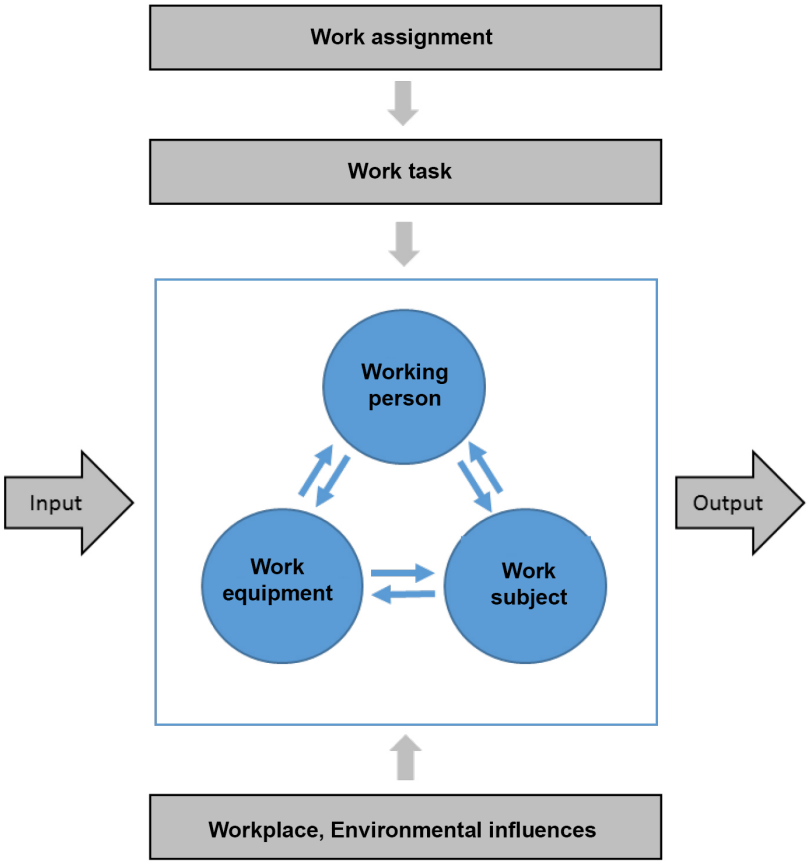

Figure 1: Elements of the work system (REFA 1971, modified)

- Environmental influences: physical, chemical, biological, organisational and social factors that affect the work system and the characteristics of the working person, the work subject and work equipment. These factors may also be generated by the work system.
- Output: material, information and energy that are modified, used or produced in order to perform the work task

Human performance capability

Farm workers are frequently confronted with the following factors that are harmful and hazardous to their health when working (Rieger 2001):

- Disabilities and health impairments as a result of work-related illnesses (e.g. back pain)
- Risk of accidents and injuries (e.g. while handling animals, chemicals, machinery)
- Physical stress and unpleasant working environments (e.g. due to heat, cold, odours, noise)
- Chemical contamination (e.g. cleaning agents, pesticides)
- Biological agents (e.g. work-related infection hazards, toxic and allergic effects owing to contact with micro-organisms, dust particles, gases, aerosols)
- Activities that involve strenuous physical labour (e.g. heavy lifting or carrying) or awkward postures

- Activities that do not allow scope for decision-making and participation in the planning and organisation of one's own work
- Social isolation or limited communication during work due to segregation of workplaces
- Organisational conditions that compromise social relationships outside of work and leisure time activities (e.g. due to unfavourable working hours)

The BKK Health Report describes a trend towards an increase in mental disorders among the different illness categories. In agriculture, such disorders are second only to musculoskeletal disorders. Significant stressors are the increasing bureaucracy, uncertainties due to changing legal framework conditions, social pressure resulting from public criticism and working to challenging deadlines and/or under financial pressure (Knoop und Theuvsen 2018).

Human work performance is subject to both inter- and intraindividual variation. Performance capability is determined by the ability and readiness to perform:

- The ability to perform: the physiological (performance capacity of organs/organ systems) and psychological (informational-mental components) prerequisites for rendering a performance
- Readiness to perform: the physiological (agitation level of organs/organ systems) and psychological readiness (performance attitudes and motives) to render a performance

Individual differences in performance capability are related to a person's constitution and disposition as well as to various skill and competence characteristics (Auernhammer 1986, Schlick et al. 2010). Whereas constitutional characteristics are not changeable in the life cycle of a person within the framework of occupational science, dispositional characteristics are assumed to be changeable. In addition, different adaptability characteristics play a role. Aptitude characteristics should be taken into account when designing work systems and, as they can influence performance both positively and negatively, they should be considered in their entirety. Characteristics that diminish performance (ageing processes) can, however, be compensated through appropriate measures for enhancing performance (qualification schemes, endurance training) (Schlick et al. 2010, Schultetus 2006).

Performance capability is further affected by different stress factors induced by the work task and environment. These constitute an external impact and also apply to other work systems (Figure 2), and can affect people positively and negatively. On the positive side, job demands are associated with a general feeling of well-being in conjunction with the activation and further development of competences. Unfavourable demands, on the other hand, lead to physical and psychological stress in the long term.

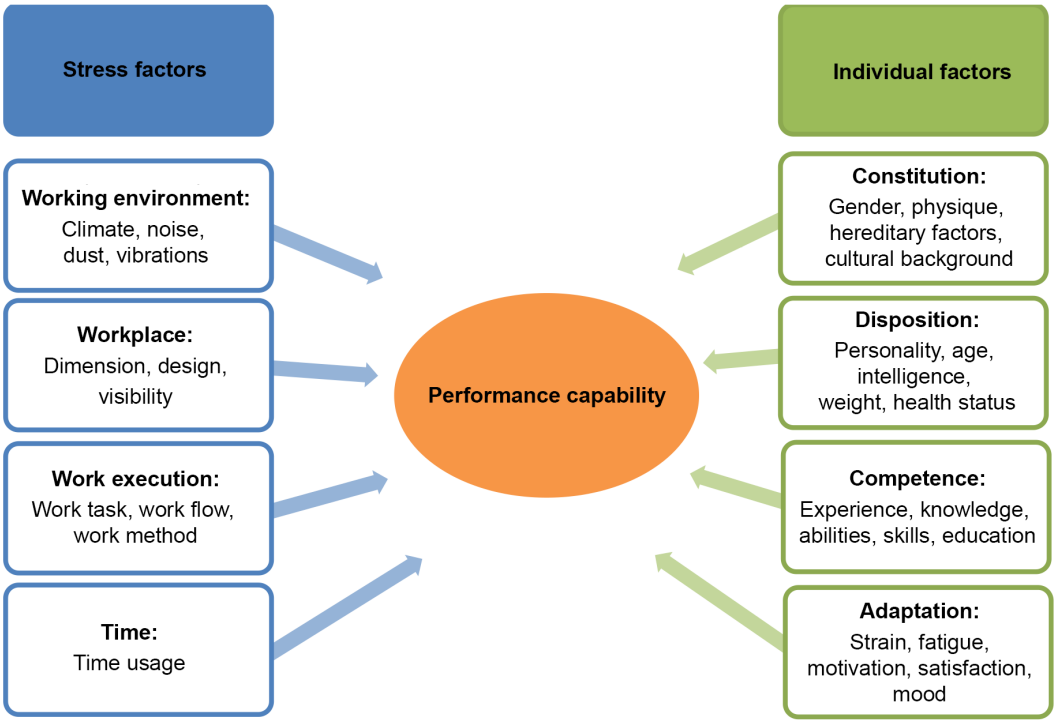

Figure 2: Stress and individual factors influencing human performance capability (Schlick et al. 2010, modified)

Work 4.0 – opportunities and risks

The digital shift – referred to as Work 4.0 as the fourth stage of the industrial revolution – is significantly impacting the working world in all sectors. The increasing use of digital and mobile technologies is bringing about a change in the content of work and job profiles. Aggregation of the data generated by digitalisation results in big data (Muckenhuber 2018). As a decision-making tool, digital data can be characterized by the five "Vs": "the ability to collect, process and store large amounts of data (volume) from different sources and with different structures (variety) at high speed (velocity) and then to evaluate them with good quality (veracity) in order to generate an economic benefit (value)" (Lippold 2017). To be used efficiently – both in general and on farms – data must be electronically accessible, machine-readable, consistently structured and equipped with practical interfaces and interoperable standards. The main goals of big data are to gain a better understanding of reality and to formulate statements based on extensive data so that informed decisions can be made (Muckenhuber 2018).

The work system is changing, with functions being divided between people and technology. The role of working persons is thus transforming from executing work towards planning and monitoring work process. This has resulted in new forms of interaction and collaborative relationships between the working person, the work equipment and the subject of work. As tasks are performed collaboratively in symbiosis, they are referred to as human-machine collaboration processes (Muckenhuber 2018). This applies, in particular, to the area of decision-making, as the working person is supported by the increasing compilation and evaluation of data and information. For example, in animal husbandry, technology (such as sensor systems that collect and aggregate data on the husbandry

environment and on the animals' behaviour as well as biological data) makes decision-making processes in herd management easier and more objective, leading to improved animal health, fertility and higher production. When combined with dedicated analytic algorithms, big data make it possible to reveal new relationships. Patterns identified in data allow the prediction of events in the short term, the development of models to forecast possible (animal health) risks and the identification of influencing factors and relationships. Farmers can therefore expect improved production processes and management activities (Hoffmann and Riekert 2018). Modern information and communication technologies are resulting in new working models, increasingly rendering traditional working hours and places a thing of the past and making the organisation of work more and more flexible (Figure 3). However, although equipping farms with digital solutions offers advantages and opportunities, it also entails potential risks that have a detrimental effect on work systems.

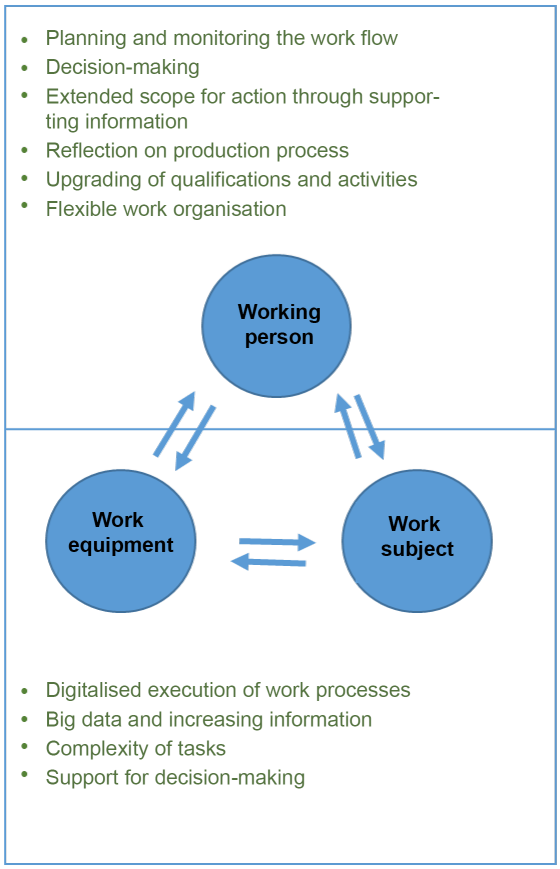

Figure 3: Change in the work flow within the work system due to increasing digitalisation

Flexibilization of activities

Digitalisation is changing the content and conditions of work. It is also inducing a polarization of qualification levels: jobs for low qualification levels without much scope for action, on the one hand, and jobs for qualified experts who have a high scope for action and who independently organise their work (Zimmermann 2017), on the other hand. The wealth of data and information has increased the complexity of tasks, placing higher demands regarding skills, abilities and competences. At the same time, manual skills are becoming less important (Krabel 2006, Zimmermann 2017). In addition to dealing with complexity, abstraction, problem-solving and communication, working persons must be able to act in a self-regulated way, organise themselves, think in a systems-oriented manner and deal creatively with open-ended processes (Becker 2015, Spiess 2017). Due to the decline in routine activities, working persons need more knowledge for reflecting on and improving production process. The long-term planning approaches that were typical in the past are being replaced by short-term planning and spontaneous decisions (Zimmermann 2017). This highly dynamic nature of digital change has shortened the half-life of working persons' know-how and skills. As a result, they are expected to be motivated and able to take on new tasks, to discard routines and to ensure that the knowledge acquired in regular professional training and education is kept up to date. To best exploit newly developed potentials, competences that enable working persons to deal with undefined, new, unstructured situations are particularly valuable (Erpenbeck and Sauer 2001).

A high level of personal responsibility and qualification is also expected in agriculture (Pierpaoli et al. 2013). Many operations take place off the farm and in the absence of the farm manager. Hence, farm staff members are responsible for deciding how to carry out a process. In addition, according to Reinecke (2015), extensive knowledge gained through experience is necessary, as errors in executing processes (e.g. in harvesting operations) often result in considerable financial losses. The exchange of experience and transfer of knowledge, for example, on how to set the different parameters of machines used on the same field, are essential for ensuring the efficiency and quality of processes as well as effective collaboration.

However, the flexibilization of activities and increased importance of knowledge and skills can also place excessive demands on working persons, increasing psychological stress. According to studies in the area of occupational science, human work in automated systems presents problems. Against the backdrop of digitalisation and technological change, the requirement to deliver the same performance within a smaller time frame as well as the increasing acceleration of processes and stress often lead to ingrained patterns of behaviour and thinking. Activities are then no longer performed consciously, but rather as a matter of course or automatically. Zimmermann (2017) refers to this as the "spiral of the autopilot mode".

Automation and robotics

Automated and/or autonomous systems positively impact not only the productivity of labour, but also the organisation of work. Routine tasks are reduced through automation. Processes become more repeatable and can be executed more precisely (e.g. GPS-based steering) (Reinecke 2015). In agriculture, physical labour is also increasingly being substituted by (unmanned) machines. Farm workers thus perform fewer monotonous tasks and activities that damage their health (Becker 2015). Relieved of repetitive tasks, they can concentrate more on work equipment and on (more) important situations, thus preventing errors and accidents (Reinecke 2015). At the same time, however, when

activities are taken over by automatic systems, there is an increased risk that workers' patterns of physical movement and overall physical activity decrease.

Automatically collected information, which is filtered and processed, can be used to facilitate work tasks such as documentation requirements. New fields of activity, such as cognitive and analytical activities as well as interdisciplinary work on new processes or on developing new products, are emerging as a result of human labour capacities being made newly available (Krabel 2016).

The increased use of machines, sensors and software is geared towards automated systems performing tasks that were conventionally carried out by humans. The concerns about rising job losses are therefore not unfounded (Krabel 2016, Spiess 2017). About 42% of farmers (including foresters and gardeners) report that they see their jobs threatened (Rennert 2017). As a result of the digital shift, new types of jobs are emerging in agriculture: data scientists, programmers, positions in commerce and services, business intelligence specialists and work planners (Pollmann 2017).

The increasing complexity of systems is seen as a hurdle, as working persons often lack sufficient knowledge about the systems' functions and processes in order to control them effectively (Hirsch-Kreinsen 2015). People can lose their autonomy to take action when systems diagnose errors and correct them independently by automatically implementing recommended actions (Mayer 2014).

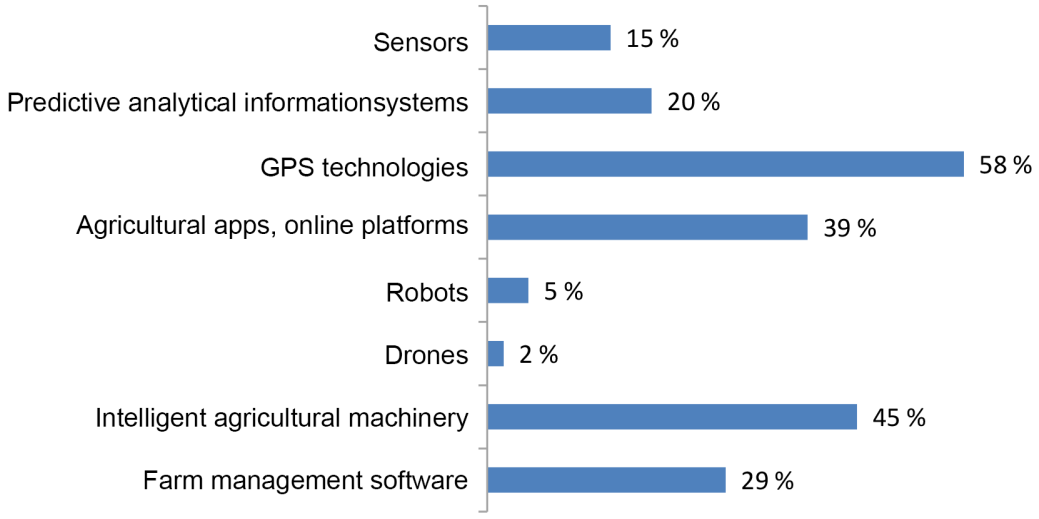

Figure 4: Use of different digital technologies and applications in crop production (Bovensiepen et al. 2016, modified)

A literature review revealed that the market for precision agriculture technologies is hardly established internationally (Pierpaoli et al. 2013). The results of a survey on the state of digitalisation in Germany published by PricewaterhouseCoopers AG Wirtschaftsprüfungsgesellschaft (PwC) revealed that more than half of farmers have already invested in digital technologies, decreasing costs and increasing process efficiency (Bovensiepen et al. 2016) (Figure 4). Bovensiepen et al. (2016) found that readiness to invest correlates positively with the total area of farm holdings. Farm size is also the most frequently cited factor influencing the adaptation of new systems in the international literature

(Pierpaoli et al. 2013). On small-scale farms, on the other hand, the implementation of digital technologies is still very limited in practice. Findings from an extensive media analysis (Roosen 2017) showed why farmers are rather reluctant to invest. The analysis – which is supported by results from international literature (Pierpaoli et al. 2013) – identified the following barriers to the acceptance of digital technologies: the return on investment, insufficient financial resources, technical susceptibility to errors, insufficient broadband coverage, incompatibility, lack of decision algorithms, complicated operation and insufficient skills (especially IT know-how). In addition, data protection and data sovereignty play a role. In order to counter accelerating structural change, the Federal Ministry of Food and Agriculture is committed to supporting small and medium-sized enterprises, in particular, with seizing and exploiting the opportunities offered by digitalisation (BMEL 2017).

Assistance systems

Assistance systems can support humans in performing complex tasks and increasingly complement them in various functions. The wealth of information generated by connectivity and data collection can be useful for humans to identify processes and make decisions based on specific indications and recommendations for action. The use of assistance systems can also enhance safety and health conditions. Sensors integrated into the work environment or clothing provide protection by means of acoustic or visual warning functions as well as pleasant and optimal ergonomic conditions. Thus, persons with lower qualifications, elderly working persons and physically or visually impaired individuals are also able to operate new technologies (Zimmermann 2017). Productivity can consequently be maintained over a longer working life (Becker 2015). The sphere of work can be extended with the help of technologies such as 3D visualisation, smart glasses or camera monitor systems (in agriculture, e.g., on a front-mounted device to expand the driver's field of vision when turning onto a road or as a driver assistance system when reversing). It is important that these individuals maintain their occupational competence.

Flexibilization of the workplace and working hours

Real-time mobile access to data and the use of increasingly powerful, Internet-capable end devices allow time-spatial flexibility of work. With the exception of most production-related work, work no longer has to be performed at a specific location, as conventionally required. Humans can access a system at any time from any location via interfaces in order to communicate, maintain and control machines and systems or to diagnose and correct errors. Thus, not only work-related travel can be reduced; people are also less exposed to hazards, such as traffic routes and storage areas for hazardous materials. It is also possible to reduce the risk of accidents for persons working in animal husbandry. For example, on pig farms, direct contact with the animals can lowered by implementing automatic sorting gates. Generally speaking, the work-life balance can be improved as professional demands and private needs become more compatible (Zimmermann 2017).

Time-spatial flexibility in the world of work significantly influences the way we communicate. Face-to-face communication between people in the workplace has decreased, undermining team cohesion, mutual trust and joint problem-solving. There is also a danger that communication only takes place when there is an underlying urgent motivation (Rump 2017). New media such as (real-time) online communication options or the use of instant messaging services increase the speed of information transmission, so that an immediate response is possible and sometimes expected. Although

this clearly has advantages, it exacerbates psychological stress as people feel more pressured (e.g. by face-to-face and online announcements) and are expected to be constantly available. In agriculture, for example, the herd supervisor (in a dairy farm with an automatic milking system) is required to be permanently on call to maintain 24-hour operations. According to studies in the field of occupational science, permanent availability, working excessively long hours on a regular basis and tendencies toward the dissolution of boundaries have a detrimental effect on the mental health and long-term performance of working persons. This results in an increased number of working days lost due to illness, resignation, demotivation and burnout (Collatz and Gudat 2011, Spiess 2017). According to Knieps and Pfaff (2019), the number of working days lost in agriculture and forestry due to mental disorders is on the rise.

IT security and data protection

The success of the digital shift depends heavily on data protection and IT security. Often, the dangers of using information and communication technologies cannot be directly detected. Systems are used to collect, analyse and store data and information relating to human beings. Self-learning algorithms can predict behaviours and events and make them transparent. There are fears that confidential personal data or company-related data can no longer be adequately protected and that self-determination has decreased (Hofstetter 2017, Lepping and Palzkill 2016). Farmers are also concerned that their operations will become increasingly transparent and that they will become dependent on third-party software solutions (Pollmann 2017). Mylonas et al. (2013) question whether users are even capable of making security-related decisions and implementing appropriate security controls. There is often a lack of basic knowledge and awareness of the risks that software poses to privacy. Until now agricultural workers have not required qualifications related to data protection and protection against misuse of their data; therefore, their understanding of the required processes is often limited (Reuter et al. 2018). Gandorfer et al. (2017) postulate that farms have to benefit directly from sharing their data if Agriculture 4.0 is to become a reality.

Conclusions

The aim of this paper was to analyse the impact of the digital shift on work systems in agriculture. Digitalisation opens up various opportunities and perspectives to farms: sustainable land management as well as optimal monitoring of animals, production and products. The primary goal is to increase productivity, profitability and competitiveness. Drawing on diverse planning and optimisation approaches, this can be achieved through extensive changes to work systems and the creation of innovative products and services. Traditional models are increasingly being discarded in favour of new ways of organising work. However, the consequences of the growing flexibilization and dissolution of the boundaries of work as well as the magnitude of these consequences are not yet clearly foreseeable.

Automation can support and replace human work. The main requirement is the commitment and ability to identify the necessary competences as early as possible and to adapt qualifications to the demands of digital change. Hence, the education system needs be more strongly geared to the new technological challenges. For this to happen, however, it is important that policy-makers create the necessary legal framework. The role of the IT sector and industry is to make products and applications that are easy to understand and user-friendly. Data storage in the cloud is often viewed critically,

resulting in data protection and data security being given a particularly high priority. It must be ensured that data is handled sensitively and that it is always possible to trace who is using data and for what purpose. Whether the potential of digitalisation can be fully exploited also depends on whether barriers to access public data (e.g. geodata) can be removed in order to make the data available to farmers. Data usage should not be hindered by different data formats. If these conditions are met, digitalisation can contribute to sustainable agriculture.

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Authors

Dr Stefanie Reith and **Dr Jürgen Frisch** are research associates in the Databases and Knowledge Technologies team and **Dr Martin Kunisch** is Managing Director at the Kuratorium für Technik und Bauwesen in der Landwirtschaft e. V. (KTBL), Bartningstraße 49, 64289 Darmstadt, e-mail: s.reith@ktbl.de.