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DIGITAL TRANSFORMATION IN THE AGRI-FOOD SECTOR – OPPORTUNITIES AND CHALLENGES

CYFROWA TRANSFORMACJA W SEKTORZE ROLNO-SPOŻYWCZYM – SZANSE I WYZWANIA

Abstract. The aim of the paper is to discuss the major opportunities and challenges that emerge in the agri-food sector as a result of digitization processes. Digital technologies with Big Data and the Internet of Things are widely considered promising new tools for both increasing productivity and competitiveness in the agri-food sector and ensuring a more sustainable use of resources. Knowledge and insights derived from ever-increasing volumes and a variety of digital data may help to optimize farm production processes, improve risk management, predict market trends and enhance strategic decision-making capabilities. Yet, advanced data analytics has also the disruptive power to reshape the whole string of markets within the agriculture value chain. Digitization may fundamentally change the relations between technology and input suppliers, farms, traders, processing units, retailers and consumers. The first evidence shows that farm data markets suffer from specific drawbacks and limitations which may constrain the transformative potential of Big Data in the food and agriculture sector. The major concerns raised relate to farm data ownership and privacy issues, market power of major agriculture technology providers and uneven distribution of benefits accruing from digitization.

Introduction

The exponential growth of digital technologies is reshaping the way various economic sectors and industries operate and perform. Digitization has also entered the agri-food sector, albeit the technology adoption and use is still in its initial phase. Yet, some researchers suggest that digital technologies will lead to the next agricultural revolution, potentially reversing some of the most negative effects of the "green revolution" witnessed by the sector a few decades ago [Powell 2017, Walter et al. 2017]. Digitization and new technologies raise hopes not only for improving agricultural productivity, but also for alleviating some of the most pressing global problems related to climate change and biodiversity loss. The current technological advances in the sector have their roots in the precision agriculture concept, but at the same time go far beyond it. With the emergence of Big Data, i.e. massive volumes of digital data coming at high speeds from a wide range of sources and in different formats, new opportunities for the agri-food sector have opened up. Thanks to the Internet of Things, cloud computing and machine learning Big Data can be analyzed in real or near-real time to extract new insights and economic value for the benefit of virtually all actors in the agri-food chain. These opportunities might change farming into smart farming and other agribusiness operations into smart businesses. Nonetheless, there are also various barriers that may impede a digital transformation in the agri-food sector. In addition, also questions about ethical and social consequences of digitization arise as new smart technologies are – to a large extent – based on artificial intelligence and systems beyond direct human inspection. Therefore, a discussion about all fundamental opportunities and challenges related to digitization processes is essential to avoid possible lock-in effects

on the road to a smart, data-driven agri-food sector. This paper aims to add to this discussion by taking a closer look at the emerging farm big data market and digital-technology induced changes in the agri-food chain. Both major benefits of big data analytics and potential problems of digitization in the sector will be highlighted.

Material and methods

Materials used in the analysis come from two sources – literature review and collection of use cases and applications as deployed in agribusiness ventures and/or developed and tested in selected research projects. The literature review included research notes, conference papers, peer-reviewed articles and industry reports related to digitization in the agri-food sector. The following electronic databases and online sources were searched: Web of Science, Scopus, ResearchGate, Google Scholar and thematic websites and blogs written by experts in the field. Overall, more than 250 materials having reference to Big Data, agriculture, Internet of Things, agri-food chain were extracted from the chosen databases, covering the period between January 2012 and February 2018. Following a closer examination, 19 materials including articles, papers and reports were selected as highly relevant for the analysis of both opportunities and challenges of digitization in the sector. Since important research and development activities in this field are carried out by companies involved directly in the agri-food operations, the review also took account of major precision agriculture products and digital applications used in the agri-food chain. Also, 19 use cases for the smart agri-food system under the project Internet of Food and Farm funded under the EU Horizon 2020 programme were scrutinized to highlight potential directions of digitization in the sector.

The uses of digital technologies in the agri-food sector

Recent years have seen an increased use of Information and Communication Technologies and robotics in farming. The bases of the current digital transformation in the sector were, however, laid down almost two decades ago along with the use of first precision agriculture technologies on farms. Now precision farming comprising Global Positioning System for yield mapping, Variable Rate Technology, ground-based sensing systems, satellite telemetry, wearable sensors for animal health and monitoring, sensors embedded in tractors, Unmanned Aerial Vehicles (UAV) and many other technological devices have become a game changer in the sector. In addition, the prospects for a smart agri-food system have been recently further expanded following the emergence of cloud computing, Big Data and the Internet of Things (fig. 1).

In contrast to traditional precision agriculture which operates on individual farm data, Big Data agriculture uses aggregated data from a large number of farms and from additional sources (e.g. from weather stations, social media feeds, mobile phones) to extract new knowledge and insights relevant for taking production and management decisions [Sonka 2016, Sykuta 2016]. Moreover, it also allows both to predict outcomes of specific farming operations and to react to various events in real time. Second, potential applications of Big Data analytics and the Internet of Things extend to the entire agri-food supply chain [Nukala et al. 2016, Wolfert et al. 2017].

There are currently many decision support tools and applications available that help farmers to reduce input costs, improve yields and increase profitability (i.a. Talking Fields using satellite images of farm land, FarmFacts providing detailed weather forecasts and predictions concerning pest infestations and fungus, Farm Management Information System or Climate Fieldview offering digital platform with tools for yield analysis and advanced crop health imaging). The review of available products and services indicates that farmers are supported at all stages of the production cycle starting from tillage and field preparation, planting, crop care and nutrient application, crop harvesting, drying, monitoring and control. Livestock farms benefit from similar guidance and support [Kamilaris et. al. 2017]. In addition, relevant information and
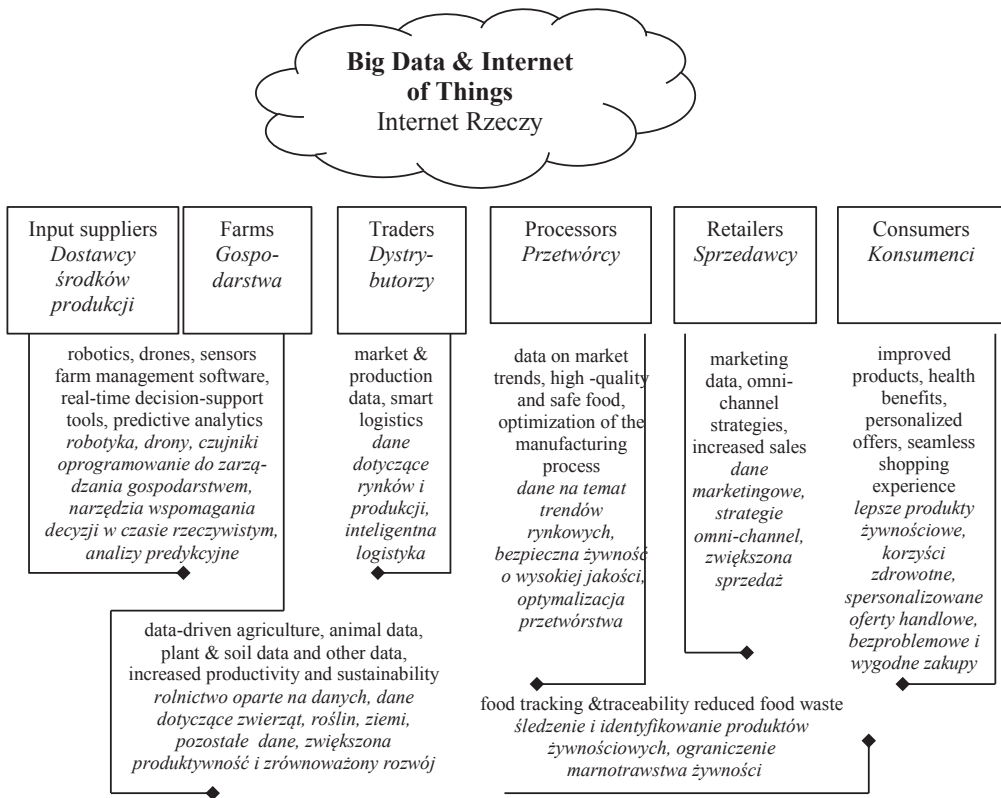
Big Data & Internet of Things
Internet Rzeczy

| Input suppliers *Dostawcy środków produkcji* | Farms *Gospo-darstwa* | Traders *Dystry-butorzy* | Processors *Przetwórcy* | Retailers *Sprzedawcy* | Consumers *Konsumenci* |

robotics, drones, sensors farm management software, real-time decision-support tools, predictive analytics *robotyka, drony, czujniki oprogramowanie do zarządzania gospodarstwem, narzędzia wspomagania decyzji w czasie rzeczywistym, analizy predykcyjne*

market & production data, smart logistics *dane dotyczące rynków i produkcji, inteligentna logistyka*

data on market trends, high -quality and safe food, optimization of the manufacturing process *dane na temat trendów rynkowych, bezpieczna żywność o wysokiej jakości, optymalizacja przetwórstwa*

marketing data, omni-channel strategies, increased sales *dane marketingowe, strategie omni-channel, zwiększona sprzedaż*

improved products, health benefits, personalized offers, seamless shopping experience *lepsze produkty żywnościowe, korzyści zdrowotne, spersonalizowane oferty handlowe, bezproblemowe i wygodne zakupy*

data-driven agriculture, animal data, plant & soil data and other data, increased productivity and sustainability *rolnictwo oparte na danych, dane dotyczące zwierząt, roślin, ziemi, pozostałe dane, zwiększona produktywność i zrównoważony rozwój*

food tracking &traceability reduced food waste *śledzenie i identyfikowanie produktów żywnościowych, ograniczenie marnotrawstwa żywności*

Figure 1. Smart agri-food system based on digital technologies
Rysunek 1. Inteligentny system rolno-spożywczy oparty na nowych technologiach cyfrowych
Source: own elaboration
Źródło: opracowanie własne

recommendations extend beyond the farm gate. Online platforms and dedicated applications provide information concerning prices, markets, access to inputs, finance and risk mitigation measures. Moreover, use cases under the research project Internet of Food and Farm indicate that digital technologies support an integrated network of actors, processes and information which might translate into more efficient food processing, intelligent food logistics, complete supply chain monitoring and food waste reduction.

Innovations based on data and digital technologies are expected to increase in the years to come. Recent investment decisions by IT and food retail companies focus e.g. on the potential uses of Blockchain technology to support the management of the global food supply chain and to improve food safety. This is expected to happen i.a. through increased transparency and more efficient tracing of sources of food contaminations [Peterson 2017]. Digital technologies, e-commerce, mobile apps, beacons and recommendations based on Big Data analytics are also changing consumer experiences. Food consumers may now benefit from personalized offers that take heed of their diet, specific nutrition or health needs. Overall, the growing flows of farm and food data combined with digital technologies and computing techniques seem to offer new and promising routes to make the agribusiness more productive, profitable and sustainable.

Many agri-food problems are already dealt with specific data-driven tools, others still await for new solutions and business applications. The availability of digital solutions for farming and agri-food operations does not however imply that digital transformation in the agri-food sector runs without problems and always in desirable directions. Since digitization and new technologies lead to disruptive changes in the sector, there are many issues and challenges that need to be identified and addressed.

Farm Data Ownership and Privacy Issues

Fundamental challenges for a data-driven transformation in the sector, as identified in the academic literature, relate to ownership and privacy of farm-related data [cf. Dyer 2016, Ellixson, Griffin 2016]. Currently, no legislation specifically regulates the issue of who owns non-personal data generated on farms with the use of advanced machinery and other devices [Kritikos 2017]. The lack of clear property rights to farm data (mostly agronomic data) is considered to be one of the major limitations and drawbacks of the emerging big data market in agriculture. Specific properties of digital data make it challenging to design a data management system that would ensure both benefits for private actors and socially optimal provision of data-related goods. Although digital data may be excludable, it is non-rivalrous. Once it is released, it may be exploited further without diminishing its initial value. Contracts between farmers and agriculture technology providers generally acknowledge farmers' ownership rights to raw data generated on their farms, but do not extend them to aggregated data sets. As the economic value of Big Data analytics rests primarily upon aggregated data stemming from large number of farms, political economy questions arise regarding the distribution of costs and benefits of digitization in the sector. Agricultural technology providers invite farmers to subscribe to and also pay for information and advice generated with the aid of Big Data analytics. Products and services based on individual and aggregated farm data may facilitate farm decision-making, but at the same time they might also serve specific business needs of agricultural technology providers or other actors in the Big Data value chain. Surveys among farmers show that they are concerned about the way their farm data is collected, processed and used. Many categories of data such as e.g. data concerning yields, soil properties or farming techniques might be considered trade secrets. As there are no clear rules concerning acceptable primary, secondary or tertiary uses of such data, fears over potential price discrimination by input suppliers or speculations in commodity markets are quite widespread among farmers [Carbonell 2016, Vogt 2016]. At the same time, there are also challenges related to securing farmers' privacy in the Big Data value chain. Currently, data gathered from hi-tech equipment, satellite imagery, mobile apps and many other sources can provide a lot of information about a farm and its activities, also without the active consent of a farmer to data collection [Kritikos 2017]. These problems might have a negative impact on farmers' trust towards data-driven agriculture and might also limit their willingness to share their data with third parties. There is however no consensus as yet among scholars and practitioners as to which data management system would be the most appropriate to deal with the challenges of digitization in the agri-food sector. Some researchers call for empowering farmers through clear property rights to farm data to increase their control over data flows within the data value chain [Foresight Study 2016]. There are however also opponents to granting exclusive property rights to non-personal digital data on the grounds that such rights may negatively affect innovation potential of the digital economy [cf. Kerber 2017].

Power relations in the agri-food supply chains and networks

Digital revolution introduces new actors, new processes and new interests into the agri-food sector, potentially leading to changes in power relations in the agri-food supply chains and networks [Bronson, Knezevitz 2016, Wolfert at al. 2017]. The emerging big data value chain

Table 1. Strategic precision agriculture partnerships among the leading input suppliers
Tabela 1. Partnerstwa strategiczne na rzecz rolnictwa precyzyjnego wśród wiodących dostawców środków produkcji

Company/ *Firma*	Input market/ *Rynek środków produkcji*	Precision agriculture product(s)/ *Produkt(y) rolnictwa precyzyjnego*	Partnership(s)/ *Parterstwo(a)*
AGCO	machinery/*maszyny rolnicze*	Fuse	Monsanto, DowDuPont
Agrium	fertilizer/*nawozy*	Echelon	Monsanto
BASF	seed&chemicals/*nasiona i środki chemiczne*	Maglis	John Deere
Bayer	seed&chemicals/*nasiona i środki chemiczne*	Zoner	John Deere
CNH	machinery/*maszyny rolnicze*	Advanced Farming Systems	Monsanto
DowDuPont	seed&crop protection/*nasiona i środki ochrony roślin*	Encirca (SM) (DuPont Pioneer)	John Deere
John Deere	machinery/*maszyny rolnicze*	FarmSight	Monsanto, Bayer, BASF, DowDuPont
Monsanto	seed&chemicals/*nasiona i środki chemiczne*	FieldView	CNH, John Deere, AGCO, Agrium
Syngenta	seed&chemicals/*nasiona i środki chemiczne*	AgriEdge Excelsior	

Source/*Źródło*: [Pham, Stack 2018, p. 132]

in the sector includes now a variety of actors ranging from agricultural technology providers and biotech businesses (i.a. John Deere, Monsanto, Cargill, DowDuPont) data start-ups, tech start-ups, large IT companies (Google, IBM, Oracle), farms, cooperatives, traders, food industry companies to agricultural data alliances, the public sector and international organizations [cf. Kempenaar et al. 2016]. The number of actors interested in extracting economic value from agricultural data has significantly risen in recent years. The presence of IT and Internet-based companies in the agri-food sector is definitely a novel development. Another noticeable trend is a concentration of market power among major input suppliers. Strategic partnerships among corporations active in the machinery, fertilizer, seed and chemicals input markets have been increasingly used in recent years to capitalize on Big Data generated in the sector (tab. 1).

These developments raise concerns not only about potential abuses of market power from input suppliers, but also about potential discrimination of particular farming systems and practices [Bronson, Knezevitz 2016]. Currently, precision agriculture products are primarily directed towards large area farms and large agricultural companies equipped with advanced machinery and tools. Due to economies of scope agricultural technology providers and data companies are not interested in collecting and processing farm data from smaller farms and units. There is therefore a risk that the new paradigm of smart farming based on Big Data analytics and digital technologies might lead to the displacement of smaller farmers by large commercial farmers, potentially decreasing the diversity of food and farming domain [Bronson 2018]. However, the consequences of uneven distribution of benefits accruing from digitization among farmers and throughout the agri-food chain are yet not well understood. This might limit the transformative potential of Big Data revolution in the agri-food sector.

Conclusions

Digitization and new technologies bring both opportunities, challenges and risks. Data-driven transformation in the agri-food sector has already started and is changing agri-food markets and relations in the agri-food chains. Yet, there is hardly any public debate on data-driven transformation in the agri-food sector. As shown in the paper, digitization might indeed solve many problems in farming and in the food system. At the same time, unclear property rights to farm data, growing market power of input suppliers and uneven distribution of benefits accruing from digitization might lead to blockades or unwanted developments in the sector. There is therefore a need for value-embedded discussions about desired directions of digital transformation in the sector.

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Streszczenie

Celem artykułu jest omówienie głównych szans i wyzwań, które pojawiają się w sektorze rolno-spożywczym w związku z postępującymi procesami cyfryzacji. Technologie cyfrowe, w tym Big Data i Internet Rzeczy, uznawane są w wielu kręgach za obiecujące nowe narzędzia zwiększenia produktywności i konkurencyjności sektora rolno-spożywczego, jak i zapewniania bardziej zrównoważonego wykorzystania zasobów naturalnych. Wiedza oraz spostrzeżenia wydobywane z wciąż przyrastających woluminów rożnych danych cyfrowych mogą pomóc w optymalizacji procesów produkcji w gospodarstwie rolnym, zarządzaniu ryzykiem, przewidywaniu trendów rynkowych i wzmocnieniu możliwości podejmowania strategicznych decyzji biznesowych. Równocześnie zaawansowana analityka wielkich zbiorów danych jest potężnym narzędziem, potencjalnie przekształcającym funkcjonowanie poszczególnych rynków w ramach rolniczego łańcucha wartości. Cyfryzacja może zasadniczo zmienić relacje między dostawcami technologii i środków produkcji, rolnikami, firmami handlowymi, przetwórcami, sieciami sprzedaży i konsumentami. Pierwsze dowody wskazują, że rolnicze rynki danych mają określone wady i ograniczenia, które mogą zahamować pozytywne efekty transformacji cyfrowej w sektorze rolno-spożywczym. Podnoszone obawy dotyczą m.in. kwestii praw własności do danych rolniczych i ochrony prywatności, pozycji rynkowej głównych dostawców technologii rolniczych oraz nierównego podziału korzyści wynikających z procesów cyfryzacji.

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