# Opportunities, risks and obstacles to the implementation of digitisation technologies in German agriculture

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**ABSTRACT**

Given that digitisation in agriculture is currently one of the most important ongoing developments in the agri-food sector in Germany, this paper presents the opportunities, risks and obstacles to implementing digitisation technologies on the German farm enterprise level. Based on an empirical survey with a response rate of 8.4 % carried out at the beginning of 2018, 329 questionnaires on this topic were evaluated and analysed. A factor analysis was used to conceptualise 20 variables regarding the individual opportunities, risks and obstacles to the implementation of digitisation technologies into 6 factors. It revealed positive effects of the use of digital systems, such as various economic and ecological advantages, as well as improved operational coordination. Risks of a socio-economic and financial nature could also be integrated. A lack of both knowledge and infrastructure continue to be major obstacles on the road to agriculture 4.0. Consequently, there is still a need for action in many areas to facilitate the implementation of digital systems in agriculture and to improve the functionality of the systems currently in use.

**Keywords:** Digitisation, Agriculture, Agribusiness

## 1. Introduction

Digital progress, one of the most important global transformation processes, is also predominant in German agriculture (Rohleder and Krüsken 2016). The use of digitisation technologies aims to increase the productivity and efficiency of agricultural production thereby contributing to sustainable development (El Bilali and Allahyari 2018). Basic technologies, such as positioning systems and the use of sensors, can launch a new era of agriculture 4.0. They permit the precise positioning of agricultural machinery in the field and optimise the use of plant protection products and pesticides in a site-specific manner (Mintert et al. 2016; Weltzien and Gebbers 2016). Radio-frequency identification technologies and sensors are used for individual animal recognition, the measurement of health parameters or to control stable technology (Weltzien and Gebbers 2016; Doluschitz and Spilke 2002). Farm Management Information Systems (FMIS) can be used to support farm data management by linking and automatically processing information from public sources and farm operating data (Griepentrog 2011; Wolfert et al. 2017). Despite far-reaching explanations of the opportunities that digitisation can open up in agriculture, the current state of digitisation in agricultural enterprises in Germany should be kept in mind. The goal of a cross-corporate data hub to link, collect and document data barrier-free along the value chain and to analyse the data fully automatically, is still a long way off (Möller and Sonnen

2016). The aim of this work is to identify the opportunities, risks and obstacles to implementing digitisation technologies in German agriculture in order to derive suitable recommendations for action on the adoption of digital systems.

## 2. METHODOLOGY

Given the explorative nature of the research aim, a written quantitative online survey was conducted. The sample consists of freely accessible e-mail addresses of agricultural training enterprises and registered cooperatives throughout Germany. The survey was carried out in two phases between the beginning of January and mid-February 2018. A total of 4,731 subjects could be contacted, of which 800 e-mails were undeliverable. The response rate to the survey was 8.4 %. The low rate is probably due to the fact that the farm enterprises receive a large number of surveys and, therefore, not all of them can be motivated to participate. Due to the selection of the sample (online portals, cooperative register), the responding farms in the sample reflect significantly larger farm structures than the average data provided by the German Farmers' Association (sample: Ø 470 ha UAA[1], median: 160 ha UAA / German Farmers' Association 2018: Ø 60.5 ha UAA) (Deutscher Bauernverband 2018). The company´s legal form of joint partnerships and legal entities are more strongly represented among the farmers in this survey. From a demographic point of view, it can also be seen that the educational level of the sampled farmers is well above the German average. These results can be explained by the fact that only agricultural training enterprises could be interviewed when selecting addresses. These farmers have a higher standard of education and it is assumed that they mainly represent full-time farm operating managers and they farm a larger agricultural area.

Overall, the results of this survey cannot be regarded as representative of German agriculture as a whole. Nevertheless, farms above the growth threshold of 100 ha are represented at an above-average rate (70.4 %). Against the backdrop of the ongoing structural change in agriculture, it can be assumed that farms will continue to grow (Stockinger 2009). Consequently, the current above-average size of the farms in the sample will, in future, be representative of German agriculture.

In the following, the structure discovering procedure of explorative factor analysis is used. The aim of this procedure is to reduce data by combining several variables into a smaller number of common factors. The method used to extract the factors is principal component analysis. In order to assess data quality, the Kaiser-Meyer-Olkin criterion (KMO) and Bartlett's significance were selected as the test parameters (Bühl 2014). Using factor analysis, 20 items were reduced to six extracted factors. The KMO measurement is 0.787 and can, therefore, be rated as "quite good" or "almost deserving" (Kaiser and Rice 1974). The significance of 0.000 underlines the suitability of the selected variables.

Further calculations were made with the six factors formed. Firstly, mean value comparisons were calculated, whereby the individual factors as dependent variables were compared with the size of the enterprise and the educational level. In addition, correlation calculations were performed between the six factors and the variable *estimate of the current significance of digitisation*. In addition, correlation calculations were performed with variables that include the *significance of individual digital systems* (IT systems, automation, data management, intelligent machines, sensors, airborne systems).

[1] Utilised agricultural area (UAA)

## 3. RESULTS

**Table 1: Result of factor analysis, sum of declared total variance= 63.28 %; KMO=0.787; rotation method: Varimax; scale from 1 (very large) to 6 (very small); source: Own survey**

| Factors | Factor loading |
|---|---|
| **Factor 1: Economic and ecological advantages** (*0.863) | |
| Improved animal welfare | 0.836 |
| Early detection of animal diseases | 0.785 |
| Increased resource efficiency | 0.752 |
| Cost savings | 0.747 |
| Positive effects on the environment | 0.740 |
| Time savings | 0.685 |
| **Factor 2: Improved cross-corporate coordination** (*0.703) | |
| Compliance with the obligation to provide evidence for official controls | 0.877 |
| Improved transparency | 0.757 |
| **Factor 3: Socio-economic risks** (*0.638) | |
| Job losses | 0.790 |
| Existential risk for small and medium-sized enterprises | 0.735 |
| Overly complex topic | 0.574 |
| Data protection | 0.423 |
| Fear of increased controls | 0.375 |
| **Factor 4: Financial risk** (*0.535) | |
| Investment risk | 0.830 |
| Uncertainty whether high investments will generate a return | 0.592 |
| **Factor 5: Educational deficits** (*0.682) | |
| Lack of practice-oriented application examples | 0.810 |
| Concerns about the functionality and reliability of technology | 0.693 |
| Lack of digital competence | 0.659 |
| **Factor 6: Lack of infrastructure** (*0.558) | |
| Lack of broadband expansion | 0.791 |
| Lack of technology or software compatibility | 0.743 |

*Cronbach's α

On the basis of a factor analysis of the variables of the topic areas of opportunities, risks and obstacles to implementing digitisation technologies, six areas could be identified that are of particular relevance to the subjects. Table 1 depicts an overview of the results of the factor analysis.

Factor 1 (economic and ecological advantages) is loaded by six elementary variables that are classified as opportunities in connection with the implementation of digital systems in farm enterprises: positive effects on the environment, cost savings, increased resource efficiency, early detection of animal diseases and improved animal welfare. Additional calculations with this factor confirmed that farms with a higher area endowment classify the economic and ecological advantages of using digital technologies as significantly greater (H-test, p=0.030). It could also be confirmed that graduates of universities or universities of applied sciences attribute higher value to the advantages than master craftsmen or technicians (U-test, p=0.025). In addition, the Spearman correlation produced highly significant correlations between the importance of all listed digital systems and the assessed economic and environmental benefits of using the technologies. The positive correlations are listed in the following: data acquisition, management and analysis (r=0.410, p=0.000), Intelligent agricultural machinery (r=0.382, p=0.000), automation (r=0.341, p=0.000), sensors (r=0.311, p=0.000), airborne systems (r=0.296, p=0.000) and IT systems (r=0.244, p=0.000). From these results it can be concluded that the economic and environmental benefits of digital technologies are deemed to be substantial as soon as they are implemented on farms. Overall, it can be deduced that farms with larger utilised agricultural areas are increasingly using digitisation technologies and that they clearly benefit both economically and ecologically. By means of corresponding economies of scale, which occur when more land is farmed, large enterprises derive greater economic benefit and consequently rate the implementation of digital systems as more positive. The results also show that skilled workers are needed in order to benefit from digitisation. In addition, improved cross-corporate coordination, which represents factor 2 and loads on two elementary variables (improved transparency, compliance with the obligation to provide evidence for official controls), is seen as an opportunity to use digitisation technologies on farms. The Spearman correlation provided highly significant results regarding the relationship between factor two and the importance of data management systems (r=0.261, p=0.000) and IT systems (r=0.263, p=0.000). Therefore, it can be concluded that farmers using digital systems to support their data management see this as a clear improvement in cross-corporate coordination.

Factor 3 reflects the socio-economic risks that are classified by the subjects through the implementation of digital systems. Here, the variables fear of increased controls, data protection, overly complex topic, existential risk for small and medium-sized enterprises and job losses play a particularly important role. In addition, elementary variables (uncertainty whether high investments will generate a return; investment risk), which are related to financial concerns about the digitisation of agricultural enterprises, load on factor 4 (financial risk). This factor represents a statistically significant negative correlation with the importance of digitisation (r=-0.140, p=0.020). This illustrates that the profitability of digital systems is questioned by non-users and can be cited as a proven reason why farmers do not invest in the purchase of digital systems.

Obstacles to the implementation of a digitisation strategy, which farmers have rated as particularly relevant, are reflected in factor 5 (educational deficits). It summarises the elementary variables *lack of digital competence*, *concerns about the functionality and reliability of technology* and a *lack of practice-oriented application examples*. These barriers can be attributed to a lack of education about the functions of digital technologies. In addition, elementary variables (lack of compatibility of technology or software, lack of broadband expansion), which indicate a lack of infrastructure, are summarised in factor 6. This factor correlates significantly and positively with the use of the following digital systems: data management (r=0.145, p=0.015), intelligent agricultural machines (r=0.256, p=0.000), automation (r=0.120, p=0.045) and sensors (r=0.194, p=0.001). These results prove that although individual digital systems are already established on farms and play a major role, the problem of the lack of infrastructure is ongoing. Therefore, it can be concluded that the lack of compatibility of technology or software and the lack of broadband expansion not only constitute an obstacle to the establishment of digital technologies, but also pose a problem for users of extensive digital systems.

## 4. DISCUSSION AND CONCLUSIONS

On the basis of the factor analysis carried out in connection with the topic areas of opportunities, risks and obstacles to implementing digitisation technologies, six areas could be identified which are of particular relevance to the subjects (KMO=0.787; p=0.000). Various economic and ecological advantages (Cronbach's α=0.863) and improved cross-corporate coordination (Cronbach's α=0.703) through the use of digital technologies were seen as major opportunities. The various risks, on the other hand, could be defined as socio-economic (Cronbach's α=0.638) and financial risk factors (Cronbach's α=0.535). The educational deficits (Cronbach's α=0.682) and a lack of infrastructure (Cronbach's α=0.558) were seen as obstacles. As the size of the farm enterprise and the level of education increased, the economic and ecological benefits were seen as greater (H-test, p=0.030; U-test, p=0.025). This confirms that economies of scale enhance the benefits of using digital technologies and that skilled workers need to be available to take advantage of digitisation. A profitability calculation by Lopotz (2013) confirms that the profitable use of digital systems for site-specific farming is very dependent on the homogeneity of the location, the size of the agricultural area used and the management capabilities. This conclusion underlines the results obtained which indicate that the extent of the use of technical systems depends on the educational level and the size of the farm enterprise (Lopotz 2013). It has also been confirmed that when digitisation technologies are implemented on farms, the benefits are proven in practice. What is particularly worth noting is that the use of IT systems that simplify data management plays a particularly important role in improving cross-corporate coordination (r=0.263, p=0.000). It also has been stressed that the lack of compatibility of technology and software (factor loading: r=0.743), and the lack of broadband expansion (factor loading: r=0.791) constitute problems for users of digital systems. Holster et al. (2012) confirm that these issues constitute a major challenge to achieving the goal of networking and exchanging data. Thus a lack of infrastructure on the way to agriculture 4.0 is still a major obstacle (Holster et al. 2012).

Positive effects can be demonstrated through the use of digital systems. However, there is still a need for action to facilitate the implementation of digital systems in agriculture and to improve the functionality of the systems currently in use.

Countries are required to digitise area data and make it available free of charge. Similarly, specific instructions for agricultural input should be digitised and made available in order to automatically check compliance with legal or voluntary standards (Deutscher Bauernverband 2016). Uniform data standards along the entire value chain should be introduced and incentives should be given to offer exclusively manufacturer independent applications and software which is compatible across platforms. Individual initiatives, such as standardised interfaces between tractors, tools and computers (ISOBUS), have not yet been sufficiently accepted in practice. Alternatively, research must advance solutions for universally compatible data integration and networking using semantic technologies. Furthermore, there should be clear legal regulations regarding data exploitation rights and data protection.

In order to overcome the educational deficits, knowledge about modern, digitised technology should be imparted both in agricultural training and in university studies. Training also has an important role to play in facilitating the use of digital systems and reducing inhibitions and prejudices in farmers who are on average older.

One starting point for an economic use of digital systems in small-scale agriculture is the creation of inter-company cooperation (e.g. machinery sharing, cooperatives). Qualified services from contractors are another option. More cost-effective applications, such as simple agricultural apps or farm management information systems, could potentially help to organise business processes more efficiently and save time by facilitating documentation.

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