Agricultural Education and Extension in the Age of Big Data

Katarzyna Kosior

Tischner European University, ul. Westerplatte 11, 31-033 Cracow, Poland

Abstract: The paper examines the role and tasks of agricultural education and extension in the Big Data age. For that purpose, major problems and challenges of Big Data agriculture have been identified. Also, a framework for leveraging Big Data applications and data innovations in the agri-food sector has been discussed. The analysis has been based on qualitative review of literature and online resources that refer to opportunities and challenges of Big Data applications in agriculture. During the selection process, particular attention has been paid to publications highlighting the benefits of Big Data usage in the agri-food sectors and possible roadblocks impeding and constraining Big Data innovations. The paper argues that enhanced digital communication, extension and education efforts in rural areas are needed to unlock the transformative potential of Big Data. Specifically, it will be crucial to increase the understanding of Big Data and the opportunities it offers to agriculture and rural economies. New education programmes and new approaches to extension would be also needed to accelerate the transition to a data-driven agriculture.

Key words: Big Data, data-driven agriculture, digital communication, innovations

Introduction

The rapid growth of ICT and the deluge of digital information in recent years have opened up new opportunities for economic development and social change. Large volumes of digital data, referred more often as Big Data, are currently considered a major source of innovation in many economic sectors. Innovative data technologies have also started to change agriculture and food industry. According to some observers, Big Data applications in the agriculture sector might in fact lead to the next agricultural revolution (cf. Powell 2017). With the use of information and knowledge hidden in large and increasingly growing volumes of digital data, agri-food sectors are expected to produce more with less environmental impact. Big Data seems therefore to offer new solutions to some fundamental global problems related to food insecurity, poverty and climate change.

Current technological progress outpaces education. Challenges and opportunities that arise from the use of Big Data in the agri-food sectors are still little known and poorly understood. This naturally leads to the question about the role and tasks of agricultural education and extension (cf. Leeuwis and Aarts 2011; Leeuwis 2013). Big Data, defined by its volume, velocity and variety, needs to be deciphered and translated into concrete applications and services that would facilitate and improve decision making in farming and related fields. Such services should be designed and developed in close cooperation with end-users to meet their real needs and requirements. Successful implementation of Big Data would therefore require enhanced education and communication among all stakeholders engaged in the agri-food chains. Data becomes important part of agricultural production assets, which undeniably redefines agricultural work and production processes. Mobile cloud computing solutions and the Internet of Things allow to acquire, store and analyze data on soil conditions, crop health, animal health or climate in real time. As farms change into networked farms and rural economies into digital economies the demand for digital skills and data literacy will be certainly increasing.

The purpose of this paper is twofold. First, based on literature review the paper will identify major problems and challenges of Big Data agriculture that should be tackled and addressed by agricultural education and extension. Second, it will discuss the framework for agricultural education and extension that could leverage Big Data applications in the agri-food sector. The paper aims therefore to provide a general overview and guidance regarding strategic goals and priorities of extension and education in the Big Data world. Particular attention will be paid to highlighting opportunities following the implementation of Big Data in agriculture and possible roadblocks that may impede and constrain the transformative potential of these innovations. These two types of forces are considered a primary reference point for building a responsive and effective extension and education system. It is hoped that the paper will encourage more focused investigations concerning the role and the importance of agricultural education and extension in promoting Big Data innovations.

Materials and Methods

The study is based on an extensive examination of research articles, papers, commentaries, reports and online resources that focus on Big Data applications in agriculture. The review included both peer-reviewed articles and grey literature with Internet resources, industry reports and case studies to capture knowledge and expert opinions relevant for the uptake and use of Big Data technologies in farming and related fields. Peer-reviewed articles were searched with the use of electronic databases of Web of Science and Scopus. Additional papers, research reports and information were extracted from Google Scholar, ResearchGate, thematic blogs and websites, including the websites of research projects exploring Big Data and the Internet of Things potential in agriculture and farming.

The search strategy has been related directly to the research question on the role and tasks of agricultural education and extension in the Big Data age. Yet, the goals and priorities of extension and agricultural education have not been defined through the perspective of specific skills to be acquired in the digital age, but through the perspective of fundamental challenges and opportunities that arise out of Big Data use. Due to exponential growth of technology the nature of digital skills needed in the Big Data world is changing rapidly, hence while analyzing strategic directions for extension and education more underlying and broader problems, gaps and bottlenecks on the road to a data-driven agriculture have been taken into account. Search terms selected for the review of literature and online resources included therefore a combination of the following: Big Data applications, Big Data uptake in farming, digital agriculture and opportunities, barriers/drivers and data-driven agriculture, Big Data management in agriculture, Big Data and agricultural and rural development, Big Data education and research, Big Data extension, digital communication and farmers.

Overall, 254 articles and papers having a reference to Big Data, agriculture, agri-food sectors, Big Data education and extension either in the abstract or in keywords were extracted from the chosen databases between March and April 2017. Most articles and papers were published in last three years, from 2014 to the present. An increasing interest in the subject can be observed, e.g. search for Big Data and agriculture in the Scopus database yielded 153 results: 2 in 2012, 14 in 2013, 22 in 2014, 41 in 2015, 65 in 2016 and 9 in the three first months of 2017. Following examination of abstracts, 47 articles and papers were selected for more in depth qualitative analysis. The theme most explored in the context of Big Data applications in agriculture concerned precision farming technologies and their uptake by farmers. Much less attention has been paid to the transformative potential of Big Data innovations in farms and rural economies that do not have access to precision agriculture equipment and tools. Other important topics included Big Data management, farmers' approach to Big Data innovations and conditions for effective operation of the emerging Big Data value chains in agriculture. In the following a critical review of the selected articles and materials will serve as a basis for indicating challenges and needs in agricultural education and extension.

Major Challenges for Agricultural Education and Extension in the Big Data World

The Lack of Understanding Big Data

The debate on Big Data applications in agriculture is in its initial phase. Although the number of research projects and peer-reviewed articles dealing with Big Data and agriculture have markedly increased in recent years, Big Data potential and relevance for the agrifood sector still is an open research question. As Bronson and Knezevitz (2016) point out, there is an underlying need to explore both affordances and limitations of Big Data. Literature survey shows that the Big Data concept has been sometimes overly simplified and squeezed into precision farming and/or sensor networks in agriculture. This can be considered a result of the infant Big Data industry which still is more a promise than reality. Sonka (2016) notices that it has not been odd to find opinions that Big Data is just a new and a trendier phrase describing precision technologies in crop and livestock production. As differences between precision farming and Big Data have tended to be blurred, the fundamental challenge for the system of agricultural education and extension will be to clarify both concepts and to explain the innovation potential of Big Data in the agrifood sector. Now, the transformative power of Big Data does not seem to be fully recognized.

Literature review allows to identify some common points and main differences between Big Data and precision farming. Fundamentally, with leveraging advanced technologies and data analytics, precision farming can be considered a part of Big Data agriculture. However, while precision farming remains a base for a data-driven agriculture, Big Data technologies go far beyond offering new qualities and opportunities (Sonka 2016; Sykuta 2016; Wolfert et al. 2017). Traditional precision agriculture uses individual farm data to increase yields while simultaneously reducing input use. Knowledge and recommendations generated for a given farm are based on data collected on that farm with the use of various high-tech devices such as water sensors, satellite images, computer-equipped machines and drones. Big Data agriculture also exploits these technologies but at the same time operates on aggregated data from large number of farms to discover new knowledge and insights relevant both for production and farm management (Sykuta 2016). Moreover, Big Data encompasses not only farm data but also large volumes of off-farm data which substantially enriches and expands data analytics (Xin and Zazueta 2016). Such analytics tools can subsequently provide a better and more thorough picture of impacts various nature- and human-based factors have on farming operations. Knowledge discovered from Big Data may consequently help in making more informed day-to-day decisions. It could also help in developing better risk management tools in agriculture.

The qualities of Big Data extend potential Big Data applications to the entire agri-food chain. Nukala et al. (2016) show how the Internet of Things, a technology in the realm of Big Data, may lead to innovations both in agricultural production, transportation, distribution and food retail. Big Data analytics has been viewed as a tool for both predicting farm output, optimizing production and improving marketing decisions, i.a. by forecasting agricultural commodity prices, consumer preferences and food demands (Wu et al. 2017; Satheesh et al. 2015; Lusk 2017). With real-time analytics and nowcasting methods based on streaming data from social media, Big Data offers unprecedented opportunities to improve performance and to increase revenues. It is also expected that data-driven tools designed to anticipate events and to react to changes as they occur will result in more competitive, more efficient and more sustainable agri-food chains (cf. Sundmaeker et al. 2016). This opens up new growth and income opportunities for various actors in the agri-food sector. With adequate governance structures enabling fair distribution of value created, Big Data has been also expected to support the achievement of global development goals related to food security, poverty reduction, food waste minimization and climate change mitigation (Evans 2016; Kshetri 2014; Mishra and Singh 2016).

Not only agri-food chains, but also a wider rural economy may substantially benefit from the adoption of Big Data. Fundamentally, Big Data - more than any other technological innovation - seems particularly well suited to the needs of multifunctional agriculture. While precision farming remains focused on sustainable and efficient agricultural production, Big Data analytics may provide advice and support also for those who quit farming to engage in other rural economy jobs. This remains a pressing need, particularly in the developing world where the number of unemployed in rural areas continues to increase (India Needs, 2016). However, when compared to the number of studies dealing with precision farming, studies that examine Big Data potential for multifunctional agriculture and rural development are still limited (Peisker and Dalai 2015; Varshney et al. 2015). To promote Big Data usage in rural areas, agricultural educators and extension professionals would need more evidence and use cases gathered possibly in a large and easily accessible database or Internet platform to show how advanced data analytics may turn villages and rural areas into smart villages and smart rural areas.

The Fear of Artificial Intelligence and Machine Learning

The extensive use of computers and data analytics leads to great improvements in many areas, but at the same time raises specific fears and concerns. Big Data has been often pictured as disruptive technology that will reshape businesses, industries and societies (cf. Loebbecke and Picot 2015). A key role in this process will be played by artificial intelligence and machine learning since traditional computing techniques are not sufficient to process and to analyze the ever-increasing volumes of digital data. Literature and press review point to two fundamental sources of concerns related to artificial intelligence and machine learning which could undermine the wider adoption of Big Data analytics. As such they should be addressed by government and taken into account when planning further research and educational work.

First, there are concerns about transferring decision-making powers to computer programmes that do not see and do not understand broader social contexts and complex human problems. Fuchs et al. (2016) note that human advices are still generally preferred over recommendations generated with the use of computer algorithms and machine learning. This phenomenon has been referred to in the literature as algorithm aversion (Dietvorst, Simmons and Massey 2015). In this case, machines are not trusted enough to be given an advisory role, particularly in areas that directly affect human lives (Mittelstadt 2016). People tend to rely more on their past experiences and even intuition. Machine learning algorithms indeed make the Big Data analytics a highly-automated process with little human inspection (cf. Japkowicz and Stefanowski 2016). Reservations persist since research on behavior of machine learning algorithms and on potential errors in algorithmic computations still is in an early stage.

Second kind of concerns has been motivated by the steadily increasing competition between men and machines on the labour market. In the agriculture sector, this has been embodied by the mentioned precision farming technologies. Robots and complex algorithms already accomplish tasks that until recently have been performed solely by humans. They are in addition more efficient, precise and quick (e.g. in detecting pests or infectious and other diseases in livestock herds). Hence, technological advancement changes the organization of agricultural work making some jobs redundant. In addition, it reduces the role of previously acquired skills in farming (cf. Digital Disruption on Farm, 2014). The research by Frey and Osborne (2017) shows that many farm jobs will probably disappear as they are highly susceptible to computerization (Table 1).

Table 1. Occupations in the agri-food sector ranked according to their probability of computerization (from most- to least-computerizable).

Occupation	Probability
Agricultural and Food Science Technicians	0.97
Farm Labour Contractors	0.97
Agricultural Inspectors	0.94
Miscellaneous Agricultural Workers	0.87
Farm Equipment Mechanics and Service Technicians	0.75
First-Line Supervisors of Farming, Fishing, and Forestry Workers	0.57
Agricultural Engineers	0.49
Graders and Sorters, Agricultural Products	0.41
Farmers, Ranchers and Other Agricultural Managers	0.047
Farm and Home Management Advisors	0.0075

Source: Based on data in appendix in Frey and Osborne (2017).

The above estimates describe the future of occupations in the US labour market, but can also be referred to labour markets in other developed countries where precision farming technologies have been widely adopted. Although farmers and farm management advisors are not yet among jobs at risk of computerization, it should be acknowledged that the context and the environment of their work have changed substantially. This change requires new approaches, competencies and skills. Education and training strategies should specifically deal with the problem of possible mental and social barriers that could undermine the concept of agriculture driven by artificial intelligence and machine learning. Farmers and extension professionals will not only have to learn to live with and use algorithmic decision-support systems, but also accommodate to dynamic changes in their work environment triggered by innovative technologies.

Data Ownership and Power Relations in the Agri-Food Chains

Big Data agriculture raises concerns also because it introduces new players and new interests in the sector. Recent years have seen a real explosion of interest in farm data from the side of different businesses and organizations. Big Data and precision farming industry include now farms, large agricultural technology providers, biotech agribusinesses, IT companies, data start-ups, tech start-ups and many others interested in extracting value from agricultural data (Kempenaar et al. 2016). There is a growing awareness that the ownership of data and the access to data will have a direct impact on the position of actors in the emerging Big Data value chain causing possible shifts in power relations in the agri-food supply chains and networks (Bronson and Knezevitz 2016; Wolfert et al. 2017).

Various studies and surveys show that farmers may resist Big Data because of concerns over the way their farm data is managed and used. Farmers are particularly worried about the security and privacy of their data and possible adverse consequences for their farms such as e.g. potential price discrimination by input suppliers (American Farm Bureau 2014; Carbonell 2016; Vogt 2016). Controversies arise since there are no clear answers to the question as to who retains ownership rights to data collected with the use of precision agricultural equipment (e.g. with cameras in agricultural drones or sensors embedded in agricultural machines). Consequently, it is also unclear who has the ultimate authority to decide on purposes of data processing and data usage (Dyer 2016; Ellixson and Griffin 2016). Applications developed by large corporations such as Monsanto or by producers of farm equipment such as Deere collect data and provide farmers with tools that facilitate decision-making and risk management on the farm. At the same time, though, data once collected can be used to serve various purposes, e.g. it can facilitate new product development or investment decisions. Farmers are afraid that Big Data tools may in fact favour some agricultural systems at the expense of others and maintain farming practices that primarily benefit agricultural technology providers and biotech businesses (cf. Poppe et al. 2015; Bronson and Knezevitz 2016). There are also concerns that precision farming might widen digital divide between small and big farmers as the former might not have enough resources or knowledge to invest in precision and data technologies (European Parliament 2016).

The lack of clear rules concerning data ownership seems now to be a major stumbling block on the road to a data-driven agriculture. The empowerment of farmers through clear property rights to farm data, including the right to control the flow of data within the data value chain and the right to remove data from the databases, has been considered essential for building farmers' confidence and trust in data-driven agriculture (cf. European Parliament 2016). The fundamental mission of extension professionals would be thus to increase farmers' awareness of their rights to data and at the same time of benefits accruing from active participation in the data value chain. Education for a data-driven agriculture would need particularly to promote an open approach to data sharing and data aggregation. Farmers and other stakeholders should be aware of the importance of data exchange and of inherent tensions between privacy of data owners and the need to examine as much data (including private data) as possible to secure the usefulness of data analysis. This also requires increasing knowledge about legal, regulatory and technological arrangements that could be used to protect privacy and security of data and to ensure integrity of Big Data projects (e.g. through anonymization and other privacy enhancing technologies, ethical standards governing the collection, storage and distribution of data, frameworks for primary and secondary uses of data analytics). As much of the current debate ignores the value of data sources outside precision farming technologies, agricultural education and extension should also explain opportunities Big Data offers to other stakeholders in the agri-food chain, including smallholder farms and other businesses in rural areas (cf. Protopop and Shanoyan 2016).

Explaining the strengths and weaknesses of specific governance models for Big Data management in the sector seems to be equally important task. Farmers and other stakeholders should be aware of the existence of various systems ranging from closed, proprietary systems to open, collaborative systems characterized by flexibility and freedom in choosing providers of data-based applications and tools (Wolfert et al. 2017). Evidence up to date shows that large industry players prefer proprietary systems in which farmers retain ownership rights to their individual data but do not have residual control rights over aggregated data. Such arrangements have been considered to yield anticompetitive advantage to selected firms contributing to lock-in effects in the data market. To avoid natural monopolies in the emerging Big Data landscape, farmers have been encouraged to form agricultural data marketing cooperatives that could aggregate data from large number of farms and hence improve farmers' position in the data value chain (Sykuta 2016). The public sector, international organizations, non-governmental organizations have also strongly promoted extensive cooperation between different authorities and stakeholders to facilitate the establishment of open data policies and standards throughout the agri-food chain. The many options for data management need to be further explored, particularly in the context of differing economic, legal and social environments in which Big Data value chain is expected to operate. Agricultural education and extension services face therefore particular challenges in this area – experts indicate that demand for data management advice is expected to rise substantially over the coming years.

Digital Engagement of Farmers

Data-driven agriculture needs digitally engaged farmers. Yet, digital engagement should not be limited to the mere uptake and use of new precision and data technologies. A growing body of research indicates that farmers themselves might become important producers and sources of digital data and promoters of data-based innovations in agriculture (for the first research in this area see Van Etten 2011). As digital communication via mobile devices, web platforms, social media, social networking sites, blogs, podcasts, wikis, and many other ICT tools steadily increases, so it does the volume of digital data to be analyzed and used for more informed decision-making. Farmers' communication through digital channels provides an excellent opportunity for networking, knowledge exchange and mutual learning. At the same time, traces of farmers' digital activity in the web add to the volume of existing data which might enrich data analytics and yield insights that would otherwise be difficult to obtain. The use of social media and other digital platforms for communication has been considered particularly important for farmers in developing countries where the access to and availability of precision technology equipment and other machines that collect farm data is, for the time being, limited. Therefore, much of the literature exploring the routes for datafication in small-scale agricultural sectors and rural economies in the developing countries focuses on ICT-based systems and participatory approaches for disseminating agricultural knowledge and farm management information (Kshetri 2014; Deichmann, Goyal and Mishra 2016).

Reports and studies exploring the use of digital technologies in agriculture point to many barriers that currently hold back the transformative potential of data. One of the fundamental problem is the limited access to high-speed broadband and mobile networks in many regions of the world, also in the most developed countries (Mark, Griffin and Whitacre 2016). From the perspective of education and extension services more challenging barriers to overcome concern however deficits in farmers' digital skills, resulting low participation rates in online activities and reluctant approaches to data sharing (Castle, Lubben and Luck 2016). This is in part a result of aging farming population – labour force in agriculture is older than in other sectors of the economy. Nonetheless, even in more technologically advanced regions with high rates of digital literacy there is a problem to maintain farmers' interest and motivation to use digital tools and the Internet for communication (Hansen et al. 2014). It is therefore necessary to disseminate knowledge and information on how digital engagement could work for farms and more broadly for rural areas.

Lindblom at al. (2016) and van der Weerdt and de Boer (2016) point out that involving farmers in the process of designing and developing applications and tools based on ICT remains crucial for the further uptake of the technology. The identification of farmers' major problems, needs and expectations allows for designing better and more effective tools for production decision support and farm management. Farmers are also more willing to use applications that have been developed in co-decision process. Continued involvement of farmers in improving the quality and efficiency of digital tools is equally important. Currently most data-based applications on mobile phones or tablets use simple communications and visualizations that do not require analytical skills or additional effort from farmers (Sykuta 2016). There is thus a risk that with ready-to-use applications farmers may become merely recipients of advice generated by data service providers. Yet, with dynamic changes both in farming systems and in economic and social contexts within which farm decision-making occurs, continuous flow of information and feedback from farmers to data service providers is required. In the Big Data era, this could be achieved most efficiently with the use of digital channels for communication. Hence, building networks of digitally engaged farmers can be considered one of the most important tasks for agricultural education and extension in the years to come.

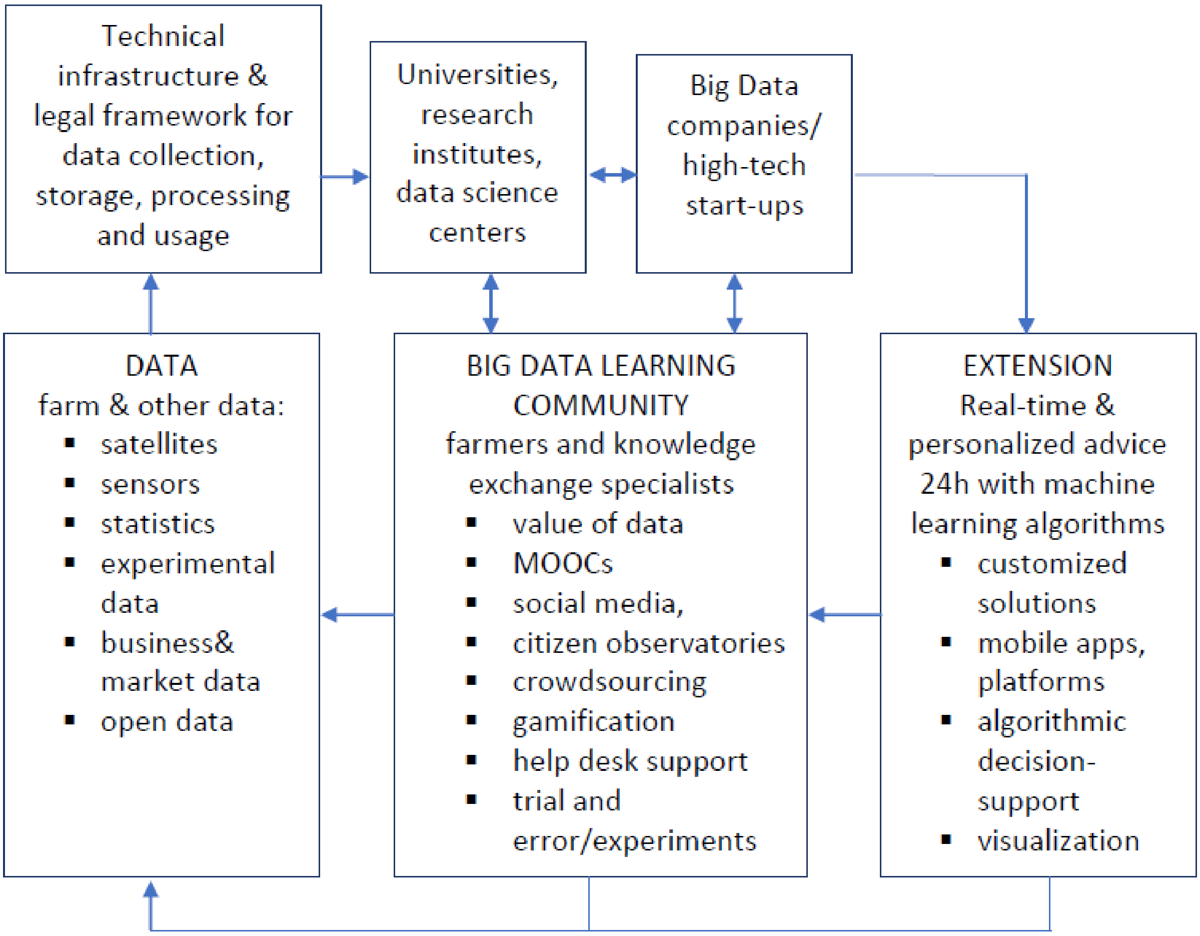
Leveraging Big Data in the Agri-Food Sector – the Role of Extension and Education Programmes

The emergence of Big Data calls not only for trainings and actions aimed at educating farmers and other stakeholders about the importance and value of digital data but also for transformation of education programmes at all levels, including undergraduate and graduate curricula at universities. Scientific Foresight Unit of the European Parliament indicates that precision agriculture requires in fact a strong push for education in farming (European Parliament 2016). Challenges in this context include relatively large school drop-out rates in rural areas and declining numbers of students attending agricultural universities and colleges. Young people do not see farming or agriculture-related jobs as attractive professions. Yet, the prospects of data-driven agriculture with precision technologies and/ or social and collective intelligence technologies might lead to renewing the interest of the youth in farming and agriculture (European Parliament 2016). Programmes offered at various levels of education should therefore keep up to speed with opportunities offered by new technologies.

Recent years have seen the emergence of academic programmes in data science – a new discipline that overlaps with computer science, network science, mathematics, statistics, machine learning, data mining, operations research and business intelligence (Granville 2014; de Veaux et al. 2017). Big Data scholars point to the need to further invest in and promote data science education in universities and colleges. Following these trends, agricultural universities and other educational institutions offering programmes in agriculture-related fields started to take a greater account of learning outcomes related to informatics and data science. Some universities already offer graduate and post-graduate levels curricula in Agricultural Informatics. There are also good practices of using online platforms to educate students about Big Data applications in farming. E.g. Bovi-analytics platform allows students of Veterinary Medicine to have access to large volumes of real-time data from dairy farms with analytic tools such as SaS, R, or power-Bi used for extracting insights and information from large databases (Hostens et al. 2016).

These developments show that agricultural education at universities becomes more and more data-oriented. Still, however, various regions and sectors experience severe shortages of data scientists and experts dealing with advanced data analytics in specific fields. Moreover, researchers stress that it is quite difficult to learn and develop competences needed in the Big Data world within one curriculum area (Tang and Sae-Lim 2016). Fundamental challenges highlighted in the literature relate thus to developing skills needed for interdisciplinary collaboration and good communication within the data value chain. Effective algorithms or models used in predictive analytics require both data science expertise and specific domain knowledge (cf. Antle et al. 2016). Hence it is recommended that data science programmes be enriched with additional courses from different fields and disciplines. At the same time, experts recommend placing a greater emphasis on science, technology, engineering, mathematics education (STEM) and communication trainings (OECD 2015; Wender 2017). Data scientists should be prepared to collaborate with representatives of various disciplines and representatives of other professions should be able to understand and respond adequately to requirements of data science. Overall, intensive cooperation and communication between agricultural universities, research institutes, data science centers, IT companies, businesses, extension professionals and farmers would be important to leverage Big Data use in agriculture.

Figure 1. Agricultural Education and Extension in the Big Data Age



Source: own elaboration

Big Data is bound to transform the role of extension and the nature of advice provided to farmers by extension professionals and other educators. The extent and the character of changes will depend on the stage and the scope of Big Data implementations in the sector. In the case of the most technologically advanced farms, traditional human-delivered advice for improving crop or livestock production will be replaced by decision support systems based on artificial intelligence. Mobile and web applications will provide farmers with real-time and personalized advice available 24/7. Big Data will therefore limit the need for on-farm visits or direct technical assistance from extension agents. Most of extension work will focus on communicating and explaining innovative opportunities arising from the use of Big Data technologies (either in production or farm and risk management) (Coble et al. 2016). These developments, undoubtedly, enhance the concept of extension as communication for innovation (cf. Leeuwis 2013). In fact, with the emergence of Big Data analytics technology centers, extension professionals more and more often perform their tasks as knowledge exchange managers or communication specialists (cf. Agrimetrics 2017).

The interactive learning community of farmers and knowledge exchange specialists coming from various fields and environments should be considered a central element of education and extension strategy for advancing Big Data applications in agriculture. Given rapid technological advances, agricultural education and extension should actively encourage the lifelong acquisition of new knowledge and skills, the use of new technologies for communication, and an open approach to trials and experiments as they constitute fundamental methods for developing innovative data solutions and applications. Extension services delivered through social media and mobile devices would be particularly important. Social media create co-working spaces for asking questions and solving problems and as such could become major platform for building expert knowledge systems. Other promising opportunity on the road to a data-driven agriculture is crowdsourcing. Recent studies exploring the potential of crowdsourcing in agriculture show that farmers as stewards of natural resources may e.g. participate in citizen science projects gathering environmental and other data and observations around the farm (by taking photos of plants, crops or birds) (cf. Dehnen-Schmutz et al. 2016). There have been also crowdsourcing projects that engaged farmers in identification of weed images and crop improvement through variety evaluation (Rahman et al. 2015; van Etten 2016).

Open learning community, supported by web and mobile technologies, multi-media instructional materials, MOOCs, online trainings, webinars, social media, crowdsourcing and gamification might greatly facilitate knowledge sharing and innovation in the agri-food sector (cf. Mushtaq et al. 2017). This would be fundamental since apart from general skills in digital communication, data-driven agriculture and precision farming require more specific skills for working with advanced machinery and robotics technologies, including data-based applications aimed at supporting sustainable and efficient production systems. Depending on circumstances, this might require increasing knowledge about farm-level data management, explaining key economic and environmental benefits of applying precision practices in agriculture or enhancing ICT skills needed e.g. for using interactive data visualizations (cf. Erickson and Widmar 2015; eXtension.org 2014). The wide array of skills and competences in the Big Data era require pluralistic extension and vocational education systems. Large producers of agricultural equipment and giant IT companies already offer various training options, online help desk support and education materials promoting the uptake and use of precision and data technologies. There is therefore a risk that private sector represented by large agri-business and other companies will dominate the landscape of Big Data education. To ensure a counterbalance, extension organizations, education institutions, international organizations, NGOs and smaller companies wishing to enter the farm data market should become more involved in explaining the opportunities and challenges of digital revolution in the sector. A sustained engagement of various actors in the Big Data education and extension would be crucial for establishing effective data value chains in the agri-food sector. Particularly, the promotion of open data policies and the use of various farm and off-farm data might fundamentally improve the prospects for realizing the promises of Big Data revolution in agriculture.

Conclusions

There is little doubt that Big Data has the potential to turn farming and the agri-food industry into a smart and high-tech business. The scope and direction of changes will to a large extent depend on the capacities of extension and education system to respond to the Big Data age challenges. The main contribution of this paper is the identification of fundamental problems that should be addressed by extension organizations and agricultural education institutions to unlock the potential of Big Data in agriculture. The paper also proposes a general framework for Big Data agricultural education and extension for further discussion. The analysis of the literature leads to the conclusion that the extent of challenges related to Big Data applications in agriculture requires enhanced communication, extension and education efforts. Open and inclusive Big Data learning community, involving actors representing different sectors and industries and fostering digital communication and participation through social networking sites and other digital technologies, seems best suited to the needs of data-driven agriculture.

As has been shown, data-driven innovations in agriculture have been primarily based on precision farming technologies, but certainly not limited to them. Much more can be derived from digital communication and massive volumes of data to the benefit of farmers and rural economies, both in developed and developing countries. Extension and education must therefore tackle the fundamental problem of limited understanding of opportunities offered by Big Data and digital communication. It can be expected that the implementation of Big Data in agriculture will vary depending on local capacities and strategies. There will be farms that will turn into fully networked and digitized businesses using customized and real-time advisory services delivered by machine learning algorithms. In this context, one might expect the redefinition of the role of extension professionals and the nature of advice provided to farmers. The need for agronomic and production advice delivered by humans will decrease, instead the importance of advisory services on data management and data value chains in the agri-food sector will increase. Yet, not all farmers will be able to invest in new technologies to make their farms connected and ready for the benefits of advanced data analytics. In this case, the role of extension and education system will be to highlight the value of other sources of data and other opportunities for data based innovations.

Without enhanced education and extension Big Data opportunities in agriculture might not be fully realized. There is also a risk that Big Data may start to be regarded as the next technological interference that moves humanity further away from the nature and traditional values linked to direct cultivation of land and raising of livestock by farmers. It would be therefore important to communicate all opportunities and challenges related to Big Data use in agriculture to overcome fears and possible machine-versus-man narratives in public debate. Farmers and other stakeholders need to understand why and how the employment of intelligent machines makes some human skills no longer needed or expected to be applied in on-farm practices and how this development protects and improves the state of the environment in rural areas. At the same time education and extension should contribute to empowering farmers in the emerging Big Data value chains. Farmers should be aware of their rights to farm data but also of their important roles as producers of data. Farmers exchanging information and data through web or mobile channels support the establishment of digital agriculture. Overall, increased communication and collaboration among farmers, extension professionals, researchers, data science centers, businesses and IT companies would be needed to accelerate transition to a data-driven agriculture.

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