Üçüncü Sektör Sosyal Ekonomi Dergisi
Third Sector Social Economic Review
58(3) 2023, 2553-2572
doi: 10.15659/3.sektor-sosyal-ekonomi.23.09.2245

Research Article

Effects of Industry 4.0 Applications on The Agriculture Sector And Economic Growth

Endüstri 4.0 Uygulamalarının Tarım Sektörü ve Ekonomik Büyüme Üzerine Etkileri

Çisil ERKAN BAL	Hasan Çebi BAL
Doktora Öğrencisi, İstanbul Üniversitesi Sosyal Bilimler Enstitüsü cisilerkan@ktu.edu.tr https://orcid.org/0000-0001-8413-8012	Dr. Öğr. Üyesi, Karadeniz Teknik Üniversitesi İktisadi ve İdari Bilimler Fakültesi hbal@ktu.edu.tr https://orcid.org/0000-0002-9568-6740

Makale Geliş Tarihi	Makale Kabul Tarihi
16.08.2023	**06.09.2023**

Abstract

From the Neolithic era, when human communities first began practicing agriculture, to the present day, there has been a significant shift in the agricultural production process from traditional farming to 3D printing. Throughout the course of history, all industrial revolutions have inevitably influenced the agricultural sector. It is well-known that agriculture has faced significant pressures related to demographics, natural resource scarcity, climate change, and food waste. With the rapid growth of the world population, the risk of agricultural production, especially food production, falling short has increased, making it increasingly important to address agricultural production issues. To address these issues, new methods and production technologies have been required in the agricultural sector.

The purpose of this study is to investigate to what extent Industry 4.0 applications will be effective in solving the existing problems in agricultural production. The study discusses the challenges that adversely affect global agricultural production. The literature on Industry 4.0 applications currently used in the agricultural sector is reviewed, and the possible future effects of these applications on the agricultural sector and overall economic growth are examined.

In this context, the study explores the areas in which Industry 4.0 applications are currently being used in agricultural production, their contributions to production, and their potential effective role in solving problems. These applications are expected to have a positive impact on economic parameters such as production, efficiency, and competitive advantage, ultimately benefiting economic growth. Furthermore, with the use of other new agricultural production methods such as vertical farming and automation, it may be possible to ensure sufficient food production for the world's population in the future. Industry 4.0 applications contribute to solving problems such as preventing an increase in food prices by increasing production, eliminating the risk of scarcity, reducing costs by using fewer inputs in precision farming, reducing environmental pollution, and transitioning to robotic applications in areas where labor supply is challenging. The result of digitization in the agricultural sector due to these applications is leading to unprecedented major economic changes with significant economic impacts.

Keywords: *Industry 4.0, Agriculture, Food supply, Economic growth, Economic impacts.*

Öz

İnsan topluluklarının ilk kez tarım yapmaya başladığı neolitik çağdan günümüze kadar, geleneksel tarımdan 3D yazıcılara tarımsal üretimin kurgulandığı oldukça farklı bir endüstriyel tarım süreci yaşanmaktadır. Tarihsel süreç içerisinde yaşanan tüm sanayi devrimleri kaçınılmaz olarak tarım sektörünü etkilemiştir. Bilindiği üzere

Önerilen Atıf /Suggested Citation
Erkan Bal, Ç. & Bal, H. Ç., 2023, Effects of Industry 4.0 Applications on The Agriculture Sector And Economic Growth, *Üçüncü Sektör Sosyal Ekonomi Dergisi*, 58(3), 2553-2572.

tarımsal üretim üzerinde yoğun bir şekilde demografi, doğal kaynakların kıtlığı, iklim değişikliği ve gıda israfının baskıları olmuştur. Dünya nüfusunun hızla artması karşısında tarımsal üretimin, özellikle gıda üretiminin yetersiz kalması riski ve tarımsal üretimde sorunların çözümü, giderek daha önemli hale gelmiştir. Sorunların çözümü için tarım sektöründe yeni yöntemlere ve yeni üretim teknolojilerine ihtiyaç duyulmuştur.

Bu çalışmanın amacı; Endüstri 4.0 uygulamalarının, tarımsal üretimde karşılaşılan mevcut sorunların çözümünde ne ölçüde etkili olacağını araştırmaktır. Çalışmada dünya tarımsal üretimini olumsuz etkileyen sorunlar tartışılmıştır. Günümüzde tarım sektöründe kullanılmakta olan Endüstri 4.0 uygulamalarına ilişkin literatür incelenmiş, bu uygulamaların gelecekte de tarım sektörü ve genel olarak ekonomik büyüme üzerindeki olası etkileri üzerinde durulmuştur.

Bu çerçevede günümüzde Endüstri 4.0 uygulamalarının tarımsal üretimde hangi alanlarda kullanıldığı, üretime katkısı ve sorunların çözümünde oynayacağı etkin rol araştırılmıştır. Bu uygulamaların, üretim, verimlilik, rekabet üstünlüğü gibi ekonomik parametreleri ve ekonomik büyümeyi olumlu etkilemesi beklenmektedir. Ayrıca dikey tarım, üretimde otomasyon gibi diğer yeni tarımsal üretim yöntemlerinin kullanılmasıyla gelecekte gıda üretiminin insan nüfusuna yetecek düzeye ulaşması mümkün olabilecektir. Üretimi artırarak gıda fiyatlarının yükselmesinin önüne geçilmesi, kıtlık riskini ortadan kaldırması, hassas tarımla üretimde daha az girdi kullanarak maliyetlerin düşürülmesi, çevre kirliliğinin azaltılması, işçi temininde zorluk yaşanan alanlarda robotik uygulamalara geçilmesi gibi sorunların çözümüne katkı sunan Endüstri 4.0 uygulamaları; işgücüne duyulan ihtiyacı azaltarak, yeni bir üretim biçimini ortaya çıkarmaktadır. Bu uygulamaların sonucunda tarım sektöründe ortaya çıkan dijitalleşme, önemli iktisadi etkilerle tarihte eşi görülmemiş büyük değişimlere yol açmaktadır.

Anahtar Kelimeler: *Endüstri 4.0, Tarım, Gıda arzı, İktisadi büyüme, İktisadi etkiler.*

1. Introduction

Agricultural production holds significant importance for various reasons, including meeting the essential food requirements for human survival, providing input for other industries, generating employment, positively impacting income distribution, and reducing poverty.

The world is facing the risk of not being able to meet the increasing demand for agricultural production due to reasons such as waste, global climate change, and conflicts. To address the decreasing agricultural production and fulfill the growing food demand, more efforts and new methods are required. In this context, the importance of Industry 4.0 applications, also known as the Fourth Industrial Revolution, becomes even more pronounced.

While Industry 4.0 is built upon innovations and inventions from previous revolutions, it significantly diverges from them in many aspects. Artificial intelligence applications, the Internet of Things (IoT), excessive computing power, and full automation have started to exclude labor and human control in Industry 4.0 applications. Technological developments in this process continue to enhance the power and control of artificial intelligence.

Today, the impacts of Industry 4.0 applications on global agricultural product supply, whether agricultural production will be sufficient to feed the population, whether it will meet the input needs of other sectors, and its effects on economic growth, employment, and poverty reduction, have become increasingly important.

Revolutionary new methods and inventions have led to four industrial revolutions since the 1700s. Industry 4.0 has begun to profoundly impact the world economic system. Industry 4.0 has begun to deeply affect the global economic system. In agriculture, along with new knowledge and methods, the production process has also changed with the use of new tools, artificial intelligence applications, and robots, resulting in significant increases in production.

With Industry 4.0 applications, the agricultural sector worldwide is rapidly digitalizing. The direct positive effects on economic growth are evident due to increased productivity, production quantity, and production quality. It is anticipated that production will continue to increase in the future.

2. Objective and Method

In the future, the quantity of production inputs and production volume in the agricultural sector will be crucial. Among the topics covered in this study are the dimensions of unemployment that will be reached in this sector, as in other sectors, as well as the economic effects of productivity, production quantity, and new production methods.

The aim of this study is to reveal the effects of Industry 4.0 applications in solving the problems affecting global agricultural production negatively. The literature related to Industry 4.0 applications in the agricultural sector has been reviewed, and the economic effects of these applications have been examined.

In this regard, the study is not only important for changing economic structures but also for its impact on food security, economic growth, and national economies. In addition to the economic importance of the agricultural sector, the study is expected to be beneficial in proposing suitable measures for potential problems and recommending appropriate precautions concerning the potential positive and negative outcomes of new agricultural practices on a global scale.

3. The Importance of The Agricultural Sector in Terms of Economic Growth

The concept of agriculture is defined by the Turkish Language Association (TDK, 2023) dictionary as "the production of agricultural and animal products, the improvement of their quality and yield, their proper preservation, processing, and marketing, agriculture, culture." In another definition, agriculture is expressed as "activities undertaken in a certain biological and socio-economic environment to obtain the animal and plant products necessary for human nutrition" (Uzundumlu, 2012, p. 35). As indicated in this definition, activities aimed at nutrition are not only essential for the continuation of human life but also crucial for the functioning of the economic system.

Agriculture is a sector of strategic importance in terms of national security (Özertan, 2014, pp. 210-211). The need to ensure food security and eliminate the risk of hunger and famine is a matter of national security for countries. Every nation prioritizes efforts to attain economic self-sufficiency, fostering self-reliance in the production of essential agricultural goods, and diminishing reliance on other countries. These objectives are crucial for bolstering both national security and economic independence. Additionally, the agricultural sector is known to have functions such as providing the workforce from the population it feeds, contributing to the increase in the country's GDP, enabling exports, having a positive impact on income distribution, and reducing poverty (Doğan, 2009a, p. 366; Byerlee et al., 2009, p. 3).

Agricultural production has positive effects on economic growth due to its contributions to increasing food supply, agricultural product exports, income, and foreign exchange income (Johnston & Mellor, 1961, p. 571). The necessity of nutrition for the continuity of life makes the agricultural sector important, and countries support the agricultural sector by channeling significant resources when needed to make the production of food items possible (Acar, 2006, p. 23).

Under the United Nations' Millennium Development Goals adopted in 2000, agriculture holds a central position in reducing poverty, promoting gender equality, and ensuring sustainable environmental management (Byerlee et al., 2009, p. 3). The contributions and economic importance of the agricultural sector emerge in four main categories: products, markets, production factors, and foreign exchange (Doğan, 2009a, p. 367; Byerlee et al., 2009, p. 15).

3.1. Contribution to Escaping Dependency and Achieving Self-Sufficiency Strategy

In today's world, risks such as inadequate global food supply and famine as seen in the Russia-Ukraine War, natural disasters, decreases in product supply caused by global climate change, and the failure of food product supply to increase in parallel with the growth of the world population, coupled with the depletion of agricultural stocks, have led to rising food prices and concerns among nations. To avoid dependency on other countries for meeting their agricultural product demand, all countries set the production of a self-sufficient quantity of agricultural products as a strategic goal (Acar, 2006, p. 23). In terms of allowing the economic structure to continue functioning without succumbing to these risks, the agricultural sector is an important sector that eliminates security vulnerabilities for the country (Tutar, 2021, p. 121; Lowenberg-DeBoer, 2022, p. 1).

3.2. Contribution to Poverty Reduction

The increase in the number of labor force working in the agricultural sector and the increase in their income have an important role in economic growth and in reducing poverty in the country (Byerlee et al., 2009, p. 15). Since a significant portion of the impoverished population resides in rural areas and is

part of the agricultural workforce, the income generated from food production has a substantial effect on reducing poverty (Doğan, 2009b, p. 26).

3.3. Product Contribution

Agriculture not only meets individuals' consumption needs but also provides input to the industrial sector (Thirlwall, 1999, p. 128; Erbay, 2013, p. 8). In other words, the forward linkage effect of the agricultural sector is quite high. For example, leather required in sectors like shoemaking; grains and similar cereal products needed for ready-made foods; tomatoes and beans for canning production; and cotton and silk required for the textile industry are supplied from the production in the agricultural sector.

3.4. Market Contribution

The importance of the purchasing power of the agricultural sector is significant in terms of creating a market for products produced by the industry and other sectors. The purchasing power of the population in the agricultural sector enables the purchase of goods and services produced in other sectors. The monetary expenditures made by the population in the agricultural sector for goods and services constitute the revenues of these firms (Doğan, 2009a, p. 369). Equipment produced for use in the production of food products, such as tractors and machines, as well as fertilizers and chemicals, are also purchased by the agricultural sector. The sale of these goods and services produced in the industrial sector and the continuation of their production depend on the sustainability of production in the agricultural sector. All these effects directly impact economic growth.

3.5. Contribution as a Production Factor

The agricultural sector makes significant contributions to providing labor, capital, and natural resources to other sectors. Some inputs required for production, such as raw materials needed by the industrial sector, are provided by the agricultural sector. Due to rapid population growth and mechanization in developing countries, surplus labor in the agricultural sector is shifting to other sectors. Therefore, the labor demand of other sectors is met by this sector. Large companies and individuals engaged in production in the agricultural sector, when transformed into investments in the industrial sector, allow the sector to invest more and grow further (Winters et al., 1998, p. 75; Karlı et al., 1996, p. 208-209).

3.6. Contribution to Foreign Exchange

Especially developing countries need foreign exchange for the import of intermediate and capital goods for production purposes. However, the foreign exchange resources of developing countries are limited. A country that produces the agricultural products needs for its citizens' consumption, primarily eliminates the need to import these products. This means saving on foreign exchange payments for imports. Similarly, a country that produces the agricultural products needed for industrial production purposes also saves on the foreign exchange required for the import of these products. To increase limited foreign exchange resources, countries need to produce and sell these products to other countries. The production and export of agricultural products provide an opportunity to supply the foreign exchange input that the economy needs (Byerlee et al., 2009, p. 15).

To understand the place of agriculture in the world economy, it would be useful to consider data related to global agriculture. In 2020, only 4.3% of the world's Gross Domestic Product (GDP) was generated by the agricultural sector. As seen in Table 1, the highest share, 64.8%, belongs to the service sector. The low share of agriculture in GDP is also related to the low prices of agricultural products in those years.

Table 1: Sectoral Ratios of World Gross Domestic Product (%)

Years	Agriculture	Industry	Manufacturing	Services
2010	3,9	27,5	15,9	62,7
2020	4,3	26,0	15,9	64,8

Source: World Bank, 2022a.

During the years 2000-2002, the agricultural sector, which accounted for 39.3% of total global employment, had decreased to 28.3% of total employment during the years 2014-2016 (World Bank, 2022b). Despite the declining employment rate due to mechanization in agriculture, the sector still employs nearly one-third of the global workforce and contributes to income generation. Therefore, the agricultural sector plays a significant role in reducing poverty.

4. Problems in Agrıcultural Productıon and The Causes of Insufficient Product Supply to Meet Demand

There are four main challenges that exert adverse pressure on agriculture in terms of meeting humanity's future food needs: demographics, scarcity of natural resources, climate change, and food wastage (De Clercq et al., 2018, p. 5). In addition to these four issues, other problems that hinder the current food supply from satisfying the growing food demand should also be considered. When these additional problems are taken into account, the factors contributing to the insufficiency of food supply are as follows:

1. Population growth
2. Depletion of natural resources
3. Global climate change
4. Covid-19 global pandemic
5. Russia-Ukraine war
6. Shortage of labor force in agriculture
7. Increased energy demand
8. High costs
9. Food wastage

The increase in the world's population leads to an increase in demand for agricultural products and, as a result of allocating agricultural lands to residential areas, a decrease in cultivable agricultural land and thus a decrease in supply. With the world's population approaching 8 billion and a decreasing amount of agricultural land worldwide, there is a risk that future agricultural production may not meet the global food demand. It is projected that by July 2023, the world's population will be close to 8 billion, reaching 8.5 billion by 2030, 9.7 billion by 2050, and 10.9 billion by 2100 (UNFPA, 2023, p. 12; UN, 2019, p. 5).

The increase in the world's population leads to two effects, resulting in the agricultural product supply being unable to meet product demand:

1. The need for more space for the increasing population's housing and other requirements leads to the allocation of land suitable for agriculture to residential purposes. The decrease in cultivable land then results in reduced production and, consequently, inadequate food supply.
2. The growing population leads to an increased demand for agricultural products, which in turn results in an insufficient supply.

In order to feed a world population approaching 10 billion in 2050, it is necessary to increase global agricultural production by 70% from the level in 2005 (FAO, 2009, p. 2). Some measures need to be taken to reduce this inadequacy in food and other agricultural product supply. Among these measures are reducing the increase in demand, increasing food supply without expanding agricultural land, increasing fish supply as an alternative food source, preserving natural ecosystems to protect production and nature, and reducing greenhouse gas emissions caused by agricultural production (Ranganathan et al., 2018, p. 1).

As a result of the inability of the world food supply to meet the increasing food demand, food prices have increased significantly. This situation has raised the risk of hunger and famine worldwide. Currently, events such as the Russia-Ukraine war, the Covid-19 global pandemic, global climate change, insufficient labor force in agriculture, depletion of natural resources, increased energy demand, high

costs, and food waste are causing a decrease in global food production, while the increasing world population is driving up global food consumption.

The natural resources required for agricultural production are decreasing (Tutar, 2020, p. 843). Among these natural resources, arable agricultural land and water are of utmost importance. The quantity of arable land in the world is decreasing (Ritchie, 2022, p. 1). Reasons for the reduction in arable land include urban expansion, the establishment of factories and similar production units on agricultural land, and the use of suitable areas for housing due to the growing population. The reduction in agricultural land leads to a decrease in agricultural production. Additionally, improper use, unbalanced fertilizer use, decreasing water resources, and climate change also result in a decrease in agricultural production (Kılavuz & Erdem, 2019, p. 134).

The temperature increase and fluctuations above the seasonal average caused by global climate change, as well as an increase in carbon emissions in the atmosphere, lead to a decrease in both plant and animal production. Moreover, excessive rainfall above seasonal norms affects plant production negatively due to soil erosion, while drought results in a decrease in the quantity and productivity of different agricultural products (Başoğlu, 2014, p. 180).

Starting from March 2020 due to the Covid-19 pandemic, measures such as lockdowns within countries and border closures between countries were implemented worldwide to minimize human contact and prevent the spread of the pandemic. These measures, which aimed to keep human contact at a minimum, such as lockdowns within countries and border closures between countries, also resulted in the inability of the workforce to continue production. During this period, just like in other sectors, there were difficulties in supplying the necessary workforce for the agricultural sector, leading to reductions in agricultural product supply (Narin, 2021, p. 52). Furthermore, problems and disruptions in the supply chain, as seen in other sectors, have not yet been resolved.

In 2020, which marked the beginning of the global pandemic, world food supply only grew by an annual rate of 1.9%, which is one of the factors causing food supply inadequacy (World Bank, 2021). The Covid-19 pandemic has rapidly brought artificial intelligence (AI) applications related to machine learning (ML) to the forefront of the business world (Ragazou et al., 2022, p. 1).

The Russia-Ukraine war, which began in 2022, significantly affects global food production. Ukraine, Russia, and Belarus are important agricultural producer countries in global agricultural production. Russia and Ukraine are among the top five global exporters of many important agricultural products such as wheat, barley, sunflower, and maize. With the war, a decrease in wheat shipments has emerged, causing importing countries to seek wheat from other sources at higher costs. Considering that Ukraine exports about 90% of its products from ports, the risk of Ukrainian farmers' products being spoiled, and the risk of scarcity in countries importing these products, is more apparent. Due to the war, the future of agricultural product production is uncertain. The death and migration of Ukrainian citizens due to the war also result in an unmet demand for labor in the agricultural sector. The refusals of Russia to allow agricultural products to exit Ukrainian ports and problems in agreements affect agricultural product supply negatively. Due to these problems, the inability of food supply to meet demand has led to inflation by increasing food prices (İstikbal, 2022, p. 4). Additionally, Russia, Ukraine, and other countries are imposing sanctions and restrictions on the export of certain agricultural products. Problems in global supply chains, which were already problematic since 2020 due to the Covid-19 global pandemic, are beginning to intensify further.

Difficulties in labor supply are experienced in some areas of the agricultural sector. In the United States, a 2017 study by the California Farm Bureau Federation (CFBF) stated that 55% of responding farmers faced problems in labor supply. It is also noted that 69% of farmers employing seasonal workers experienced difficulties in labor supply (CFBF, 2017, p. 1). The difficulty in labor supply (lack of labor supply) in agriculture negatively affects agricultural product supply.

Energy is required in all stages of food production processes (Martinho, 2016, p. 544). The energy requirement for all food chain processes from field to transportation, industrial transformation, and commercialization is increasing (Pereira, 2017, p. 2987).

In the future, high labor costs are expected in the agricultural sector (McCalla, 2001, p. 5). Due to the low supply of labor in the sector, the inability to meet labor demand will lead to high wages in the market. Both the depletion of natural resources and high-energy demand result in high costs and high prices.

Food waste occurs in all stages of food production and consumption. These wastes can be classified as food products lost for various reasons during the production process, such as collection and transportation, and edible food waste lost during consumption but preventable (Nordin et al., 2020, p. 1).

5. Industry 4.0 and The Digital Transformation of The Agriculture Sector

Efforts to increase food production quantity and efficiency have always held a significant place in human history. In 1974, electronic identification was introduced for farm animals in the United States, and in 1983, the government allowed civilian use of GPS. Computer-controlled VRT (Variable Rate Technology) fertilization was implemented in 1987, a milking robot was developed in 1992, and in 2006, automatic sprayer boom section controllers were introduced. In 2011, a weeding robot was invented, followed by the development of a combine harvester operator assistance system in 2013. In 2017, the production of the first completely autonomous field crop was achieved. In 2018, autonomous guidance systems began to be used in production, and by 2022, large-scale autonomous tractors became ready for use. These developments and similar ones have constituted significant stages in the transition to digital automation in agriculture (Lowenberg-DeBoer, 2022, p. 5).

Today, increasing efficiency and utilizing next-generation Industry 4.0 technologies will be crucial. In this context, the importance of preventing food waste, preserving the soil, slowing down the ripening process in agricultural products, and finding solutions for sustainable choices is evident. The use of Industry 4.0 applications in the implementation and monitoring of each stage of the measures to be taken offers the possibility of achieving highly effective results (Akay, 2018, p. 3).

The digital transformation brought about by Industry 4.0 applications has profoundly affected the production process and continues to do so. Smart farming applications are continuously evolving at an increasing pace (Mumtaz & Nazar, 2022, p. 23). During the Covid-19 pandemic, the need to minimize interpersonal contact has underscored the importance of Industry 4.0 applications, making the pandemic a "catalyst" for Industry 4.0 applications.

To increase efficiency in agriculture, it is necessary to collect production process data and analyze this data. As a result of the analysis, production is carried out with the help of artificial intelligence and robots managing complex structures, using the emerging technology of the Internet of Things (IoT).

5.1. Industry 4.0 Applications in Agriculture

Industry 4.0 applications are currently being used in the agriculture sector, enabling digital transformation. Precision farming applications that will continue to lead significant transformations in agriculture in 2023 and beyond include the following (StartUs, 2023):

1. Satellite technology,
2. Internet of Things (IoT),
3. Artificial intelligence (AI),
4. Variable Rate Technology (VRT),
5. Agricultural robotics,
6. Drones,
7. Big data and analytics,
8. Emission reduction technology.

Access to secure and high-quality data, real-time analysis over large areas, and live livestock tracking have greatly benefited from satellite technology.

The Internet of Things (IoT) is revolutionizing the agriculture sector by enabling machines to communicate and work together continuously (Aldağ et al., 2018, p. 3). IoT not only increases agricultural production but also enhances agricultural product quality, reduces labor costs, and boosts farmers' income by facilitating agricultural modernization (Xu et al., 2022, p. 1). IoT applications lead to water conservation in irrigation, monitor crop development, and track animal and plant life data. Additionally, IoT-connected smart agricultural machinery ensures continuous monitoring of production, including planting, cultivation, sowing, fertilization, pest control, feeding, irrigation, harvesting, and collection, to ensure agricultural product safety (Xu et al., 2022, p. 16-18).

In contrast to the previous decision-making process based on the farm manager's prior experience, artificial intelligence (AI) applications assist farmers, including real-time decisions, using data, including big data (Aldağ et al., 2018, p. 5). AI applications make data-driven, smart decisions in all stages of production, such as harvest management, crop management, pest and disease detection, soil and irrigation management, and weed control, reducing costs, increasing productivity, and minimizing post-production losses (Güzel & Okatan, 2022, p. 204-211).

Variable Rate Technology (VRT) is a technology that allows various applications to be made at different levels and in different areas in agriculture. For example, the water, fertilizer, and pesticide requirements of the soil vary in each region. Sensors at the front of the tractor, which determine these needs, allow the tractor to apply varying amounts of water, fertilizer, or pesticides as needed (Güler & Kara, 2005, p. 113). This practice increases efficiency, reduces costs, and minimizes environmental impact by using less water, fertilizer, and chemical pesticides (FAO, 2022, p. 63).

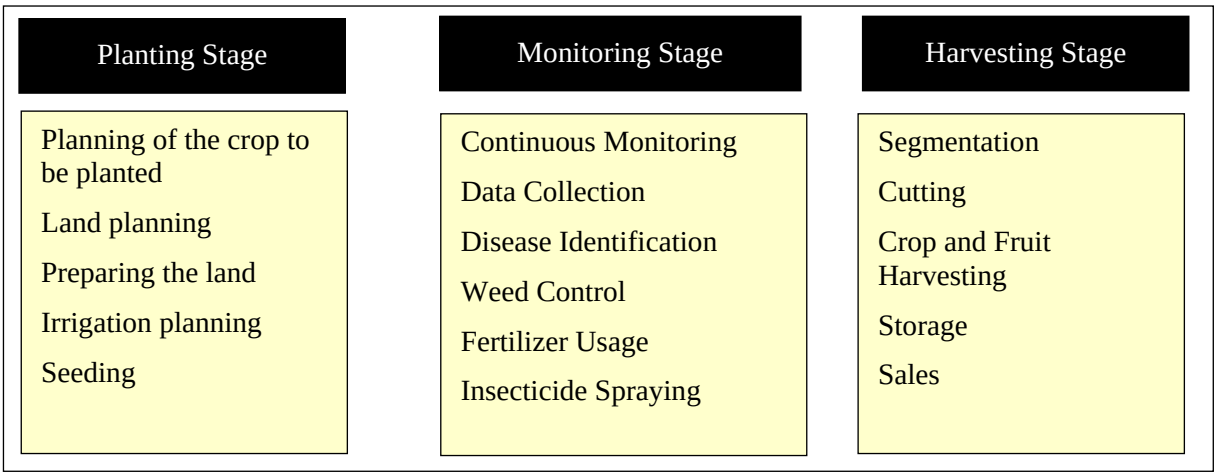
In smart agriculture, drones play a vital role in assessing the condition of agricultural products using aerial and near-infrared imaging techniques (Mumtaz & Nazar, 2022, p. 23). Robots instead of human labor now perform labor-intensive and repetitive tasks in the agricultural sector. Robot-assisted tasks include product harvesting and collection, disease and weed control, soil cultivation, irrigation, fertilization, and pesticide application, reducing the use of chemicals by up to 90% (Özgüven et al., 2022, p. 70). Robots can perform intensive processes in the production process, such as supervision and data collection, which can be more efficiently performed by computers. Robots with sensors and camera systems that remove weeds growing among plants also reduce the use of chemical pesticides.

To achieve better quality and higher yields in agriculture, reliable and adequate information is required. Smart decisions, such as which crops to plant to increase profitability and when to harvest, are crucial. These data, collectively referred to as big data (BD), are essential. Big data includes vast amounts of data generated from sensors and other devices, as well as data produced by social media and users. Developments in machine learning (ML), deep learning (DL), artificial intelligence (AI), and data science, combined with advances in computing power, have allowed for the performance of real-time analytical learning models and automated decision-making (Misra, 2020, p. 6306).

Incorporating Industry 4.0 practices in farming methods contributes to carbon sequestration, reduces emissions in the use of precise raw materials and storage areas, and promotes emission reduction (Misra, 2020, p. 6320).

Today, robots and artificial intelligence applications manage the process autonomously in solving various problems related to agricultural activities. These include product harvesting and collection, fruit processing, data collection and transformation, pest reduction, classification, sorting, and harvesting to prevent food waste, greenhouse production, weed control, autonomous harvesting, pruning, sowing, spraying, dilution, sorting, and packaging. Artificial intelligence monitors the process, makes decisions, and provides solutions, while tractors and other devices connected to the system perform the production (Wakchaure et al., 2023, s. 2). The application of artificial intelligence technologies in agricultural activities is illustrated in Figure 1.

Figure 1: Implementation of Artificial Intelligence Techniques for Agricultural Activities



Source: Wakchaure vd., 2023: 2.

Artificial intelligence methods such as fuzzy logic, artificial neural networks, genetic algorithms, particle swarm optimization, artificial potential fields, simulated annealing, ant colony optimization, artificial bee colony algorithm, harmony search, bat algorithm, cell decomposition, and firefly algorithm are applied during the planting, monitoring, and harvesting stages (Wakchaure et al., 2023, pp. 2-7). These methods aim to improve product quality, increase production quantity, reduce costs, and significantly minimize product losses, thus enhancing the profitability of farmers.

5.2. Agricultural Robots and Agricultural Production Worldwide

Digital technologies enable the analysis of large volumes of data that would be impossible to process manually and allow for the continuous monitoring of processes. Furthermore, digital technologies eliminate human error, ensuring the acquisition of consistently accurate data (Nezamova et al., 2022, p. 1). With these advantages, digital agriculture paves the way for producing more with lower costs and contributes significantly to solving issues in the agricultural sector. When advanced connectivity is established with devices used in agricultural production, the agriculture sector is one of the seven sectors that will increase the global GDP by 2 to 3 trillion dollars in the next ten years (Goedde et al., 2020, p. 2).

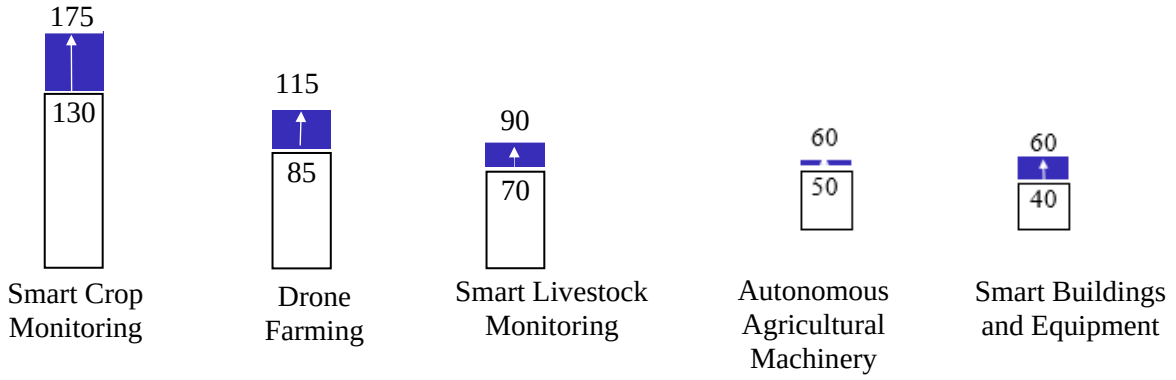
Robots that perform many tasks in agricultural production are machines that are injury-free, faster, capable of working for longer durations, and highly productive. They prevent product losses by harvesting products when there is a labor shortage. Today, robots are being increasingly used in agricultural fields due to many advantages such as waste reduction, error-free and precise operation capabilities, and low costs (Cope, J., 2023, p. 1).

The main areas of use for robots in the agricultural sector include vineyards, orchards, and fruit gardens, field crops, and livestock farming. In livestock farming, robots can perform tasks such as milking, feeding, feed pushing, bedding scraping, slurry scraping, bedding disinfection and ventilation, load carrying, grazing, and animal welfare operations (CEMA, 2022, p. 7).

In today's world, the technological connections between drones used in production, automatic agricultural machinery, and other devices are increasing with connections such as fiber networks, wide area networks (LPWAN), Wi-Fi 6, 5G, and radio frequency identification (RFID). These communication links between devices accelerate the digital transformation of agriculture in many ways, increasing GDP (Goedde et al., 2020, p. 2).

The use of connectivity in agricultural production improves the operation and maintenance of machines contributes to increased efficiency in production, optimization of inputs, and reduced overall expenses. Figure 2 predicts a global value increase of between 85 billion and 115 billion dollars in the agricultural sector by 2030 with the use of drones in production. Continuous monitoring of animal health and growth conditions will contribute between 70 billion and 90 billion dollars to agricultural production by 2030 (Goedde et al., 2020, pp. 2-6).

Figure 2: Estimated Global Potential Value Through the Use of Integrated Systems in Agricultural Production (By 2030), billion dollars

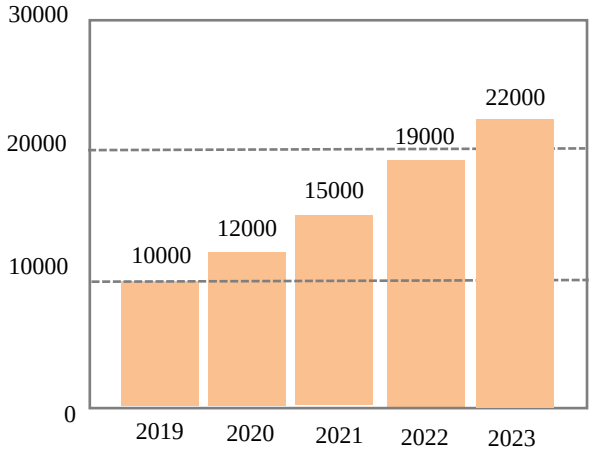


Source: Goedde et al., 2020: 6

By 2030, the total value of additional production obtained through the use of connected systems in agricultural production, along with direct and indirect results, will exceed 620 billion dollars, in an agricultural production industry with an estimated cost of around 120 billion dollars (Goedde et al., 2020, p. 9). The global market size of the agricultural equipment industry, which has a high level of internationalization, is estimated to be around 145 billion euros. Globally, agricultural machinery accounts for 46%, agricultural tractors for 35%, and parts and components for 19% of the global agricultural machinery market (CEMA, 2022, p. 4).

As seen in Figure 3, the annual sales of agricultural robots worldwide are on the rise. Agricultural robot sales, which were 10,000 units in 2019, reached 19,000 units in 2022, and it is expected to be 22,000 units in 2023 (CEMA, 2022, p. 7).

Figure 3: Annual Sales of Agricultural Robots Worldwide (Number of Units Sold)



Source: CEMA, 2022, 7.

According to a market research report, the agricultural robot market is expected to reach 83 billion US dollars by 2030, up from 8 billion US dollars in 2022, with an annual compounded growth rate of 33.70% expected during the forecast period of 2023-2030. The report lists countries covered by the agricultural robot market as the United States, Canada, Mexico, Germany, France, the United Kingdom, the Netherlands, Switzerland, Belgium, Russia, Italy, Spain, Turkey, China, Japan, India, South Korea, and other countries (DataBridge, 2023).

6. The Impacts of Industry 4.0 Applications in Agriculture on Economic Growth

The use of artificial intelligence applications resulting in smart agricultural automation, combined with sensors and agricultural machinery, leads to the digitization of production. New systems that enable machines to dominate production through the Internet of Things reduce human labor to a minimum. In this process of digitization that enables more production with fewer errors, various results affecting economic growth emerge. These impacts can be analyzed under two main headings: positive and negative effects.

6.1. Negative Effects

The increasing digitalization in agriculture has various negative effects in different areas. The primary and significant negative effect of digitalization is the reduction in employment (Lowenberg-DeBoer, 2022, p. 27; Öcal & Altıntaş, 2018, p. 2078). With digitalization, there will be less need for the workforce involved in manual, mechanized, or partially automated production in agriculture (Susskind, 2020, p. 259; Sergi et al., 2019, p. 8). The developments in this field will not create new job opportunities for the existing workforce (Acemoğlu, 2023, p. 7). Non-working individuals will have more time for themselves (Brynjolfsson & McAfee, 2014, p. 286). The implementation of smart technologies across sectors will lead to a gradual reduction in employment (Rifkin, 2019, p. 336). As a result of the integration of artificial intelligence, sensors, and machines, extensive data is analyzed, and production is optimized under the most suitable conditions. Consequently, the need for labor decreases significantly, and the system is controlled by artificial intelligence. This leads to a permanent reduction in employment in the agricultural production process.

Agriculture not only contributes to economic growth but also plays a crucial role in reducing poverty and inequality (Doğan, 2009b, p. 26). Income inadequacy is often associated with areas with a high concentration of impoverished individuals due to factors such as lack of education and the absence of social support systems (Mhlanga, 2021, p. 10). With the achievement of digitalization in agriculture, the demand for labor decreases. Therefore, the second negative effect of digitalization is the increase in poverty due to the permanent reduction in employment, leaving the previously salaried agricultural labor force without this income. While the decline in employment in the wage-earning sector resulting in a loss of income has negative consequences, it is possible to view positively the potential reduction of poverty in the future by providing a basic income for all unemployed individuals, especially in the contemporary discussions regarding universal basic income.

6.2. Positive Effects

The positive effects brought about by digitalization in agriculture through Industry 4.0 applications include the resolution of labor shortage, increased productivity, environmental impacts, cost reduction, enhanced competitiveness, increased production, more efficient functioning of logistics and supply systems, and poverty reduction.

The achievement of digitalization in agriculture provides a solution to the problem of labor shortage (labor supply inadequacy) and the difficulties encountered in labor procurement (Fao, 2022, p. 9).

The growing global population and the resulting issues of hunger and nutrition require increased productivity in agricultural production. Industry 4.0 applications enable the enhancement of productivity to address these challenges.

6.2.1. Environmental Impacts

Industry 4.0 applications in agriculture contribute to environmental preservation by promoting water conservation, reducing the use of harmful chemicals, and preventing soil erosion. This results in less harm to the environment in agricultural production processes (Bucci et al., 2018, p. 6; Arıcıoğlu et al., 2020, p. 6).

6.2.2. Cost Reduction

Digitalization at every stage of agricultural production leads to reduced use of inputs such as labor, fuel, seeds, water, and chemicals, thereby lowering unit costs. Software enables precise cost calculations that farmers can use to plan their production by understanding how various inputs affect costs. Increased

productivity per unit area reduces unit costs. Furthermore, price control, along with monitoring sales prices and profit margins at each stage, is tracked through barcode readers and integrated systems. Employers use Industry 4.0 applications to reduce production costs by employing fewer workers. For example, in 2015, in the city of Dongguan, China, there were only three employees responsible for controlling and monitoring the production lines. Just a few months earlier, 650 workers were employed to perform these tasks on the same production line (The Economic Times, 2015, p. 1). The use of robots in production has significantly reduced costs, equivalent to the payments made to 650 workers.

6.2.3. Increased Competitiveness

The agriculture sector, where digitalization is extensively applied, has higher competitiveness compared to other countries and regions due to reduced costs and higher product quality.

6.2.4. Increased Production

Several advantageous Industry 4.0 applications, such as increased production per unit area through more efficient combat against plant diseases and pests, obtaining more products from a unit area with big data, less spoilage and decay in agricultural products harvested by robots, and opening previously unproductive areas to agriculture through new information technologies, significantly enhance productivity in agriculture (Borowski, 2021, p. 10). Vertical farming and soilless agriculture practices also achieve higher yields with fewer resources.

6.2.5. More Efficient Logistics and Supply Chain Operations

Companies are focusing on creating value in response to increasingly informed customer requirements in terms of delivery times, product availability, and reliability. Industry 4.0 applications offer opportunities to meet customer needs by providing the latest solutions and contribute to the development of logistics and supply chain management (Witkowski, 2017, p. 769; Arıcıoğlu et al., 2020, p. 6).

6.2.6. Poverty Reduction

While the digitalization of agriculture may lead to reduced demand for labor, resulting in increased poverty, it also has several positive effects that can alleviate poverty. Low costs and low selling prices can increase the purchasing power of lower-income groups, reducing poverty (De Janvry et al., 2000, p. 2).

Additionally, the promotion of Industry 4.0 applications may encourage individuals who have migrated from rural to urban areas and are not using their land to return to their villages and engage in agriculture. This can lead to increased income and, consequently, a reduction in poverty. The increase in poverty due to the decrease in employment in the agricultural sector can potentially be offset by the implementation of a universal basic income, a concept widely discussed and debated in the literature.

Discussion and Conclusion

The world's population is continuously increasing. The agricultural sector is under pressure to feed the most dense population in history, which is expected to reach 10 billion by 2050. To feed this population in 2050, we need to produce more agricultural products than have been produced in the past 8,000 years of human history. It is essential for agriculture to be sustainable and compatible with nature in this production process. Otherwise, food problems will present even more severe consequences in the future.

The most significant challenges preventing the supply of agricultural products from meeting the demand include population growth, dwindling natural resources, global climate change, the COVID-19 global pandemic, the Russia-Ukraine conflict, labor shortages in agriculture, increasing energy requirements, high costs, and food wastage.

The components of the Fourth Industrial Revolution, Industry 4.0, continue to evolve and affect not only all sectors but also the agricultural sector. Artificial intelligence and robotic applications, in their new forms, continue to reshape and transform the production process, with both positive and negative effects such as increasing the quality and quantity of agricultural products, reducing raw material usage, and lowering costs, but also contributing to increased unemployment. The COVID-19 pandemic has highlighted the growing importance of Industry 4.0 applications in agriculture and accelerated their integration into the production process. The Russia-Ukraine conflict has led to a global food crisis,

demonstrating the validity of concerns about food security. These concerns provide a basis for countries to turn to new agricultural policies using new technologies to produce the agricultural products they need.

To feed the population, five main measures are essential in agriculture: robotic farming, soil preservation, ending food wastage, making smart choices, and slowing down the ripening process. Robots are used for repetitive tasks in agriculture. For example, three robots are used in planting, analyzing data obtained through monitoring, and spraying pesticides. These robots minimize the use of production inputs and reduce pollution. Robots used for soil preservation help retain air and water, allowing for efficient nutrient use and increased productivity.

To end food wastage, software programs that enable the sale of remaining but still edible products at reasonable prices to consumers are necessary. Industry 4.0 applications make it possible to prevent food wastage in both production and consumption stages. Food products lost during collection, transportation, and other stages, as well as food waste in consumption, can now be prevented. Slowing down the ripening process also helps reduce food wastage. Making smart choices involves governments and businesses making changes to planting, cultivation, production, harvesting, transportation, storage, and sales models. Taking these measures will increase food supply.

In areas where there are difficulties in providing for the agricultural sector and production disruptions, Industry 4.0 technologies have eliminated the need for labor with devices such as robots and drones. This has not only prevented labor shortages but also reduced costs and increased efficiency. While scarcity of natural resources, high energy and input requirements, and high costs have been associated with agricultural production inputs, new technologies have made it possible to reduce the quantity of inputs used and lower costs.

Collecting and analyzing data during the production process now enhances agricultural efficiency. IoT applications provide water savings from agricultural inputs, increase agricultural product quality, reduce labor costs, and increase farmers' income. IoT is used for product development and monitoring animal and plant life information. Smart agricultural machines are used for planting, cultivating, sowing, fertilizing, spraying, feeding, irrigating, collecting, and harvesting. They ensure the safety of agricultural product quality, increase the quantity of products produced, and enable savings by using inputs in line with the region's needs in areas with different water, fertilizer, and pesticide requirements.

Methods for increasing food production without converting more land into agriculture are also under consideration worldwide. Scientific research is being conducted at universities to genetically modify plants for more effective photosynthesis. These studies aim to reduce soil and water use while increasing productivity.

The primary economic impact of the use of Industry 4.0 applications in agriculture is the reduction of employment and, consequently, the increase in poverty. However, with the income that has already begun to be implemented as unemployment benefits and will inevitably be implemented in the future as a basic income for citizenship, people will have more time, and poverty will be reduced by equalizing incomes. The use of these new technologies in agriculture, which is carried out with robots, artificial intelligence, and other Industry 4.0 applications, provides solutions to the problem of labor supply shortages in some areas. It ensures precision in agricultural production, increases efficiency, reduces adverse environmental effects, lowers costs with reduced labor, fuel, seed, water, and chemicals, and increases competitiveness. It also enhances food supply, ensures more efficient operation of logistics and supply systems, and reduces poverty. With the use of robots in production, the risk of human injury is reduced, and risks in occupational health and safety are also minimized.

The development of agricultural technologies will make the agricultural technology market profitable and encourage more investment in this field. This will further the development of agricultural technologies and, consequently, increase agricultural productivity.

To solve the problem of hunger worldwide and eliminate the inadequacy in food supply in the future, certain measures need to be taken. It is necessary to reduce the rate of population growth and, at least, slow down the increase in demand. Increasing the supply of fish as an alternative food is essential, and measures to protect production and the natural ecosystem are necessary. Preventing the reduction of

land allocated to agriculture and increasing food production are crucial. Reducing greenhouse gas emissions caused by agricultural production is also essential for increasing sustainable production without harming the ecosystem. Besides the full implementation of Industry 4.0 applications, vertical farming in cities, soilless farming, and new lighting systems are expected to increase agricultural production.

In the future, agriculture will be based on interconnected machines and elements such as artificial intelligence, leading to a production structure that is entirely dependent on automation and requires no human labor. In such a scenario, there is a need to address important risk factors such as malicious individuals exploiting software vulnerabilities and uncontrollable robots that may disrupt agricultural production and impact the economy.

Countries and regions that still rely on traditional methods of inefficient production and are dependent on imports should give due importance to agriculture by using these new technologies to solve global food and hunger problems.

References

Acar, M. (2006). *DTÖ ve AB Işığında Türk Tarımının Geleceği*, Ankara: Orion Yayınevi.

Acemoğlu, D. (2023). Yapay Zekâyı Yeniden Tasarlamak. (H. Dölkeleş, Çev.). Ankara: Efil Yayınevi.

Akay, M. (2018, July 16). Endüstri 4.0 ile Akıllı Tarıma Geçiş. Retrieved from https://www.researchgate.net/profile/Melek-Akay-2/publication/326550785_ENDUSTRI_40_ILE_AKILLI_TARIMA_GECIS/links/5d2d95ff92851cf440874342/ENDUeSTRI-40-ILE-AKILLI-TARIMA-GECIS.pdf

Aldağ, M. C., Eker B. ve Eker A. A. (2018, September). Tarım Makinaları İmalatında Yapay Zekâ Uygulamaları. 31.National Agricultural Mechanization and Energy Congress, Uludağ Üniversitesi, Bursa

Arıcıoğlu, M. A., Yılmaz, A. ve Gülnar, N. (2020). 4.0 For Agriculture. European Journal of Business and Management Research, 5(3), 1-8. https://doi.org/10.24018/ejbmr.2020.5.3.364

Başoğlu, A. (2014). Küresel İklim Değişikliğinin Ekonomik Etkileri. Karadeniz Teknik Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 7, 175-196. Erişim Adresi: https://www.ktu.edu.tr/dosyalar/sbedergisi_8fd33.pdf

Borowski, P. F. (2021). Innovative Processes In Managing An Enterprise From The Energy And Food Sector In The Era Of Industry 4.0. Processes, 9(2), 381. https://doi.org/10.3390/pr9020381

Brynjolfsson, E. & McAfee, A. (2014). The Second Machine Age. (L. Göktem, Çev.). İstanbul: Türk Hava Yolları Yayınları.

Bucci, G., Bentivoglio, D. & Finco, A. (2018). Precision Agriculture as a Driver for Sustainable Farming Systems. Quality – Access to Success, 19, 114-121. Erişim Adresi: https://www.researchgate.net/publication/324212481_Precision_agriculture_as_a_driver_for_sustainable_farming_systems_State_of_art_in_literature_and_research

Byerlee, D., de Janvry, A. & Sadoulet, E. (2009). Agriculture for Development: Toward a New Paradigm. Annual Review of Resource Economics, 1(1), 15–31. https://doi.org/10.1146/ANNUREV.RESOURCE.050708.144239

CEMA European Agricultural Machinery Association. (2022). European Agricultural Machinery Industry Key Figures. Brussels.

CFBF California Farm Bureau Federation (2017). Agricultural Labor Availability Survey Results. California.

Cope, J. (2023, May 1). How Robots Are Used In Agriculture [Web log post]. Retrieved from https://www.parvalux.com/how-robots-are-used-in-agriculture/

Data Bridge (2023, March). Küresel Tarımsal Robot Pazarı - Endüstri Eğilimleri ve 2030 Tahmini. Retrieved from https://www.databridgemarketresearch.com/reports/global-agricultural-robots-market

De Clercq M., Vats A., Biel A. (2018, February). Agriculture 4.0: The Future of Farming Technology. World Government Summit, Dubai

De Janvry, A., Graff, G., Sadoulet, E., & Zilberman, D. (2000). Technological Change in Agriculture and Poverty Reduction. J. Cooper, L. M. Lipper & D. Zilberman (Eds.), Agricultural Biodiversity and Biotechnology in Economic Development (pp. 361-386). New York, Springer New York.

Doğan, A. (2009a). Ekonomik Gelişme Sürecine Tarımın Katkısı: Türkiye Örneği. Sosyal Ekonomik Araştırmalar Dergisi, 9(17), 365-392. Erişim Adresi: https://dergipark.org.tr/tr/download/article-file/289257

Doğan, A. (2009b). Yoksullar Lehine Büyümede Tarımın Rolü: Sahra-Altı Afrika Örneği. KMU İİBF Dergisi, 11(16), 21-38. Erişim Adresi: https://earsiv.kmu.edu.tr/xmlui/bitstream/handle/11492/356/Yoksullar%20Lehine%20Büyümede%20Tarımın%20Rolü.pdf?sequence=1&isAllowed=y

Erbay, R. (2013). Ekonomik Kalkınmada Tarımın Rolü: Türkiye Üzerine Bir Değerlendirme. Balkan Sosyal Bilimler Dergisi, 2(4), 1-16.

FAO (2009, October 12). High Level Expert Forum - How to Feed the World in 2050. Retrieved from https://www.fao.org/wsfs/forum2050/wsfs-forum/en/

FAO (2021). World Food and Agriculture - Statistical Yearbook 2021. Rome: https://doi.org/10.4060/cb4477en

FAO (2022). The State of Food and Agriculture 2022. Leveraging automation in agriculture for transforming agrifood systems. Rome: https://doi.org/10.4060/cb9479en

Goedde L., Katz, J., Ménard A.,, and Revellat, J., (2020, October 9). Agriculture's connected future: How technology can yield new growth. McKinsey Center for Advanced Connectivity and Agriculture Practice, Retrieved from https://www.mckinsey.com/industries/agriculture/our-insights/agricultures-connected-future-how-technology-can-yield-new-growth#/

Güler M., Kara T., (2005). Hassas Uygulamalı Tarım Teknolojisine Genel Bir Bakış. OMÜ Ziraat Fakültesi Dergisi, 20(3), 110-117. Erişim Adresi: https://dergipark.org.tr/tr/download/article-file/187588

Güzel B., Okatan E, (2022). Tarım ve Yapay Zekâ. M. Bilen (Ed.), Yapay Zekânın Değiştirdiği Dinamikler kitabı içinde, Konya: Eğitim Yayınevi.

İstikbal, D. (2022, Mart). Perspektif: Rusya-Ukrayna Savaşının Küresel Gıda Enflasyonuna Muhtemel Etkileri. Setav Perspektif, 336. Erişim Adresi: https://setav.org/assets/uploads/2022/03/P336.pdf

Johnston, B. F., & Mellor, J. W. (1961). The Role of Agriculture in Economic Development. The American Economic Review, 51(4), 566–593. Erişim Adresi: https://www.jstor.org/stable/1812786

Karlı, B., Çelik, Y., & Paksoy, S. (1996, Eylül). Türk Ekonomisinin Gelişmesinde Tarım Sanayi İlişkilerinin Rolü ve Tarımın Sanayi Sektörü İle Entegrasyonu. Türkiye 2. Tarım Ekonomisi Kongresi, Adana

Kılavuz, E., & Erdem, İ. (2019). Dünyada Tarım 4.0 Uygulamaları ve Türk Tarımının Dönüşümü. Social Sciences, 14(4), 133-157. https://doi.org/10.12739/NWSA.2019.14.4.3C0189.

Lowenberg-DeBoer, J. (2022). Economics of adoption for digital automated technologies in agriculture. Retrieved from https://policycommons.net/artifacts/3136531/economics-of-adoption-for-digital-automated-technologies-in-agriculture/3929829/ on 11 Jun 2023. CID: 20.500.12592/nq51xd

Martinho V.J.P.D. (2016). Energy consumption across European Union farms: efficiency in terms of farming output and utilized agricultural area. Proceedings of the ICE – Energy, 103, 543–556. http://dx.doi.org/10.1016/j.energy.2016.03.017

McCalla, A. F. (2001). Challenges To World Agriculture In The 21st Century. Agriculture and Resource Economics, 4(3), 1-2. Erişim Adresi: https://s.giannini.ucop.edu/uploads/giannini_public/48/01/4801e886-3406-4e10-b499-ed6147f457e8/spring2001_1.pdf

Mhlanga, D. (2021). Artificial Intelligence in the Industry 4.0, and Its Impact on Poverty, Innovation, Infrastructure Development, and the Sustainable Development Goals: Lessons from Emerging Economies? Sustainability, 13(11), 5788. https://doi.org/10.3390/su13115788

Misra, N. N., Dixit Y., Al-Mallahi, A., M. S., Bhullar, R. Upadhyay & A. Martynenko, (2020). IoT, Big Data, and Artificial Intelligence in Agriculture and Food Industry. in IEEE Internet of Things Journal, 9(9). 6305-6324. https://doi.org/10.1109/JIOT.2020.2998584.

Mumtaz, N., & Nazar , M. (2022). Artificial Intelligence Robotics in Agriculture: See & Spray. Journal of Intelligent Pervasive and Soft Computing, 1(01), 21–24. Retrieved from https://scirep.institute/journals/index.php/jipsc/article/view/7

Narin M, (2021). Covid-19 Genel Salgın Sürecinin Tarım Sektörü Üzerine Etkileri. H. Ç. Bal (Ed.), Covid-19 Genel Salgın Sürecinin Sosyoekonomik Etkileri kitabı içinde, Bursa: Ekin Yayınevi.

Nezamova, O. A., & Olentsova, J. A. (2022). The Main Trends Of Digitalization In Agriculture. In IOP Conference Series: Earth and Environmental Science, 981(3). https://doi.org/10.1088/1755-1315/981/3/032018

Nordin, N., Kaida, N., Othman, N. A., Akhir, F. N. M., & Hara, H. (2020). Reducing Food Waste: Strategies for Household Waste Management to Minimize the Impact of Climate Change and Contribute to Malaysia's Sustainable Development. IOP Conference Series: Earth and Environmental Science. 479, 1-8. https://doi.org/10.1088/1755-1315/479/1/012035.

Öcal, F. M. & Altıntaş, K. (2018). Dördüncü Sanayi Devriminin Emek Piyasaları Üzerindeki Olası Etkilerinin İncelenmesi ve Çözüm Önerileri. OPUS International Journal of Society Researches, 8 (15), 2066-2092. https://doi.org/10.26466/opus.439952

Özertan, G., (2014). Yeni Tarım Düzeni ve Türkiye Tarım Sektöründe Kalkınma İçin Teknoloji Kullanımının Rolü. A. F. Aysan, D. Dumludağ (Ed.), Kalkınmada Yeni Yaklaşımlar kitabı içinde, Ankara: İmge Kitabevi Yayınları.

Özgüven, M. M., Altaş, Z., Güven, D. & Çam, A. (2022). Tarımda Drone Kullanımı ve Geleceği. Ordu Üniversitesi Bilim ve Teknoloji Dergisi, 12 (1) ,64-83. https://doi.org/10.54370/ordubtd.1097519.

Pereira, L.S. Water, (2017). Agriculture and Food: Challenges and Issues. Water Resour Manage, 31, 2985–2999. https://doi.org/10.1007/s11269-017-1664-z

Ragazou, K., Garefalakis, A., Zafeiriou, E., & Passas, I. (2022). Agriculture 5.0: A new strategic management mode for a cut cost and an energy efficient agriculture sector. Energies, 15(9), 3113. Erişim Adresi: https://www.mdpi.com/1996-1073/15/9/3113

Ranganathan, J., Waite R., Searchinger T., & Hanson C. (2018). How to Sustainably Feed 10 Billion People by 2050, in 21 Charts. Washington:World Resources Institute.

Rifkin, J. (2019). Üçüncü Sanayi Devrimi. (P. Sıral ve M. Başekim, Çev.). İstanbul: İletişim Yayınları.

Ritchie, H. (2022, May 30). After millennia of agricultural expansion, the world has passed 'peak agricultural land. Our World In Data (a project of the Global Change Data Lab). Retrieved from https://ourworldindata.org/peak-agriculture-land

Sergi, B., Popkova E., Bogoviz A., & Litvinova T. (2019). Understandıng Industry 4.0. First edition, England: Emerald Publishing Limited.

StartUs (2023). 8 Precission Agriculture Trends in 2023. Retrieved from https://www.startus-insights.com/innovators-guide/precision-agriculture-trends/#

Suskind, D. (2020). Çalışılmayan Bir Dünya. (T. Gezer, Çev.). İstanbul: Türkiye Teknoloji Geliştirme Vakfı Yayını.

The Economic Times (2015, July 27). China Sets Up First Unmanned Factory; All Processes Are Operated By Robots. Retrieved from https://economictimes.indiatimes.com

Thirlwall, A. P. (1999). Growth and Development with special reference to developing economies. Hampshire London: Macmillan Press Ltd.

Tutar, E., Kutluay Tutar, F. & Tok, A. (2020). Geleneksel Üretim Yönteminden İyi Tarım Uygulamalarına Geçiş: Türkiye Örneği. International Social Mentality and Researcher Thinkers Journal, 6(32), 832-844. http://dx.doi.org/10.31576/smryj.527

Tutar, F. K., Ekici, M., & Tutar, N. F. (2021, Kasım). Covid-19 Pandemisinin Tarım Sektörü Açısından Değerlendirilmesi. Uluslararası İktisadi ve İdari Bilimler Kongresi: Krizler, Belirsizlikler ve Arayışlar Kongresinde Sunulan Bildiri, Bingöl Üniversitesi, Bingöl. Erişim Adresi: https://www.bingol.edu.tr/documents/iibf%20kongre%20ozet%20metin%20kitabi.pdf

UNFPA. (2023). State of World Population Report 2023. United Nations Department of Economic and Social Affairs Population Division. New York.

Uzundumlu, A. S. (2012). Tarım Sektörünün Ülke Ekonomisindeki Yeri ve Önemi, Alinteri Journal of Agriculture Science, 22(1), 34-44. Erişim adresi: https://dergipark.org.tr/en/pub/alinterizbd/issue/2385/30482

Wakchaure, M., Patle, B.K., Mahindrakar, A.K., (2023). Application Of Ai Techniques And Robotics In Agriculture: A Review. Artificial Intelligence in the Life Sciences, 3. https://doi.org/10.1016/j.ailsci.2023.100057.

Winters, P., Janvry, A., Sadoulet, E., & Stamoulis, K., (1998). The Role Of Agriculture In Economic Development: Visible And Invisible Surplus Transfers, The Journal of Development Studies, 34(5), 71-97. https://doi.org/10.1080/00220389808422537

Witkowski, K. (2017). Internet of Things, Big Data, Industry 4.0 – Innovative Solutions in Logistics and Supply Chains Management, Procedia Engineering, 182, 763-769. https://doi.org/10.1016/j.proeng.2017.03.197

World Bank (2021, June 12). World Development Indicators, Worldbank Data Bank. Retrieved from https://data.worldbank.org/indicator/NV.IND.TOTL.ZS?end=2020&start=1961&vie

World Bank (2022a, June 12). World Development Indicators: Structure of output. Retrieved from http://wdi.worldbank.org/table/4.2

World Bank (2022b, June 12). World Development Indicators: Agricultural inputs. Retrieved from http://wdi.worldbank.org/table/3.2

Xu J., Gu B., & Tian G. (2022). Review Of Agricultural Iot Technology, Artificial Intelligence in Agriculture, 6, 10-22. https://doi.org/10.1016/j.aiia.2022.01.001.

Araştırma Makalesi

Effects of Industry 4.0 Applications on The Agriculture Sector And Economic Growth

Endüstri 4.0 Uygulamalarının Tarım Sektörü ve Ekonomik Büyüme Üzerine Etkileri

Çisil ERKAN BAL	Hasan Çebi BAL
Doktora Öğrencisi, İstanbul Üniversitesi	Dr. Öğr. Üyesi, Karadeniz Teknik Üniversitesi
Sosyal Bilimler Enstitüsü	İktisadi ve İdari Bilimler Fakültesi
cisilerkan@ktu.edu.tr	hbal@ktu.edu.tr
https://orcid.org/0000-0001-8413-8012	https://orcid.org/0000-0002-9568-6740

Genişletilmiş Özet

Tarımsal üretimdeki azalmanın önüne geçilmesi ve artan gıda ihtiyacının karşılanması için, daha fazla çabaya ve yeni yöntemlere ihtiyaç duyulmaktadır. Bu yönden bakıldığında, tarımsal üretimin yetersizliği sorununun çözümünde Dördüncü Sanayi Devrimi olarak da adlandırılan Endüstri 4.0 uygulamalarının önemi daha da artmaktadır.

Günümüzde Endüstri 4.0 uygulamalarının dünya tarımsal ürün arzına etkileri, tarımsal üretimin nüfusu besleyebilecek seviyede gerçekleşip gerçekleşmeyeceği, diğer sektörlerin girdi ihtiyaçlarını karşılamada yeterli olup olmayacağı, istihdam ve yoksulluğa ilişkin etkileri gibi konular önem kazanmaktadır.

Ekonomik yapıda üç sektörden birisi olan tarım sektörünün gelecekte alacağı biçim oldukça önemlidir. Diğer sektörlerde olduğu gibi bu sektörde de işsizliğin ulaşacağı boyut, verimlilik, üretim hacmi ve yeni üretim biçimlerinin iktisadî etkileri, bu çalışmada ele alınan konular arasında yer almaktadır. Tarım sektörünün ekonomik öneminin, dünyada yeni tarım uygulamalarının gelecekteki olumlu ve olumsuz sonuçlarının ülke ekonomilerini nasıl etkileyeceğinin ortaya koyulması ve ortaya çıkması olası sorunlar için uygun önlemlerin önerilmesi bakımından çalışmanın yararlı olacağı öngörülmektedir.

Tarımın ülke güvenliği bakımından stratejik bir sektör olmasının yanında; beslediği ülke nüfusunun emek piyasasında yer alması dolayısıyla işgücü temin etmesi, ülke GSYH'sının artışına katkı sağlaması, ihracata imkân vermesi, gelir dağılımına pozitif etki yapması ve yoksulluğun azaltılması gibi fonksiyonlara da sahip olduğu bilinmektedir.

Bunların yanında; gıda güvenliğini sağlama ve açlık/kıtlık riskini ortadan kaldırma ihtiyacı, ülkelerin ulusal güvenlik sorunudur. Ekonominin kendi kendine yeterliliğini sağlamak amacıyla; kendi ihtiyacı olan tarımsal ürünlerin üretiminde yeterli hale gelerek başka ülkelere bağımlı olmaktan kurtulma çabaları, önemli bir ulusal güvenlik ve ekonomik bağımsızlık konusudur.

Tarımsal üretim; gıda arzını, tarımsal ürün ihracatını, geliri ve döviz girdisini artırıcı etkileri nedeniyle, iktisadi büyümeye olumlu etkilerde bulunmaktadır.

Tarım sektörünün katkıları ve iktisadi önemi; ürün, pazar, üretim faktörü ve döviz olmak üzere dört ana başlıkta ortaya çıkmaktadır. Tarım, bireylerin tüketim ihtiyaçlarını karşıladığı gibi, sanayi sektörüne de üretim girdisi sağlamaktadır. Diğer bir ifadeyle tarım sektörünün ileriye bağlantı etkisi oldukça yüksektir. Örneğin ayakkabıcılık ve benzeri üretim alanlarında ihtiyaç duyulan deri, üretilen hazır gıdalar için ihtiyaç duyulan un ve benzeri tahıl ürünleri, konserve üretimi için domates, fasulye, tekstil sektörü için ihtiyaç duyulan pamuk ve ipek gibi girdiler tarım sektörünün üretiminden tedarik edilmektedir.

Tarım sektöründe yer alan nüfusun satınalma gücü, diğer sektörlerde üretilen mal ve hizmetlerin satın alınmasına imkân sağlamaktadır. Zira tarım sektöründe yer alan nüfusun mal ve hizmetler için yaptıkları

parasal harcamalar, bu firmaların gelirlerini oluşturmaktadır. Sanayi sektörünün üretimde ihtiyaç duyduğu bazı girdiler, tarım sektörü tarafından sağlanmaktadır.

İnsanlığın gelecekte ihtiyaç duyacağı gıdanın karşılanması çerçevesinde tarımın üzerinde olumsuz baskı oluşturan dört ana sorun, demografi, doğal kaynakların kıtlığı, iklim değişikliği ve gıda israfıdır. Bu dört soruna, günümüzde gıda arzının artan gıda talebini karşılamasını engelleyen diğer sorunları da eklenmesi gerekir. Bunlar;

1. Dünya nüfusunun artışı,
2. Doğal kaynakların azalması,
3. Küresel iklim değişikliği,
4. Covid-19 küresel salgını,
5. Rusya-Ukrayna savaşı,
6. Tarımdaki işgücünün yetersizliği (emek arz yetersizliği),
7. Artan enerji ihtiyacı,
8. Yüksek maliyetler,
9. Gıda israfıdır.

Dünya nüfusunun artışı; tarımsal ürünlere olan talebin artmasına, tarımsal arazilerin yerleşim yerlerine tahsis edilmesi sonucunda da ekilebilir tarımsal alanların ve dolayısıyla arzın azalmasına yol açmıştır. Doğal kaynakların azalması, küresel iklim değişikliği, Covid-19 küresel salgını ve Rusya Ukrayna savaşı ise tarımsal ürün arzının azalmasına neden olmaktadır.

Dünya nüfusunun 8 milyara yaklaşması ve dünyada tarım alanlarının giderek azalması nedenleriyle; artan nüfusa oranla tarımsal üretimin gelecekte dünya gıda ihtiyacını karşılayamaması riski bulunmaktadır. 2023 yılı temmuz ayında 8 milyar olan dünya nüfusunun; 2030'da 8,5 milyar, 2050 yılında 9,7 milyar, 2100 yılında ise 10,9 milyar olacağı öngörülmektedir.

Dünya nüfusunun artışı iki etkiyi ortaya çıkararak, tarımsal ürün arzının ürün talebini karşılayamamasına yol açmaktadır;

1. Artan nüfusun barınma ve diğer ihtiyaçları nedeniyle daha çok alana ihtiyaç duyulması; tarıma uygun alanların da yerleşime açılmasına, ekilebilir alanları azalmasına, üretimin azalmasına ve dolayısıyla gıda arzının yetersiz kalmasına yol açmaktadır,
2. Artan nüfus nedeniyle tarımsal ürünlere olan talep artmakta, bu da arzın yetersiz kalmasına yol açmaktadır.

2050 yılında 9 milyarı aşacak olan dünya nüfusunun beslenebilmesi için, 2005 yılındaki dünya tarımsal üretiminin %70 oranında artırılması gerekmektedir.

Dijital teknolojiler; manuel olarak işlenmesi mümkün olmayan büyük miktarda veriyi analiz etmeye ve süreçleri sürekli olarak izlemeye imkân sağlamaktadır. Ayrıca dijital teknolojiler ile insan hatası ortadan kaldırılmakta ve her zaman kesinlikle doğru veriler elde edilmektedir. Bu avantajlarla dijital tarım daha düşük maliyetle daha çok üretmenin önünü açmakta, tarım sektöründeki sorunların çözümüne önemli katkılar sağlamaktadır. Tarımsal üretimde kullanılan aygıtlarla gelişmiş bağlanabilirlik sağlandığında tarım sektörü; küresel GSYİH'ya önümüzdeki on yıl içinde 2 trilyon ile 3 trilyon dolar artıracak yedi sektörden birisidir.

Tarımsal üretimde robotlar pek çok işlem için kullanılmaktadır. Sürücüsüz tohumlama işlemleri, olgun ürünleri işgücüne ihtiyaç olmadan toplama, en iyi ürünleri türlerine göre paketleme, forklifte ihtiyaç duymadan paletleme, bitki budama, yabani ot temizleme, böcek ilacı ve besin uygulama, sulama, ineklerin beslenmesi ve sağılması, otlatma için arazilerin izlenmesi gibi pek çok işlemi insan gücüne ihtiyaç duymadan tarım robotları yapabilmektedir. Bu işlemleri yaparken robotlar; yaralanma riski olmayan, daha hızlı ve uzun süre çalışabilen ve verimlilikleri oldukça yüksek olan araçlardır. İşçi temininde zorluk yaşandığında ürünleri toplayarak ürün kaybını engellemektedir. Atık azaltma, hatasız

ve hassas işlem kabiliyeti ve düşük maliyet gibi pek çok avantajlarıyla robotlar günümüzde tarım alanlarında çalışmakta ve gün geçtikçe daha yaygın olarak kullanılmaktadırlar.

Tarım sektöründe robotların ana kullanım alanları; bağ, bostancılık ve meyve bahçeleri, tarla bitkileri ve hayvancılıktır. Bostancılık ve meyve bahçelerinde çim yönetimi ve hasat işlemleri robotlar tarafından yerine getirilmektedir. Hayvancılık alanında; sağım, besleme, yem itici, altlık kazıma, bulamaç emme, altlık dezenfeksiyon ve havalandırma, yük taşıma, hayvan refahı işlemleri robotlarca yapılabilmektedir. Tarla bitkileri alanında; gübreleme, ilaçlama, sulama, toprak işleme (ot temizleme) işlemlerini robotlar yerine getirmektedir. Bağ işlemlerinde ise; biçme, tomurcuklanma, budama, yaprak soyma vb. bağ işleri, püskürtme, otlatma vb. toprak işleme, yük taşıma gibi işlemleri robotlar yapabilmektedir.

Günümüzde her geçen gün fiber ağ, geniş alan ağları (LPWAN), Wi-Fi 6, 5G ve radyo frekansı tanımlama (RFID) gibi bağlantılarla, üretimde kullanılan drone, akıllı mahsul izleme, otomatik tarım makineleri ve diğer aygıtlar arasında teknolojik bağlantıların kullanım alanları artmaktadır. Bu aygıtlar arasındaki iletişim bağlantıları pek çok yönden tarımın dijital dönüşümünü hızlandırmakta, GSYH'yı artırmaktadır.

Dünya çapında tarım robotlarının yıllık satışları giderek yükselme eğilimindedir. 2019 yılında 10 bin adet olan tarımsal robot satışı, 2022 yılında 19 bin adede ulaşmış, 2023 yılında ise 22 bin adet olması beklenmektedir.

Yapılan bir pazar araştırmasında; 2022'de tarım robotu pazarı 8 milyar ABD doları iken, 2030'da 83 milyar ABD dolarına ulaşması ve 2023-2030 tahmin döneminde yıllık birleşik büyüme oranıyla %33,70'lik bir büyüme artışı öngörülmektedir. Raporda; tarımsal robot pazarının kapsadığı ülkeler ABD, Kanada, Meksika, Almanya, Fransa, Birleşik Krallık, Hollanda, İsviçre, Belçika, Rusya, İtalya, İspanya, Türkiye, Çin, Japonya, Hindistan, Güney Kore vb. ülkelerdir.

Üretim sürecinde verilerin toplanması ve analizi ile tarımda verimliliği artırmak artık mümkündür. IoT uygulamaları tarımsal girdilerden suda da tasarruf sağlamakta, tarımsal ürün kalitesini artırarak işçilik maliyetini azaltmakta ve üretimi artırarak çiftçilerin gelirini artırmaktadır, IoT ile ürün gelişimi, hayvan ve bitki yaşam bilgileri izlenmektedir. Akıllı tarım makineleri kullanılarak ekim, yetiştirme, dikim, gübreleme, ilaçlama, besleme, sulama, toplama ve hasat yapılmakta, tarımsal ürün kalite güvenliği sağlanmakta, üretilen ürün miktarı artırılmaktadır. Su, gübre ve ilaç ihtiyacı farklı olan bölgelerde, bölgenin ihtiyacı kadar girdi kullanılarak, tasarruf sağlanmaktadır.

Dünyada gıda ve açlık sorununun çözümü için, tarımda hala geleneksel yöntemlerle verimsiz üretim yapan ve dışa bağımlılığı olan ülkeler ve bölgeler, bu yeni teknolojileri kullanarak tarıma gereken önemi vermelidirler.

Gelecekte tarım; birbirine bağlı makineler ve yapay zekâ gibi unsurlardan oluşacağından, tamamen otomasyona bağlı, insan gücü gerektirmeyen bir üretim yapısı ortaya çıkacaktır. Bu durumda ülkelerin yazılımla ilgili güvenlik açıklarını kullanabilecek kötü niyetli kişilerin ve kontrol edilemeyebilecek robotların tarımsal üretimi durdurmaları ve ekonomiyi etkilemeleri de, üzerinde çalışılması gereken önemli risk konuları arasında yer alacaktır.