AGRICULTURE 4.0 – CONCEPTS, TECHNOLOGIES AND PROSPECTS

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Abstract

Agriculture 4.0 is seen as a new possibility in overcoming the global challenges related to the scarcity of resources, climate change and food security. In this context, the aim of the paper is to outline the main definitions, concepts, technologies and trends in Agriculture 4.0 development and discuss the challenges, as well as opportunities and prospects. Based on the literature overview, it can be concluded that Agriculture 4.0 will play a crucial role in transforming the agri-food sector and shaping future agricultural production models. On the other hand, the new concepts should be linked to the Green Deal and sustainable development goals to ensure a fair and resilient agricultural system. Along with the benefits of Agriculture 4.0, there are challenges associated with farmers' perceptions and ability to change, the development of infrastructure, especially in rural areas and the lack of standards for implementing the new technologies. The government and policymakers' role is essential and should be directed in supporting the implementation of the concept Agriculture, 4.0.

Key words: *digitalization, innovation, sustainable development*

INTRODUCTION

Agriculture is considered a key sector providing food for the growing population and ensuring the viability and resilience of rural areas. On the other hand, agriculture is facing a number of global challenges related to the scarcity of resources, climate change and food security, combined with the COVID-19 pandemic.

In this context, the European Green Deal and Farm to Fork strategy focus on agricultural models oriented towards the transition to a clear circular economy [15].

Therefore Agriculture 4.0 is seen as a new possibility in overcoming these global issues. Agriculture 4.0 as a term is related to different concepts such as digital agriculture, smart, vertical and precision farming [4, 22, 26, 27, 43, 61]. In addition, it is expected that Agriculture 4.0 will impact the production systems and agricultural supply value chain. [5, 16, 50, 57]

Along with the number of benefits related to increased productivity and environmental protection [2, 41, 51], some authors outline challenges associated with the social effect of digitalization [19, 37, 48].

The paper aims to outline the main definitions, concepts, technologies, and trends in Agriculture 4.0 development and discuss the challenges as well opportunities and prospects.

The study is structured as follows: First, the applied materials and methods are presented. The second part shows the definitions, concepts and technologies related to Agriculture 4.0. The main challenges and barriers are also outlined. In the third part, some conclusions and recommendations are highlighted.

MATERIALS AND METHODS

The study is based on the theoretical framework presented by de Alcantara et.al [9]. The survey applied discourse analysis. The method is related to the institution's discourses that foster new technologies implementation [36].

In order to observe the challenges in Agriculture 4.0 implementation the study uses the proposed by European Commission Digital Economy and Society Index (DESI). The indicator monitors key digital policy areas and tracks country profiles. According to European Commission data DESI includes a three-level structure with four sub-dimensions: Human capital, Connectivity and Digital public service [14]. The data is based on the DESI key indicators dataset.

RESULTS AND DISCUSSIONS

Origin and drivers for Agriculture 4.0 development

Agriculture always has played an important role in humans' livehood. The new technologies that influence farm models have a long history of development. Zhai et al. [65] mark four stages of agricultural transformations. Agriculture 1.0 is labour intensive and related to animal forces use. Agriculture 2.0 is associated with different agricultural types of machinery. Various chemicals are also introduced. However, these trends increased productivity but also caused environmental harm and waste of resources [65].

Computer technologies led to the development of Agriculture 3.0 in the 20th century. The application of chemicals was reduced. The sustainable agricultural development concept was introduced [47]. However, the global challenges the world faces alongside the rapid development of digital technologies [5, 18] emerged Agriculture 4.0.

A number of global challenges influence the sustainability of the agricultural system. According to [10], four main drivers stressing agriculture and requiring new farming models and the implementation of Agriculture 4.0: growing population, climate change, food waste and resource scarcity.

United Nations World Population Prospect [58] indicates that the population will increase to 10 billion by 2050. This latter will lead to growth in food demand. Based on FAO data [17], agriculture will have to provide 70% more food by 2050. These trends require increased productivity and efficiency. By contrast, 33% to 50 % of produced food becomes a waste [17].

In this regard, food security remains a huge issue causing poverty and hunger. According to World Health Organization [62], 700 million people are extremely poor, and 800 million are chronically hungry. The clime change impacts agriculture and decreases yield due to the higher temperatures [20]. In addition, the Intergovernmental Panel on Climate Change (IPCC) concluded that greenhouse gas emissions from agriculture and forestry are doubled over the past 50 years [25]. In order to decline the environmental impact of agriculture and adapt to climate change, new farm models have to be proposed.

According to De Clercq et al. [10], Green Revolution and new technologies have increased agricultural production three times since 1960. However, overcoming the global challenges requires not only changes in agricultural practices but also new business models and new political agenda in rural areas.

Definitions and basic concepts

The term Agriculture 4.0 is closely linked to other concepts in scientific literature and is even used as a synonym of smart agriculture, digital and precision farming [7]. Agriculture 4.0 is introduced and explained based on different dimensions and perspectives.

Based on the literature review, Sponchioni et al. [54] outline six standpoints for Agriculture 4.0 definition: the first perspective defines Agriculture 4.0 as an evolution of precision farming. Klerkx et al. [27] consider that smart farm, precision agriculture, and agriculture 4.0 have the same meaning. In addition, Kong et al. [29] pointed out that agriculture 4.0 can improve precision agriculture.

Second perspective links Agriculture 4.0 to Industry 4.0 [3, 40, 64]. Liu et al. [31] observed the relations between Agriculture and Industry in the context of lessons learned from industrial revolutions.

The third dimension presents Agriculture 4.0 related to the digitalization of agriculture and digital technologies. Fielke et al. [19] outline the importance of interaction between digital technologies and farm management.

Forth perceptive defines Agriculture 4.0 as an opportunity for new farm models to integrate data and decision making. By Decision Support Systems implementation, Agriculture

4.0 is based on mathematics and less on beliefs and intuition [34, 39, 55].

The fifth concept is beyond the farm gate and links Agriculture 4.0 to the food value chain. The Agriculture 4.0 technologies are helping farmers to connect with the other actors in the food value chain [33, 60].

The sixth perceptive presents Agriculture 4.0 in context to its main objectives. Different authors highlight that Agriculture 4.0 increases profitability and ensures the sustainability of farming [11, 64].

The main definitions that reflect these six perspectives are presented on Table 1. Based on literature review some authors present own definition aiming to integrate all dimensions of Agriculture 4.0 [35, 54].

Table 1. Summary of Agriculture 4.0 definitions and perceptive

Authors	***Definition***	***Perspective***
Monteleone et. al. [45], p. 3	*„This concept appeared at the beginning of the 21st century, as an evolution of the PA concept through the diffusion of IoT“*	Agriculture 4.0 as a Precision Farming Evolution
Piwowar, [45], p. 170	*“Similarly to the concept of Industry 4.0, the transformation process in Agriculture 4.0, aimed at increasing competitiveness, is also implemented through the use of modern information technology”*	Links Agriculture 4.0 to Industry 4.0
Sott et.al.[53], p. 149855	*„ refers to the use of information and communication technologies such as Big Data and Analytics to explore the variability of data and use it to deal with changes in the agricultural scenario“*	Agriculture 4.0 and digital technologies
Kong et. al. [29], p. 2	*“Agriculture 4.0 also improve the agricultural system’s responsive performance with accurate decision making in response to operational uncertainties and real time data updates. “*	Agriculture 4.0 and decision making
Kovács, Hust,[30], p. 38	*“It is broader and more comprehensive, as it seeks to integrate all actors in agri-food production through a technological value chain.*	Agriculture and food value chain
Huh and Kim, [24], p. 8	*“represents the use of emerging technologies to create a value chain to integrate organizations, farmers, customers, and all stakeholders in favour of economic, social, and environmental sustainability.*	Agriculture 4.0 and its main goals

Source: Own survey based on [8, 54].

There is not globally accepted definition of Agriculture 4.0 and the concept is transforming and shifting towards sustainability and inclusion. [48, 49, 65]. However, the term agriculture 4.0 is still developing and evolving [27, 64].

Agriculture 4.0 Technologies

Agricultural 4.0 technologies are important in implementing smart specialisation and innovation strategies. Different authors outline different core technologies and use various classifications. Ting et al. [56] and da Silveira et al. [8] divided agricultural production into subprocesses and defined the technologies as pre-field, in-field, post-field.

Pre-Field are directed to seeds and genetic development and include sensing technologies and the Internet of things [26].

In-Field technologies are related to planting and harvesting [56] and associated geoinformatics, new hardware and software. Wolfert et al. [59] point out that with the implementation of machinery and sensors on the farms, decision–making is guided by data. Ferrandez-Pastor et al. [18] consider that the Internet of Things could help farmers' management.

Post-Field technologies are linked to distribution, processing, and consumption [56]. This stage relates to AIoT, blockchain, cloud computing, and big data. Zhai et al. [65] highlight that the optimisation of the supply value chain is one of the most effective approaches to overcome issues with food waste.

Based on the literature review, Araújo et al. [1] define the core technologies in Agriculture 4.0. The authors show the data flow between the core technologies and users. On that base, five stages and types of technologies are identified: sensor and robotics; Internet of Things; cloud computing; data analysis and decision support system.

Based on the new technologies in the future, farms will be run very differently, allowing higher profitability and efficiency. On the other hand, the lack of globally accepted definition and policy challenges Agriculture 4.0 implementation.

Main challenges and barriers

Although Agriculture 4.0 is a widely discussed topic and the benefits of its implementation are identified in scientific literature, there are a number of challenges for developing the new concept.

Based on the literature review, da Silveira [8] divided the main barriers of Agriculture 4.0 implementation into five dimensions: technological, economic, political, social, and environmental. As technological barriers can be considered operational and technical problems [12, 18]. Other issues are associated with managing information and data [3, 59, 65]. The implementation of Agriculture 4.0 requires the development of infrastructure in rural areas, and the lack of it is seen as a significant challenge [3, 6, 64].

The main economic barriers are linked to the high investment costs [12, 18, 44]. The social and environmental implications may also lead to potential costs that is challenging agriculture 4.0 implementation and diffusion [21, 49]. Another essential economic factor is skilled labor costs [18].

Political barriers include differences in the politics created by developed and developing countries [42]. Another issue is the lack of policies that promote start-ups [64] and farmer-centred approaches [38]. Social barriers are related to a lack of highly qualified labour with technical knowledge and digital skills [18, 27]. Another critical factor is training and qualification [64].

Environmental barriers are linked to the capability of Agriculture 4.0 technologies to influence the climate and the behaviour of the system (Braun et al., 2018; Grieve et al., 2019). The limited acceptance of agricultural technologies are also a challenge [32, 50].

One of the main barriers to Agricultural 4.0 implementation is the infrastructure and digital skills. They are a significant issue for the development of the concept. In this regards Table 2 presents the DESI-total score as an indicator for Member States of the EU digital progress and the development of digital society.

Based on the data, several conclusions can be drawn. The indicator's highest level is registered in Denmark, followed by Finland, Sweden, and the Netherlands. By contrast, there are many Member-States, which are below the EU. The lowest score, however, is recorded in Bulgaria and Romania.

The 2030 target of the EU is at least 80% of people to have at least basic digital skills [13]. On the other hand, in 2021, only 56% possess basic digital skills [14].The increase in digital competence is low and lagging behind the EU goals for the analyzed period.

The observed trends explain the low level of Agriculture 4.0 implementation and serious challenges in rural areas in Bulgaria and Romania [63].

It should be outlined that having an Internet connection and using the Internet is insufficient. Implementing new concepts like Agriculture 4.0 requires appropriate skills and competencies.

Another barrier for Agricultural 4.0 development is associated with digital infrastructures. Denmark registers the highest score in connectivity, followed by the Netherlands and Spain. Greece and Bulgaria have the weakest score in the Digital infrastructure dimension [14]. In rural areas, digital infrastructure and digital competencies remain serious challenges.

Table 2. DESI-total (aggregate score, %)

Countries	2016	2017	2018	2019	2020	2021
Austria	38.9	42.6	45.2	47.7	50.2	56.9
Belgium	38.9	41.6	44.1	46.1	51.1	53.7
Bulgaria	26	28.1	30.9	32.7	34.4	36.8
Cyprus	29.4	32	34.6	37	39.3	43.5
Croatia	30.1	33.1	35.3	38.4	40.5	46
Czech Republic	33	34.9	38.4	41.1	43.7	47.4
Denmark	50.1	53.3	54.8	57.9	61.8	70.1
Estonia	44.4	46.5	49.5	52.1	54.7	59.4
Finland	49.5	52.1	55	58.1	62.8	67.1
France	35.3	38	40.7	44	47.2	50.6
Germany	38	39.9	42.2	45.1	49	54.1
Greece	23.5	26	27.8	30.1	32.9	37.3
Hungary	29	31.6	33.5	35.3	38.5	41.2
Ireland	40.3	43.3	46.8	49.1	54.1	60.3
Italy	29.8	32.8	35.3	38.5	40.8	45.5
Latvia	38.5	40.9	43.2	44.5	47.2	49.5
Lithuania	37.6	40.4	44.3	46.7	49.4	51.8
Luxembourg	44.1	47.3	49.3	51.5	55.5	59
Malta	43.1	45.2	48	52	56.5	59.6
Netherlands	45.9	49.1	52.1	54.5	58.9	65.1
Poland	26.2	28.8	31.5	33.9	37.6	41
Portugal	36.8	39.3	42.1	44.3	47.5	49.8
Romania	21.4	23.2	25.7	27.1	30	32.9
Slovakia	30.6	33.4	36.3	37.7	39.7	43.2
Slovenia	38.1	40.5	43	45.9	48.2	52.8
Spain	39.7	42.9	46.3	49.6	52.7	57.4
Sweden	48.3	50.9	55.3	58.4	61.6	66.1
EU	35.3	37.9	40.6	43.1	46.3	50.7

Source: European Commission [14].

Among the main advantages Agriculture 4.0 can be considered increased financial returns [24, 28], reducing costs [44].

On the other hand, there are environmental benefits such as reducing waste, water, and energy [21, 46, 65]. Social benefits are related to farmers' security [59] and jobs creation in the agricultural sector [46].

By contrast, as disadvantages of agriculture 4.0, some studies point out risks in implementing new technologies [44] and exclusion or discrimination against the not digitally skilled farmers [27].

In addition, Klerkx and Rose [26] also outline the difficulty in assessing the environmental, social, and economic impacts on Agriculture 4.0 diffusion.

In this regard, the main challenges should be analyzed and observed to stimulate and encourage the Agriculture 4.0 implementation.

Therefore, coordination between governments, investors and other stakeholders is needed [23, 52].

CONCLUSIONS

Agriculture 4.0 is considered a central pillar in shaping the future agri-food sectors. The concept is related to economic benefits such as optimising agricultural production, supply-chain and distribution. In addition, the term is linked to new opportunities in the labour market and new types of business models. Environmental benefits are associated with the rational use of resources and chemical products.

This study is directed to analysing the development of agriculture 4.0 - main definitions, technologies, barriers, challenges and opportunities. Based on the survey, it can be concluded that agriculture 4.0 is defined differently based on the researchers' perspective and agenda.

Alongside the emerging technologies and benefits, a number of challenges are outlined. The future of Agriculture 4.0 should be directed to establishing strategies to overcome the challenges and barriers and define the actors related to these barriers.

Agriculture 4.0 is changing governments, policymakers, and other stakeholders' perspectives on agriculture. Governments will play a key role in shaping the environment for Agriculture 4.0 development. In order to overcome the global challenges, agricultural production and distribution models should shift towards an innovation- and knowledge-based agenda.

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