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Editorial Staff:
Jl. SWK 104 (Lingkar Utara), Condongcatur, Yogyakarta 55283 (Kampus Pusat)
Telp. +62 274 486733
http://agriculture.upnyk.ac.id/
e-mail: email@upnyk.ac.id

PREFACE

The industrial revolution 4.0 brought many changes with all the consequences. The industry will be more compact and efficient, but there are also risks that might arise, such as reduced human resources because it is replaced by machines or robots. With all the potential that exists we must be active actors who get benefit from the big changes.

It is a must for stakeholders in the agricultural sector to be able to prepare themselves and adapt to changes in the era of the industrial revolution 4.0 to answer the challenges of the future, and turn threats into opportunities.

Improvement of the agricultural sector must be done, and farmers must be strong in technological capabilities. Agro-industry is able to produce environmentally friendly products, substitute non-renewable materials and energy, avoid or minimize the use of toxic chemicals, and minimize emissions. Agro-industry development needs to be directed to integrate the upstream and downstream aspects of the system in a sustainable manner for more prosperous farmers and more advanced agro-industries.

Following the successes of the 1st, 2nd and 3rd International Conference on Green Agro-Industry (ICGAI) were held on 2013, 2015 and 2017 at Yogyakarta, Faculty of Agriculture, Universitas Pembangunan Nasional "Veteran" Yogyakarta, Indonesia in conjunction with its global partner is proudly to announce the 4th ICGAI. The conference will be held on October 22 - 23, 2019, at Yogyakarta, Indonesia. The conference will address problems of primary importance for food security, discussing and proposing a more constructive and progressive approach to ensure future societal sustainability. The meeting will provide a common forum for a wide range of researchers and practitioners specializing in a range of subjects related to the conference themes.

Yogyakarta, March 2020

Editor

DAFTAR ISI

KEYNOTE SPEAKER

PRESENTER SPEAKER
ECONOMICS, SOCIAL AND BUSINESS

AGRICULTURAL ENGINEERING

ANY OTHER TOPICS

CROP AND CROP MANAGEMENT

ENVIRONMENT

SOIL AND WATER MANAGEMENT

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Farming in the Era of Industrial Revolution 4.0: The Environmental Challenges

Partoyo

Faculty of Agriculture
Universitas Pembangunan Nasional "Veteran" Yogyakarta
Jl. Lingkar Utara Condongcatur Yogyakarta 55283
Email: partoyo@upnyk.ac.id

Abstract.

The Industrial Revolution 4.0 proposed a cross-cutting impact of information and communication technologies, especially the Internet of Things in various industrial sectors. This revolution supported the development of systems that transfer the advantages of the internet and information systems towards physical systems. In the agricultural industry, the concept of farming in the industrial revolution 4.0 era refers to the increased integration of information and communication technology with farming activities. A smart, networked system, combining various types of data from multiple sources, promised to increase productivity and efficiency. This revolution changes the tools used in agriculture sectors replaces leads to smart farming that must be sustainable agriculture. This paper reviewed the implementation of the industrial revolution concerning smart farming activities and discussed environmental opportunities and challenges raised.

Keywords: industrial revolution 4.0, smart farming, sustainable agriculture, environmental challenges

Introduction

Food demand in the world is continuing to increase. Jelle Bruinsma, in World Agriculture: Towards 2015/2030, stated that the world is facing an enormous challenge. He raised a challenging question, "How to feed 2 billion more mouths in 2030?" But, he also convinced that the world could feed more people (Bruinsma, 2015). As the population increases and revenues increase, demand for food is also growing. He estimates that the total need for agricultural products in 2030 will be around 60% higher than in 2015. At least 85% of this increased demand will be in the developing world.

The population growth has decreased from 1.7% per year for the last 30 years to 1.1% annually to the year 2030. It was expected that the world population would be around 8.3 billion people in 2030. Consequently, the world growing demand for foods is estimated to slow down, from an average of 2.2% per year during the last 30 years to 1.5% annually. In developing countries, it was found a larger decrease in demand from 3.7% per year to around 2% to 2030 (FAO, 2015).

As in the past, agriculture will respond to increasing demand by producing more. But in fact, the FAO expects that with 2030 about 440 million people will still be deficient in chronic nutrition (Bruinsma, 2015). Besides, although the potential to increase production exists, we need to add investment in agricultural development and, in particular, in agricultural research, which is not only to raise the rate of results but also to maintain the level of products. The intensification of agriculture may induce an environmental problem whenever technology is not used correctly. Environmental damage has been found due to pollution caused by excessive application of fertilizers or pesticides, or due to no regulations adequate to protect the natural resources (Gaffney *et al*., 2019). Therefore, we need to introduce adaptable agronomic strategies and rules that consider environmental protection to meet sustainable farming targets.

As environmental problems are becoming an urgent issue, so sustainable agriculture then developed into environmentally sound farming. Agriculture developments tend to automation production and environmentally smart technologies (Lehmann *et al*., 2012). Nowadays, farming required a method that is sustainable in terms of productivity, economic, environmental, and social (Far & Rezaei-Moghaddam, 2018).

The concept of farming in the era of Industrial Revolution 4.0 refers to the increased integration of information and communications technology (ICT) with farming activities. A smart, networked system, combining various types of data from multiple sources, promised to increase productivity and efficiency. This revolution changes the tools used in agriculture sectors replaces leads to smart farming. Smart farming considers both high productivity and sustainability according to environmental safety.

This paper discusses industrial revolution 4.0 and its implementation in agriculture. A brief review will present several definitions and concepts of industrial revolution 4.0 and technologies and implementation of ICT in agriculture. The next part will be a discussion on the challenges and opportunities of farming in the era of industrial revolution 4.0, particularly related to environmental issues. The last part will be an epilogue and a conclusion.

Definition And Concepts

Industrial Revolution 4.0.

It was Professor Schwab, who declared the emergence of the Fourth Industrial Revolution in 2015 (Schwab, 2015). The 4.0 industry then became a topic of general discussion in research, academic, and industrial communities. The main idea is to explore the strengths of new concepts and technologies, including (Rojko, 2017):

• The readiness and application of the Internet and IoT,

• Incorporation of technical and business processes in the enterprise,

• Digital mapping and virtual modeling,

• Smart factories, smart production, and intelligent goods.

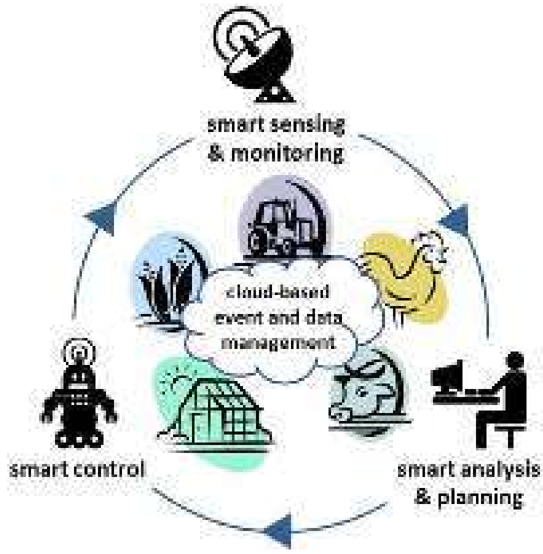
Five years after the first introduction in Germany, the 4.0 industry concept is well-known worldwide. It has also been transferred from its original application field in the manufacturing industry to other engineering and non-engineering (Rojko, 2017). Furthermore, the 4.0 industry is generally adopted as the concept of the 4.0 Industrial Revolution (Rojko, 2017). There have been many experts discussed this concept. However, a universal definition of the Industrial Revolution 4.0 has not yet been confirmed (Lee *et al*., 2018).

Farming in the era of the Industrial Revolution 4.0

The application of the Industrial Revolution 4.0 in agriculture includes three parts. The first part is sensor-based technology for data collection of several parameters related to crops, soil, and weather conditions. The second part is big data analysis resulting requirement of plants regarding water content and fertilizers on appropriate timing. The third part consists of control systems of various farm machinery inputted by database processed from a computerized geographical information system (GIS). The system transformed farming infrastructures into connected tractors and machines, connected farms, and new production equipment. This part will contribute to productivity improvement, environmental protection, and quality assurance of agricultural products.

Figure 1 describes the smart farming concepts. It is the cycle of the cyber-physical system, consists of smart devices connected to the internet and controlling the whole farm system. Intelligent devices, including conventional pieces of equipment (tractors, rain gauge, and computer) completed with autonomous capabilities by sensors, artificial intelligence, capacity for self-operating, and doing remotely. Robots may have an essential function for control. In this cyber-physical cycle, the role of analysis and planning becomes almost autonomous. Machines increasingly assist humans. The system still needs humans with a higher level of intelligence. The humans responsible for the whole process but organizing machines to do execution activities (Wolfert *et al*., 2017).

Fig. 1. The cyber-physical management cycle of Smart Farming enhanced by cloud-based event and data management (Wolfert et al., 2014).



The most related farming activities with industry revolution 4.0 is Smart Farming. Smart farming intelligently manages farming practices, including monitoring, plan, and control of farming activity. This concept needs the implementation of various systems of hardware and software (Kruize *et al*., 2016). The use of unmanned aerial vehicles (UAVs) has been popularly implemented. The technology of GPS and drones with cameras support better decision making and risk management process in agricultural practices (Wolfert *et al*., 2017).

The Industrial Revolution 4.0 created technologies of artificial intelligence (AI) that benefits in decision-making ability and big data, which helps in the analysis of statistical data collected by different techniques. These technologies ease agricultural activities like analysis of soil moisture, the healthiness of crop, prediction of exact harvest time of the plant, and the scheduling of pest control. System termed internet of things (IoT), making it possible to operate farm remotely through mobile devices.

Precision Agriculture

The concept of precision agriculture has evolved since the 1990s and then thoroughly intended to study and manage spatial heterogeneity in agricultural production. The other variability and agriculture-related factors then also to be considered in the concept properly. "Precision Agriculture is a management strategy, including gathering, processing, and analyzing temporal, spatial, and individual data and combines it with other information. It supports management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability, and sustainability of agricultural production." (ISPA, 2018)

Precision farming includes a wide range of technology, targeting a more precise agricultural production. These technologies have different acceptance in agricultural practice. Adoption of site-specific seed and fertilizer management continues to lag (Hauser & Wagner, 2018).

Precision agriculture customizes plant and soil management cautiously, considering the land heterogeneity. Plants and soil characteristics on the ground not only vary spatially in horizontal and vertical but also temporal. This heterogeneity issue becomes an important distinction between precision farming and conventional farming. Rapid advances in agricultural technology and applications help increase productivity. Precision farming under agriculture 4.0 is a promising pathway to improve the sustainability of agriculture by increasing farm profitability, reducing manual labor, and reducing environmental impact.

Smart Farming

Smart farming or intelligent agriculture has not yet been popular term as precision farming. As precision farming takes into account variability in the field, intelligent agriculture creates activities based on the field and data. The data was connected with the context and situation and initiated from real-time events (Wolfert *et al*., 2017).

Smart farming has developed in line with the concept of the digitalization of farms (van der Burg *et al*., 2019). The digitization of agriculture presented as a promising technology for a variety of social and technical issues. It could solve problems, such as food supply for the population, reducing farming impacts on the environment, promoting food safety, and increasing public acceptance (Wolfert *et al*., 2017). Smart farming does agricultural activities in such an efficient way. Many types of equipment, like weather satellites, sensors, software algorithms, and robots, are applied together, making agriculture smart. Efficient work can be executed, such as scheduling irrigation, monitoring of plant health based on data collected from the satellites and sensors. Also, all the collected data can be merged and analyzed across the region. Based on more data, the analysis provides even resulted in better information.

Understanding the spatial variability of soil chemical and physical attributes optimizes the profitability of nutrient and water management for crop development. Soil mapping systems with various types of proximal soil sensors provide crop growers with an excellent opportunity to access soil heterogeneity at a sub-meter spatial scale in an efficient and less invasive manner. Studies suggest that sensing information linked to soil pH, electrical conductivity, organic matter content, soil moisture, etc., can be obtained in a relatively cost-effective manner (Huang *et al*., 2018).

Digitalization of farms

The literature about the digitization of agriculture from the perspective of natural or technical is available in various forms. A literature review shows that the future agenda of inter and trans-disciplinary research is urgent for developing the science on precision agriculture, smart farming, digitalization in agriculture, and agriculture 4.0 (Klerkx *et al*., 2019).

Big Data and Smart Farming are both interrelated and may modify the scope and arrangement of agriculture. Research and development activity of both developed fastly. Big data applications far exceed the farm itself but cover the whole cycle of the supply chain. Development of the IoT, connect all kinds of equipment and tools wirelessly in farms and supply chains, generates a lot of new real-time data (Wolfert *et al*., 2017). Concerning Figure 1, management and operation of farming will change to automatic and autonomous processes due to broad access of real-time data, concurrent prediction, types of equipment tracking, and combined with IoT development (Wolfert *et al*., 2017).

ICT in agriculture

Smart farming is a practical application of ICT in agricultural activities. ICT techniques support the efficient process of production (Walter *et al*., 2017). Fast development in ICT technology has motivated practitioners, companies, and scientists to work together in creating innovative technology to support farmer's activities. Implementation of ICT technology in agricultural processes has been beneficial by the utilization of satellite imagery, robotics agriculture, various sensor for data collection, and unmanned aerial vehicles (UAVs) for an aerial photograph. In the European Union countries, cooperation on the future smart digital technology and development of sustainable agriculture in the country and rural areas was declared in April 2019 by the 24 EU member countries (Bacco *et al*., 2019).

ICTs hold the potential contribution to the transition in agriculture sustainability due to their disrupting potential (Bello & Aderbigbe, 2014). According to Wolfert *et al*. (2017), ICT's trends interfere with many platforms, including cloud computing, geo-information, Internet of Things, social media, and connected open data).

ICT and Big Data, including in digital agriculture, is continuing to transform society (El Bilali & Allahyari, 2018). Extension activity will provide better information and services as data was collected and combined from many sources, including satellite imagery, cropping models, and sensors from many locations. Farmers also have the opportunity to improve the learning process during agricultural activities. They can share experiences and ask questions to the extension facilitator during a two-way extension process. ICT makes it possible to provide information directly to farmers using smartphones (Bruce *et al*., 2018).

Innovative urban agriculture (IUA)

Innovative urban farming (IUF) produce food crop using less amount of soil and water than ordinary farming (Rothwell *et al*., 2016). Each agricultural system needs inputs, including planting media, irrigation, fertilizer, and agrochemicals. However, IUF usually practices a circular system. It uses such construction that possible for using alternative planting media other than soil, and automatic types of equipment. Some IUF experiments claim that IUF may increase the efficiency of water and fertilizer use. For example, the application of the aquaponics double-recirculating system (DRAPS) for one cubic meter of water increases

23.6% efficiency of fertilizer higher than conventional hydroponic systems. It produces similar quality and many tomatoes, and additional product 1.5 kg of tilapia per cubic meter of water (Suhl *et al*., 2016).

This effectiveness claim is just based on the single production process. Commonly, IUF practitioners might also apply more amounts of manufactured goods, such as plastics, metals, or chemical fertilizers that could potentially increase a carbon footprint higher than rural agriculture (Sanyé-Mengual *et al*., 2015). Impact of precision agriculture on the environment has been importantly raised from the wrapping and transport of products, an ecological packaging, and preservation (Rothwell *et al*., 2016; Llorach-Massana *et al*., 2016; Abeliotis *et al*., 2016). According to a life cycle analysis, the complete IUF's system for food production systems may require more equipment and energy compared to rural agriculture. Therefore, a full LCA is required before justifying the environmental outlook of the IUF system (Armanda *et al*., 2019).

Challenges And Opportunities

Development of ICT in the era of Industrial Revolution 4.0 boosts farming practices into smart farming that effective and efficient and makes it safe to the human and environment. This type of information requires the recommended dose of fertilizer and specific pest control on site to succeed in agricultural production. Analysis of the digital image of rice leaves can be applied to determine the adequacy of plant nutrients and pest levels. Develop information on recommended fertilizer doses and pest control for a site-specific, in line with the precision of agriculture. Digital image analysis of rice leaf samples can obtain the necessary data to determine the level of nutrient adequacy and pest attack. This research collects technology for combining artificial neural network (ANN) techniques with data communication of digital image techniques to tailor fertilizer needs and pest control recommendations. This application eases the farmers to know the recommendation of fertilizer doses and pest control required for their farmland by simply sending paddy leaves photos using a smartphone application (Partoyo *et al*., 2013).

Technology that uses drones (unmanned aerial vehicles- UAV) to capture images of crops for analyzing big data is beneficial. With the use of drones, farmers can identify which part of the land needed irrigation or fertilizers quickly. Nowadays, this drone used as remotely fertilizing vehicles in farming so that specific areas or individual plants can be accessed easily. This data collected by drone forwarded through ortho-mosaic maps for spatial analysis. Different techniques used to manage the data for agricultural sector development is called Big Data. Big Data denotes processing the massive amount of data collected from information, and communications technologies (ICT) leads to rapid decision-making data for improving crop productivity. Since all data is available from consecutive periods in storage, each farmer may take preventive measures for different weather conditions.

Recently under industrial revolution 4.0, a new technique of machine learning called Artificial Intelligence (AI) increases demands in various activities. This Artificial intelligence (AI) used the previously stored data for decision making and requirement of agricultural sectors with the preparation of the schedule of farming activities. Industrial Revolution 4.0 also results in the utilization of robots in many farming pieces of equipment. This revolution in the agriculture sector may enhance productivity through automation, unmanned farming, and eco-friendly farming.

ICT can facilitate to reduce agricultural inputs (water, fertilizer, pesticides, and energy) as well as reduce environmental costs (Lehmann *et al*., 2012) as described in Table 1. ICT serves as the fundamental for other technology such as geographic information systems (GIS) and global positioning systems (GPS) in precise and specific location farming (El Bilali & Allahyari, 2018). Examples use of ICT in agriculture to improve efficiency is precision agriculture (Balafoutis *et al*., 2017; Allahyari *et al*., 2016; McBratney *et al*., 2005). Precision agriculture is a model of modern agriculture consisting of sensor utilization to optimize water, fertilizers, and pesticides use. The precision farming method relies predominantly on satellite navigation, positioning technology, sensor technology, and the internet of things (El Bilali & Allahyari, 2018).

Table 1. ICT impacts food chain sustainability, especially in environmental aspects.

Expected positive impact
• Increase the efficient use of resources and inputs. • Reduce the cost of the environmental impact of agricultural and food processing (for example, water pollution). • Decrease agricultural sector contributions to the emission of GHG. • Reduce food defeats, and waste.
Potential negative impacts
• Creating electronic waste and dumping of ICT device in agricultural areas

Sources: Adopted from El Bilali & Allahyari (2018)

Precision agricultural technology includes variable-level nutritional applications, variable-level irrigation, variable-level application of pesticides, variable-level of planting, precise weeding technology, autonomous driver engines, permanent traffic-controlled of farming vehicles (Balafoutis *et al*., 2017). In precision agriculture technology, data collected from different sensors allows adjusting the number of inputs to crop needs and various amount to each of the entire area. Reduced use of this input has a positive environment (Balafoutis *et al*., 2017; Hedley, 2015), and economics (Balafoutis *et al*., 2017; Snyder *et al*., 2015) impact. The decision support system based on ICT helps farmers increasing production efficiency, whereas suppressing production expenses and their operating environment footprint (Hedley, 2015). Intelligent irrigation systems based on ICT can reduce the use of water use and energy (Mutchek & Williams, 2010). Generally, precision agriculture may produce lower emissions of GHG due to increased carbon absorption in the soil (European Union, 2014). It may also reduce tillage (Angers & Eriksen-Hamel, 2008), reduce nitrogen rates (Khan *et al*., 2007), reduce inputs use (Mutchek & Williams, 2010), and reduce fuel consumption (Balafoutis *et al*., 2017).

USDA-Natural Resources Conservation Services promoted an efficient irrigation technology as well as protecting water quality. The technology consists of the conversion of furrow irrigation and high-pressure pivot irrigation to low-pressure pivot irrigation and micro-irrigation systems, scheduling irrigation based on weather and sensor data, and planning of soil conservation or fertility management (USDA-NRCS, 2019). Improvements in technology and management of irrigation have improved the efficiency of irrigation and overall water use efficiency (Gaffney *et al*., 2019).

The other opportunity to develop autonomous farming activities is using unmanned aerial systems (UAS). The UAS comprised of components for data acquisition and processing for obtaining field data and processing information provided to the users. Data acquisition conducted by unmanned aerial vehicles (UAVs) and controlling ground stations, comprised of GPS receivers, data capturing sensors, and connection to ground stations with digital storage to save the collected data.

The UAV obtained a mosaic of orthophoto, a three-dimensional model, a digital elevation model (DEM), and a 3D point cloud. An orthophoto provides data for image processing algorithms, consists of DEM provides elevation data from the terrain surface and DSM or

DTM. DSM contains elevation data of features on the ground surface (digital surface model). The DTM contains data of ground elevation (digital terrain models). This model considers a three-dimensional cloud point obtained from the onboard sensor of UAV. The DTM and DSM subtraction resulted in the elevation model consisting of only the above-ground objects called digital-differential-model (DDM), or canopy-height-models (CHM) (Pádua *et al*., 2017).

Atmospheric conditions may interfere application of remote sensing techniques to obtained aerial data. The adverse weather condition in the climatic zone with abundant water vapor in the atmosphere will become constrained to capture a clear image from optical remote sensing instruments. These situations cause difficulties in the interpretation of remote sensing imagery. Radar-based remote sensing may change optical remote sensing implementation. It will be no constraint for obtaining the image according to the case of atmospheric unclear (Liu *et al*., 2019).

Epilogue

Currently, the interest of the young generation to work in the agriculture sector is low. In many countries, agriculture production involves mainly older people. There are opportunities to develop smart farming activity will be interesting for the young generation. They are promoting farming activities that are related to automation, information technology, internet application, using drones. Some farming practices implement high technology. Those are a smart greenhouse, hydroponic techniques, aeroponics technology, and aquaponics technology.

We are Faculty of Agriculture UPNVY promotes a tagline," Bringing knowledge for a better future." It is elevating the interest of students to be sure that with a better understanding of agriculture, it will bring them to a better future. The knowledge provided for the students is modern agriculture, urban farming, aquaponics, tissue culture, GIS, and remote sensing. We have implemented such a curriculum since 2017. We have several students who did their thesis with the topic of sensors for smart greenhouse.

We have the data that the animo of new students to apply for an agro technology program study have increased, and even the entry competition is much thought. It was a significant update that the interest of the young generation to learn agro technology has raised. It might be related to the millennial generation that is interested in modern agriculture.

Conclusion

Farming under the industrial revolution 4.0 era is a promising pathway to increase the sustainability of agriculture by increasing farm profitability, reducing manual labor, and reducing environmental impact. This revolution in the agriculture sector may enhance productivity through automation, unmanned farming, and eco-friendly farming.

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