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Economic growth and smart farming*

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ABSTRACT

Agriculture is of vital importance for each country around the world. Changes in technology affect the methods and tools of agricultural activities. In line with Industry 4.0, agricultural sectors have been experiencing technological developments. Especially, the Internet of Things has enormous influences on agricultural applications in terms of data collecting, analyses, increasing productivity and fertility, future predictions, etc. The main objective of this article is to discuss the importance and effects of smart farming applications. Its examples worldwide show that higher rates of profit and productivity can be achieved through relatively smaller areas. Also, given that certain examples of smart farming applications and trials of new methods such as drone crop spraying, smart soilless agriculture solutions have been implemented in Turkey. In addition, the increase in productivity in the agricultural sector due to smart agricultural practices contributes significantly to countries' GDP. Consequently, it is argued that smart farming applications offer a significant rate of productivity and profit despite their challenges. This study aims to explain agricultural technology and its applications after addressing the technological developments in the agricultural sector.

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ÖZ

Tarım, dünyadaki her ülke için hayati öneme sahiptir. Teknolojideki değişiklikler tarımsal faaliyetlerin yöntem ve araçlarını etkilemektedir. Endüstri 4.0 ile uyumlu olarak tarım sektörlerinde teknolojik gelişmeler yaşamaktadır. Özellikle Nesnelerin İnternetinin veri toplama, analiz, üretkenlik ve verimlilikte artış, geleceğe yönelik tahminler vb.

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açısından oldukça önemli etkileri vardır. Bu makalenin temel amacı akıllı tarım uygulamalarının önemini ve etkilerini tartışmaktır. Dünyadan verilen örnekler, daha küçük alanlarda daha yüksek kâr ve verimlilik elde edilebileceğini göstermektedir. Ayrıca, drone ile ilaçlama, akıllı topraksız tarım çözümleri gibi yeni metotların denemelerinin ve akıllı tarım uygulamalarının bazı örneklerinin Türkiye'de uygulandığı belirtilmektedir. Sonuç olarak, akıllı tarım uygulamalarının çeşitli zorluklarına rağmen önemli bir verimlilik ve kâr oranı sunduğu öne sürülmektedir. Ayrıca akıllı tarım uygulamalarının sonucu tarım sektöründe gerçekleşen verimlilik artışı ülkelerin hasılasına da önemli katkılar sunmaktadır. Bu çalışmanın amacı, tarım sektöründeki teknolojik gelişmeleri ele aldıktan sonra tarım teknolojisini ve uygulamalarını açıklamaktır.

1. Theories of economic growth

Economic growth is the real increase that is measurable and can be observed in a country's production capacity or real GDP in a year. Economic growth, one of the most important economic policy targets of governments, is measured by the increase in GDP compared to the previous period. In other words, economic growth means increasing production capacity and producing more goods and services. The economic growth rate of the countries may vary depending on the resources they have and various factors (Agwu, 2015, p. 487). The concepts of economic growth and development are different from each other in terms of their scope. While economic growth refers only to quantitative increases in national income or per capita income in one country, the development also includes improvements in social, political, and cultural areas.

Economic growth and its factors are subjects that many economic schools and thinkers have given importance since the Mercantilists. Mercantilists aim to increase the stock of highly valuable mines in foreign trade, as they measure growth with precious mines owned by the country. Physiocrats state that the agricultural sector is the main capital accumulation source required for economic growth (Müller, 1978). Concerning tax policy, the Physiocrats took such a stand, arguing that rising government debt, which largely maintained a prosperous class of tax farmers and privileged monopolists, was hampering the growth of productive resources, particularly in agriculture (Gleicher, 1982, p. 357). They opposed the mercantilist system, which is also referred to as a commerce system, in favor of an agricultural system to increase the prosperity of a country (Yong, 1994, p. 5).

Classical economists explain growth through capital accumulation, population growth, division of labor, and technological development. According to classical economic theory, capital accumulation, which is the essential source of economic growth, is explained by savings (Brewer, 2010, p. 4). A. Smith, one of the pioneers of classical economics, states that one of the most important economic growth sources is specialization in economic activities. Of course, according to Smith, capital accumulation is one of the important factors for growth. It is claimed that the source of capital accumulation is profit and savings (Berber, 2006, p. 59). However, Ramsey's (1928) classic article, "A Mathematical Theory of Saving" is the starting point of the modern growth theory. He explains the growth theory with reference to the consumption functions of households over time (Ramsey, 1928).

Keynesian economics deals with growth along with investment, consumption, and savings decisions. According to Keynes, investment expenditures increase the income level, and accordingly, the level of savings increases. Of course, growth will be positively affected as the increase in savings will increase the capital stock through investments. In other words, in order to achieve the desired growth level, savings-investment equality must be ensured (Berber, 2006, p. 103-104). Although Harrod (1947) and Domar (1959)'s growth models are mainly based on Keynesian analysis, they explain growth with savings and capital accumulation. According to this model, continuous growth requires continuous net investments. However, the process will be interrupted when the increase in output resulting from investments is not balanced by demand. In other words, in cases that the investment saving and supply-demand balance are achieved, the growth process will continue steadily in the long term (Acemoglu, 2007, p. 25,73; Agwu, 2015, p. 487-488; Snowdon and Vane, 2005, p. 600-601).

Solow (1956), who made significant contributions to the neo-classical model, explains growth with population growth rate and technological development. These variables take place in the model externally. In the model, there is causality from population growth rate and technological development to growth. Technological development, which is based on scientific inventions and innovations, determines the long-term steady-state growth rate. Solow (1956) and Swan (1956) give two basic predictions in their work. First, the country with relatively more savings will be more prosperous than the country with fewer savings. However, this increase in savings does not affect the growth rate, and it only creates a level effect. Secondly, it is the convergence hypothesis that developing countries will catch them as a result of their faster growth than the rich countries (Acemoğlu, 2007, p. 25, 73; Agwu, 2015, p. 487-488; Cameron, 2003; Jones, 2015, p. 7-8, 19-20).

The endogenous growth theories that emerged with P. Romer (1986) and R. Lucas (1998) against the neo-classical model first object to the idea that handles technology externally. Besides, Lucas (1998) argues that the assumption that the marginal productivity of capital decreases is not correct, and since human capital is included in the model, it can provide long-term growth. Endogenous growth models state that the continuity of growth will be achieved, especially by evaluating technological innovations in economic activities. In addition to the internalization of technology, Romer (1986) states that the information produced by one company creates positive externalities on the production of other companies. Romer (1986; 1990) states that R&D studies may be the source of the continuity of growth, Barro (1990) states it as public spending, Rebelo (1991) states it as cumulative capital, and Pagano (1993) state it as financial markets. In other words, according to endogenous growth theories, factors such as human capital, research, and development activities, new production processes, new ideas, patents and copyright, international trade, technology, and capital inflow should be taken into consideration for the continuity of growth (Jones, 2015, p. 6-10, 19-20; Szostak, 2009, p. 65-66).

It is evident that agricultural growth has played a historically important role in the mechanism of economic development; data from both developed and developing countries indicate that the sector has been the driver that leads to overall economic growth (Izuchukwu, 2011, p. 193). In Canbay and Kırca's article (2020, p. 165), it is seen that there is a one-way causality relationship from agricultural production to economic growth and one-way causality from industrial sector production to agricultural production in the short run, according to the Granger causality test results. Also, by utilizing the vector error correction model (VECM), their analysis attempts to estimate the impact of agriculture on economic growth in a time series context in Nigeria (Sertoğlu, Ugural, and Bekun, 2017, p. 551), and they find out that agriculture plays a vital role in the economic growth in Nigeria.

In summary, the concept of growth is handled differently in traditional growth theories and modern and contemporary theories. According to traditional growth theories, growth refers to savings and an increase in physical capital. Endogenous growth theories, which include technology that is accepted as an exogenous factor by traditional growth models, as an internal production input in the model, consider the factor productivity and human capital increase created by the use of technology as basic data for growth (Koç, 2013, p. 242).

2. Agricultural sector and technology

The agricultural sector plays an essential role in economic development and growth. The fact that agriculture affects economic growth, improves the income level of the relatively low-income segment engaged in agriculture, provides input to other sectors in the economy, and creates demand for these sectors has made agriculture critical. Particularly in underdeveloped countries, the contribution of agriculture to economic growth is higher due to its significant share in employment.

Technological development, on the other hand, is the use of technological opportunities to make the production processes of a good or service more efficient. Today, it is emphasized that the phenomenon of growth is related to the technology level of the countries. According to an economist, technology is a tool that increases the well-being and standard of living of nations and a measurement technique stuck between resource inputs and outputs of production. Besides, it is a set of methods used to produce a good, according to an engineer. In other words, technology is the source of information used to improve the production and marketing efficiency of existing goods and services and to produce new goods and services (Kılıçarslan and Dinç, 2007). Technology, which has a dynamic structure, is a criterion used in the classification of countries. Industrialization and economic policies are determined in accordance with technology in developed countries. The generally accepted argument in the world arena is that there is a significant positive relationship between countries' production with advanced technology, economic growth, and development. Based on this view, it can be clearly stated that economic growth policies that are evaluated independently from technological developments will be deficient.

Besides, there are many reasons for the low productivity in the agricultural sector; technological development is one of the most critical factors contributing to solving this problem. Advanced technology in agricultural production processes such as cultivation, fertilization, irrigation, pesticide application, harvesting, and storage of crops allows for increased productivity. On the other hand, especially in underdeveloped countries, the lack of advanced technology in the agricultural sector prevents reaching the desired production level (Taban and Kar, 2016, p. 94-97).

In the literature, it is argued that agriculture is an indispensable part of economic growth. Golin, Parente, and Rogerson (2002, p.160) stress that agriculture is essential for economic growth. Their study concludes with a structural transformation model that includes the agricultural sector in a one-sector neoclassical growth model. Also, in their research, Thirtle, Lin, and Piesse (2003, p. 1973) show that growth in agricultural productivity has a major effect on reducing poverty. They suggest that inequality raises poverty and decreases GDP per capita growth (Thirtle, Lin, and Piesse, 2003, p. 1973). In another study that examines "data on 15 developing countries and transition economies in Africa, Asia, and Latin America", it is seen that the agricultural sector is a driving factor behind economic growth (Awokuse, 2009, p. 20).

With the increase in production in the manufacturing industry and agriculture sectors, all environmental, social, economic, and institutional elements of sustainable development are positively affected, and increase growth (Behun et al., 2018, p. 23). The contribution of the manufacturing industry and the agricultural sector to GDP will be higher with the development of factors such as productivity, raw material supply, technology, innovations, and improvement of the quality of the workforce that will affect the factors as mentioned earlier (Kopuk and Meçik, 2020, 264). As a result, it can be stated that the impact of these sectors in favor of GDP depends on efficient use of production factors, increasing technology and R&D investments, providing a qualified workforce, utilizing necessary subsidies and supports, encouraging domestic production, and producing the substitutes of imported goods within the country, and taking necessary steps of using domestic inputs (Kopuk and Meçik, 2020, 272).

Self and Grabowski (2007, p. 395) argue that developments in agricultural technology are a prerequisite for long-term growth and substantially affect it. Their empirical findings show that advanced agricultural technology in the 1960s had a meaningful, positive influence on growth from 1960 to 1995, using these proxy measures of agricultural productivity and "the measures of agricultural modernization seem to have statistically significant positive effects on human development." (Self and Grabowski, 2007, p. 403). In their article, Muhammad Azhar Khan, Muhammad Zahir Khan, Khalid Zaman, and Muhammad Mushtaq Khan (2013, p. 2007) show that agricultural technology is a key factor that reduces rural poverty in Pakistan. By using cointegration theory, variance decomposition, and Granger causality test, they analyze the annual data in Pakistan from 1975-2001.

3. The road to agriculture 5.0

Changes in agriculture as a result of supplying food demands in the middle of the 1600s in England led to the First Industrial Revolution, and agricultural lands became more organized and well-conducted. Together with the Second Industrial Revolution, batch production and electricity use paved the way for mass production and the increase in mechanization in agriculture. Afterward, the Third Industrial Revolution emerged due to the introduction of computers and digital devices (Kılavuz and Erdem, 2019). The changes in the agricultural sector during this period are defined as the "Green

Revolution”. It “describes the developments for rice and wheat, the term has since referred to the development of wide yielding varieties for several major food crops important to developing countries” (Hazell, 2009). The stages of agriculture are defined and summarized as follows (Kılavuz and Erdem, 2019; Zambon et al., 2019):

- Agriculture 1.0: The use of Animal Power and Mechanization
- Agriculture 2.0: The Combustion Engine and agrimotors
- Agriculture 3.0: Guidance Systems and Precision Farming
- Agriculture 4.0: Connection to Cloud
- Agriculture 5.0: Digitally integrated enterprise using robotics and artificial intelligence

Technology makes its presence felt more and more in the agricultural sector. Technologies that facilitate farmers’ work by increasing productivity, profit, and quality in agriculture have become smarter with Industry 4.0. While the world is quickly adopting the 4th Industrial Revolution, it is aimed to increase the speed and productivity by the interaction between agricultural machines, which is one of the outputs of Industry 4.0. These technologies are able to provide the use of conscious knowledge, decrease costs, increase productivity, and ease farmers’ work.

Since the 2000s, the agricultural sector has started to evolve parallel to the revolution in the industry called Industry 4.0. This process is also referred to as “Agriculture 4.0, Smart Agriculture, Digital Agriculture” and points out the application of smart technologies including sensors, microprocessors, autonomous decision systems, cloud-based information, and communication technologies in the agriculture sector (Saygılı et al., 2019). With the contribution and application of the IoT, it is aimed to “empower farmers with automation technologies that are uneventfully capable of integrating knowledge, product, and services in order to obtain better quality, productivity, and profit” (Elijah et al., 2018).

4. The need for transformation in agriculture

Countries are in for a digital transformation race in order to create added value. The parameters of this process are consumer demands and mass privatization; the importance of data and new business models; resource limits and sustainability; and the transition to the qualified labor force (TÜSİAD, 2017). Also, “the globalization of the value chains of agriculture, and food products provides a global division of labor in food production” (Tümen and Özertan, 2020). While these developments offer significant opportunities to countries that can effectively use the possibilities offered by advances in production technologies and integrate them into global value chains, they push countries that cannot keep up with them into a series of problems, primarily in sustainability concerns, increased foreign dependency and low value-added production (Tümen and Özertan, 2020).

Along with digital transformation, the development of the communication infrastructure with the technological advances made in recent years has enabled the use of digital technologies in agriculture as well as in all other sectors. Due to the increasing population, global warming, climate change, and the decrease in agricultural areas, the agricultural sectors in developed countries are conducting R&D and field studies to benefit from digitalization rapidly. Such developments force countries to review their current and traditional agricultural policies and adopt new agricultural policy instruments focusing on digitalization, R&D (Research and Development) activities, agricultural technologies, and productivity/added-value (Tümen and Özertan, 2020).

Agriculture is of vital importance to every community and is one of the most critical issues worldwide. The main aim of agriculture is to enable the use of natural resources sustainably in a sustainable way and provide sufficient and balanced nutrition for society. According to OECD-FAO Agricultural Outlook 2019-2028 report, it is stated that demand for agricultural products is expected to increase by 15% because of population growth between 2019-2028 (OECD-FAO, 2019), and also the global population is expected to grow “to around 8.5 billion in 2030, 9.7 billion in 2050, and 10.9 billion in 2100” (Figure 1.) (United Nations Department of Economic and Social Affairs, 2019).

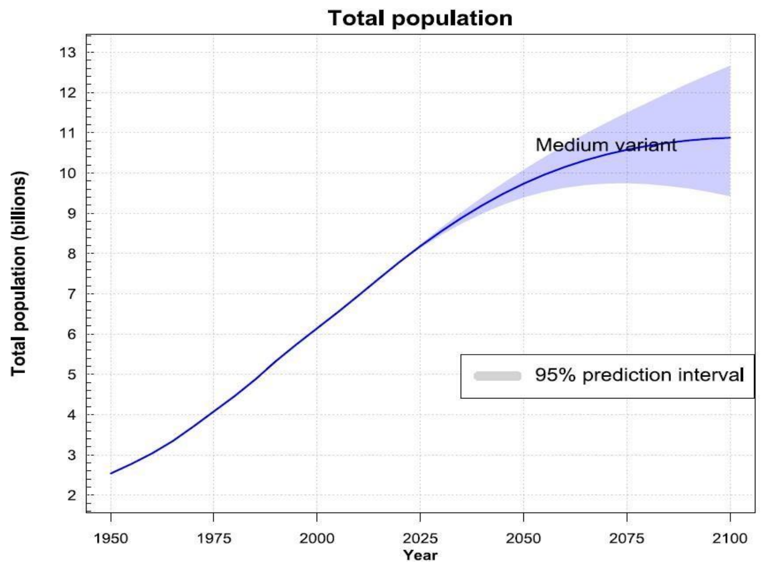

Figure 1. The Global Population Predictions towards 2100. Source: https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf

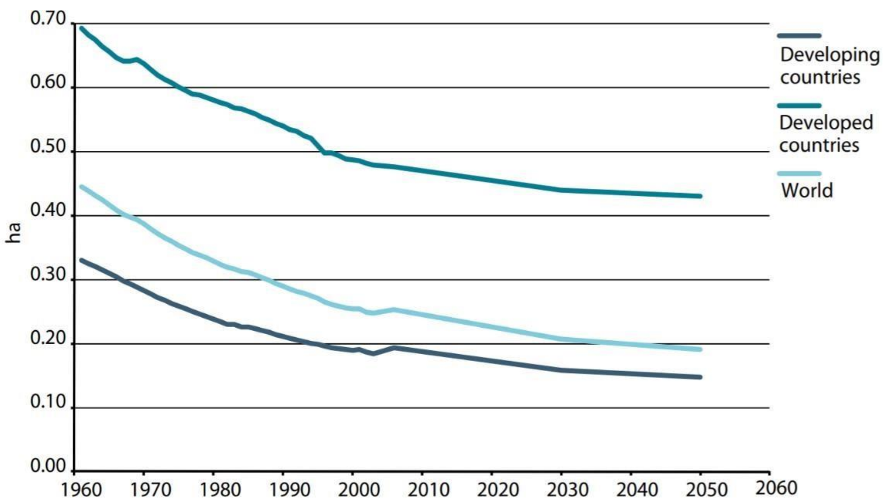

Figure 2. Arable Land per Capita. Source: http://www.fao.org/3/ap106e/ap106e.pdf

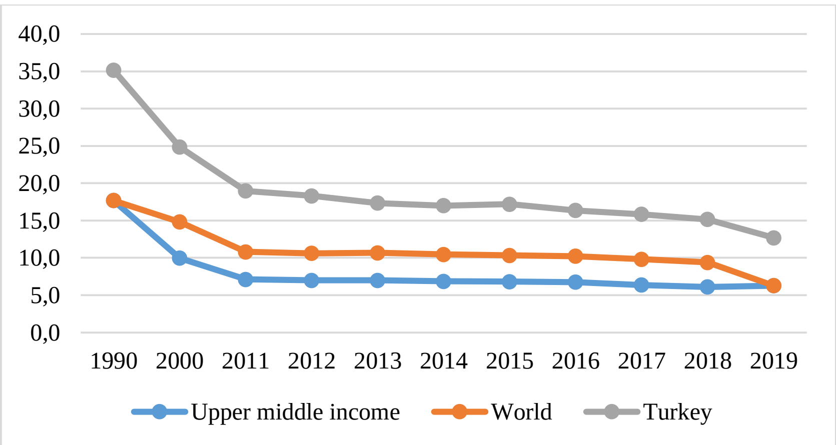

Figure 3. Agriculture, Forestry, and Fishing Value-added (% of GDP). Source: https://databank.worldbank.org/reports.aspx?source=2&series=NV.AGR.TOTL.ZS&country=UMC,WLD,TUR#

Besides the importance of agriculture for the survival of countries, it is seen that the agriculture value-added (billion USD) is increasing in upper-middle-income countries and the world, unlike Turkey. Since agricultural productivity becomes significant and gradually increases (Figure 3.), the new practices applied in agriculture have resulted in a gradual increase in agriculture value-added (billion USD). On the other hand, it is observed that the percentage of agriculture value-added in GDP is decreasing in the world. Since the other sectors such as services and industry have developed much more and become significant factors in the economy, the rate of agriculture in GDP is decreasing gradually. The comparison of the two graphs shows that although there is a decrease in the agriculture value-added in terms of its rate in GDP, the productivity and its value-added in terms of billion USD are increasing. As seen in both graphs (Figure 3.), agriculture value-added (billion USD) has been declining in Turkey as opposed to upper-middle-income countries and the average of the world. At the same time, it shows a similar rate of decline in agriculture value-added in terms of GDP. It can be said that although upper-middle-income countries, as Turkey[1], have an increasing rate of agriculture value-added (billion USD), Turkey does not have the same rise. With the inclusion of smart agricultural techniques, this rate is expected to increase.

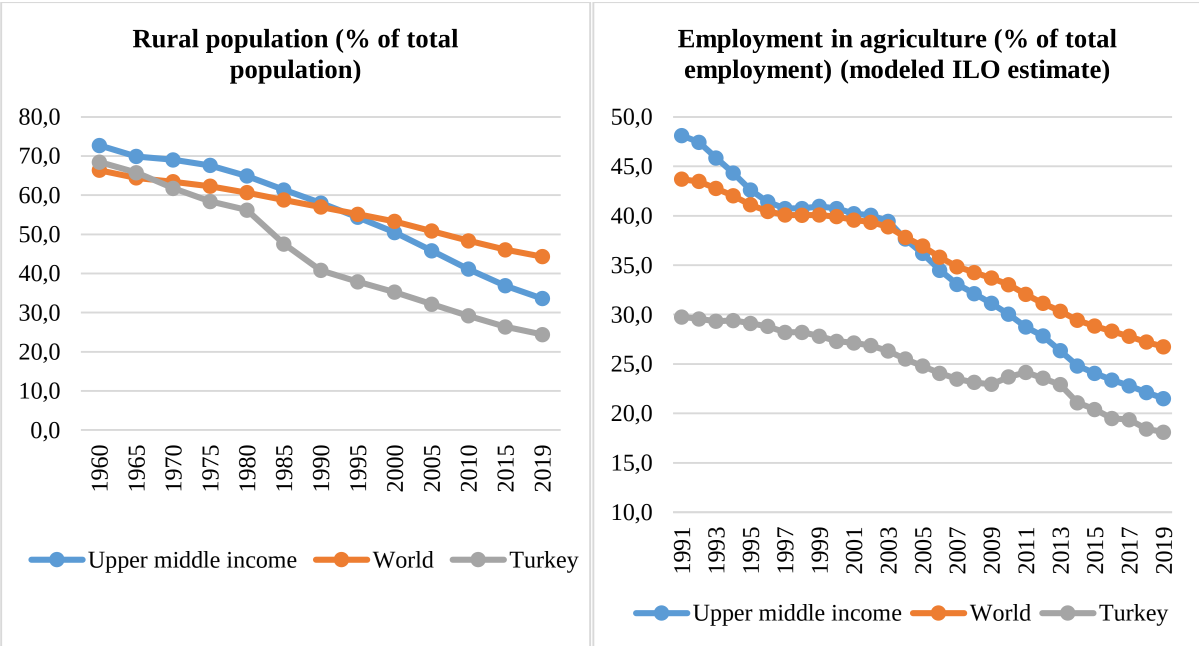

Figure 4. The Ratio of Rural Population to total population (%) and Rate of Employment in Agriculture to Total Employment. Source: https://databank.worldbank.org/reports.aspx?source=2&series=SL.AGR.EMPL.ZS&country=UMC,WLD,TUR#

Due to the decline in growth rate and arable land around the world (Figure 2.), the decrease in rural population, and agricultural employment (Figure 4.), there is a need to increase productivity. Achieving this target is shaped according to the agricultural potential of each country. Especially in the field of smart agriculture, the development of IoT (Internet of Things) and the technological developments in communication infrastructures such as 4.5G, 5G have enabled the advancement of drone, satellite, and sensor technologies, which are called Remote Sensing Systems, thus making them available in farmlands and fields.

5. Smart agriculture

Smart farming is defined as modern agricultural technology and technique that provides soil and crop management, more economical use of resources. It minimizes environmental damage in order to

[1] https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

increase agricultural productivity, the agricultural industry with the infrastructure to leverage advanced technology – including big data, the cloud, and the internet of things (IoT)–for tracking, monitoring, automating, and analyzing operations. Smart farming, also known as precision agriculture, is software-managed and sensor-monitored." (Demirel Atasoy, 2019; Smart Farming, n.d.). Some resources refer to smart agriculture as climate-smart agriculture, (CSA) and it is defined as "an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support the development and ensure food security in a changing climate (Food and Agriculture Organization of the United Nations, n.d.)". It has three main objectives: adapting and building resilience to climate change, reducing and/or removing greenhouse gas emissions, and sustainably increasing agricultural productivity, where possible (Food and Agriculture Organization of the United Nations, n.d.).

The following items can be highlighted to list the most important objectives of smart farming (Tarımın Geleceği: Akıllı Tarım Sistemleri, 2017):

- Reduction in the use of agricultural chemicals and, accordingly, healthier and more quality products. On the other hand, costs that stem from these chemicals will be diminished.
- Reduction in environmental pollution by utilizing smart agriculture. In fact, global warming, which is becoming more and more dangerous due to pollution, can also be reduced in this way.
- Reduction in costs, which is another advantage of using the internet of things in the agricultural sector. Thanks to these systems, which ensure that every natural resource is used sufficiently, there is no waste.

Figure 5. The Components of Smart Farming.
Source: https://iotforall.com/smart-farming-future-of-agriculture/

Smart farming has six components: sensing technologies, software applications, communications systems, telematics and positioning technologies, hardware and software systems, and data analytics solutions. Sensing technologies are defined as "a technology that uses sensors to acquire information by detecting the physical, chemical, or biological property quantities and convert them into readable signals" (Yokogawa, n.d.). It provides data in order to "help farmers monitor and optimize crops, as well as to adapt to changing environmental factors, monitor the main behaviors, health, and well-being of an animal in livestock by providing data of animal identification, heat detection, and health monitoring" (Schriber, n.d.; Calderone, 2019). Software applications can be defined as "the interaction between actors on top of a common technological platform resulting in a coherent set of ICT (Information and communication technology) products or services" (Kruize et al., 2016). Communication Systems, also, has a vital role in "benefitting the resource-strapped farmers with up to date knowledge and information on agricultural technologies, best practices, markets, price trends, and weather conditions. Experts in public and private research and extension system could easily connect, collaborate and established working online and offline platform using the ICT tools" (Derso and Ejiro, 2015, p. 408). Telematics (Telecommunication and Informatics) is defined as "transmitting of data through wireless communication links between the home base and field units by providing the simplest way to collect data from the machines and distribute it to the places of the managers by using a combination of the sensors, positioning system, telecommunication technologies and a way of processing these data" (Heacox, 2008; Mohamed, 2013). Data analytics solutions is considered as "the complex process of examining large and varied data sets, or big data, to uncover information – such as hidden patterns, unknown correlations, market trends and customer preferences which helps organizations make informed business decisions" (Sarker et al., n.d.).

With the spread of the internet of things in the agricultural sector, soil fertility is expected to increase; thus, farmers will gain profit. Also, people will not have any trouble with the products they buy due to the production of healthy products. Natural resources will be protected through advanced technology, and hazardous substances in the soil will be detected easily, green energy will be produced, saving time will be possible by remote operations, and most importantly, environmental pollution will be prevented.

Nowadays, pressures to reduce the cost and environmental impacts of agricultural inputs are gradually increasing as technology develops. These pressures are rising in the presence of physical and geographical variabilities, non-uniform soil, crop and environmental factors, the environmental impacts of inputs, and the rise of costs. Smart agriculture foresees economic efficiency through effective use (in a required quantity) of inputs, thus reducing its impacts on the environment. Additionally, data obtained from agricultural technology is guiding decisions not only at the farm level but also for the producers of inputs and equipment (Coble et al., 2018). Under these circumstances, uniformity in product quality can be achieved. In this respect, the objectives of smart agriculture can be stated as follows (Demirel Atasoy, 2019, p. 5):

- Reduction of chemical input costs such as fertilizer and pesticide,
- Reduction of environmental pollution,
- Providing a high quantity of quality products,
- Providing a more efficient information flow for business and farming decisions,
- Establishment of the registration order in agriculture.

In the technological development of smart agriculture, the data collection process has started, and data analysis affects business development decision-making procedures (Demirel Atasoy, 2019). Agricultural data has a strategic significance. The collection of this data with instruments such as drones, satellites, sensors, meteorological stations, and soil analysis instruments is an indispensable part of measurable agriculture and production. With the use of technologies such as artificial intelligence, machine learning, and deep learning from the agricultural data collected in sufficient amounts, projections and predictions can be made, and make disease and pest prediction and make early warning systems and significant progress in agricultural control. At the end of 2020, the number of devices collecting agricultural data is expected to reach 75 million (TÜSİAD, 2020).

5.1. The internet of things in agriculture

Throughout history, humankind has been searching for improving agricultural techniques by combining them with technology to decrease workload. Although humans must meet their food needs by agriculture, not all countries are able to supply their food demand which is vital for survival because arable lands are not homogenously spread. Furthermore, agricultural land existing across the world is not only affected by climate and land patterns but also economic and political factors and population density, "while rapid urbanization is constantly posing threats to the availability of arable land" (Ayaz et al., 2019). Increasing population, climate change, decreasing arable land, and natural resources are also other factors that affect food security; therefore, the use of the Internet of Things has become a significant issue in order to cope with the food demands in the future.

The Internet of Things (IoT) is defined as "a system of interrelated computing devices, mechanical and digital machines, objects, animals, or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction" (Elijah et al., 2018). It tries to combine the physical world and virtual world through the Internet, which serves as a mediator for connection and information exchange (Elijah et al., 2018). By integrating these worlds and tools with automated processes, it is possible to collect and analyze information and transform it into action (Burgess, 2018).

IoT has recently begun to affect many industries and sectors from production, energy, and communications to agriculture to decrease unproductivity and enhance the performance in all markets. "This is because of the capabilities offered by IoT, including the basic communication infrastructure (used to connect the smart objects—from sensors, vehicles, to user mobile devices—using the Internet) and range of services, such as local or remote data acquisition, cloud-based intelligent information analysis, and decision making, user interfacing, and agriculture operation automation" (Ayaz et al., 2019). "The development of sensors, robots and sensor networks combined with procedures to link variables to appropriate farming management actions has open the opportunities for IoT applications in agriculture" (Vermesan et al., 2015, p. 51). These systems are expected to create changes in the agricultural sector by increasing efficiency and productivity because of their capability to integrate several technologies.

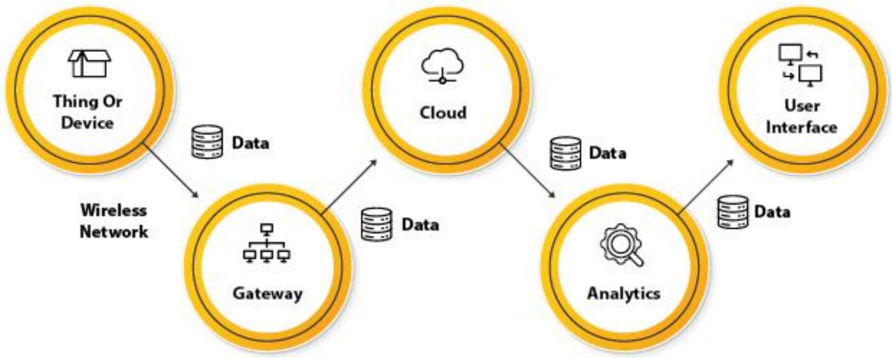

Figure 6. The Components of the Internet of Things. Source: https://www.rfpage.com/what-are-the-major-components-of-internet-of-things/

A thing or device, gateway, cloud, analytics, and user interface are considered as the components of IoT (NewGenApps, 2018). Firstly, devices and sensors collect data and transfer the data to the next layer. Another component is a gateway which operates "the bidirectional data traffic between different networks and protocols" (RF Page, 2018). "A smart gateway plays an important role between the sensing layer and network layer, which can shield the heterogeneity of the sensor networks, especially on the Internet" (Guoqiang, Yanming, Chao, and Yanxu, 2013, p. 720). "Gateways that bridge these devices to the Internet in the context of real-world applications" (Folkens, 2015). On the other hand, the IoT cloud is a highly complex, "high-performance network of servers that optimized to perform high-speed data processing of billions of devices, traffic management, and deliver accurate analytic" (RF Page, 2018). Analytics is a method of transforming analog data into practical information from billions of digital devices and sensors that can be analyzed and used for comprehensive research. Lastly, a user interface is "the visible, tangible part of the IoT system that users can access" (RF Page, 2018) through a smartphone, tablet, or PC.

Table 1

Summary of Agricultural Sensors

Type of sensors	Functions	Examples of Applications
Optical	Use of light to measure soil properties	Photodiodes and photodetectors to determine clay, organic matter, and moisture content of the soil
Mechanical	Use of probes to measure soil compaction or mechanical resistance	Tensiometers detect the force used by the roots in water absorption and useful for irrigation interventions
Electrochemical	Use of electrodes to detect specific ions in the soil	Use of ion-selective electrodes (ISE) and ion-selective field-effect transistor sensors (ISEFT) for detecting nitrogen phosphorus potassium (NPK) in soils
Dielectric Soil Moisture	Use of electrodes to assess moisture levels by measuring the dielectric constant in the soil	Frequency domain reflectometry (FDR) or time domain reflectometry (TDR) to sense soil water content
Airflow	Measure soil air permeability	Properties such as compaction, structure, soil type, and moisture level can be measured
Location	Use of Global positioning system (GPS) satellites to determines the latitude, longitude, and altitude	The GPS provides precise positioning for which is a cornerstone for precision agriculture.

Source: Elijah, O., Rahman, T. A., Orikumhi, I., Leow, C. Y., and Hindia, M. N. (2018). An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges. *IEEE Internet of Things Journal, 5*(5), 37583773.

Many indicators point out that “the availability of sensors, mapping technology, and tracking technologies have changed many farming systems and the management of the food system as it flows from producers to consumers” (Coble, Ferrell, Griffin, and Mishra, 2018, p. 79). Nowadays, almost all agricultural machines, from agrimotors to crop tools, are equipped with sensors. The internet of things enables devices to be in touch with each other throughout the production process. Agricultural equipment and fields equipped with digital sensors help farmers by demonstrating how much and what type of fertilizer is needed, the weather conditions, the minerals that plants need, the condition of the soil, and the estimated harvest time in a detailed and real-time manner. Thus, it is aimed that farmers’ work will be facilitated and efficiency will be maximized compared to traditional methods. Agricultural equipment will decrease the costs and workload.

With the agricultural revolution accompanied by Industry 4.0 and sometimes referred to as Agriculture 4.0, no doubt that agriculture will be more fertile and people will produce the best quality products quickly and inexpensively (Türkiye'nin Endüstri 4.0 Platformu, 2019). It is thought that the Internet of Things solutions in agriculture forms a cycle as monitoring through sensors, analysis and planning, and smart control, all linked by a wireless network connected to a cloud service (Andrew, Bogatinoska, and Malekian, 2018). The Internet of Things is also capable of producing and developing solutions to many challenges that the agricultural sector faces with the application of smart agriculture practices such as drought response, irrigation, land suitability, pest control, and yield optimization (Ayaz et al., 2019).

It is aimed to maximize productivity utilizing the concept of the Internet of Things that have started to be used in the agricultural sector. Thanks to several smart systems produced for agriculture, natural resources are not overused, thus reducing costs. Under these circumstances, the products become more profitable, and the environment can be protected. Through smart agriculture, it is aimed to reduce the risk of water scarcity, which is gradually influencing all countries around the world in recent years because farmers will know where and how much water should be used; therefore, they will not waste it. Its usage area can be stated as the following: automation, disease and pest control, crop and livestock, water quality and irrigation systems, monitoring weather, etc.

5.2. Benefits

Several benefits are mentioned in the literature on the effects of the IoT in agriculture. Some of them are stated as the following (Ayaz et al., 2019):

1. Awareness
2. Assess Management
3. Community Farming
4. Competitive Advantages
5. Cost Reduction and Wastage
6. Operational Efficiency
7. Wealth Creation and Distributions
8. Safety Control and Fraud Prevention

5.3. Challenges

1. Data convergence and Ownership
2. Lack of interoperability
3. Security and Privacy
4. Heterogeneity of IoT devices,
5. Uncertainty in business models

5.4. Application examples of countries

Recently, many countries have given importance to start-ups focusing on developing smart agricultural technologies. Using agricultural techniques by combining them with the internet of things, producers have started to achieve increased productivity, decreased costs, monitoring, etc., opportunities in the same field. Therefore, countries that are benefitting from these techniques are capable of gain increased agricultural value-added in terms of their GDP. Below (Figure 7.), there are examples and data on certain countries that promote start-ups related to agriculture in the world. It is seen that the USA is the leading country in terms of agricultural exports and has advanced and early-stage start-ups. Although having a smaller area compared to other foremost countries, Israel is the country that invests most. Holland is a significant example in terms of its arable land and agricultural exports. Even though it has rather a smaller surface area, it is one of the leading countries in terms of agricultural exports due to its improved agricultural methods.

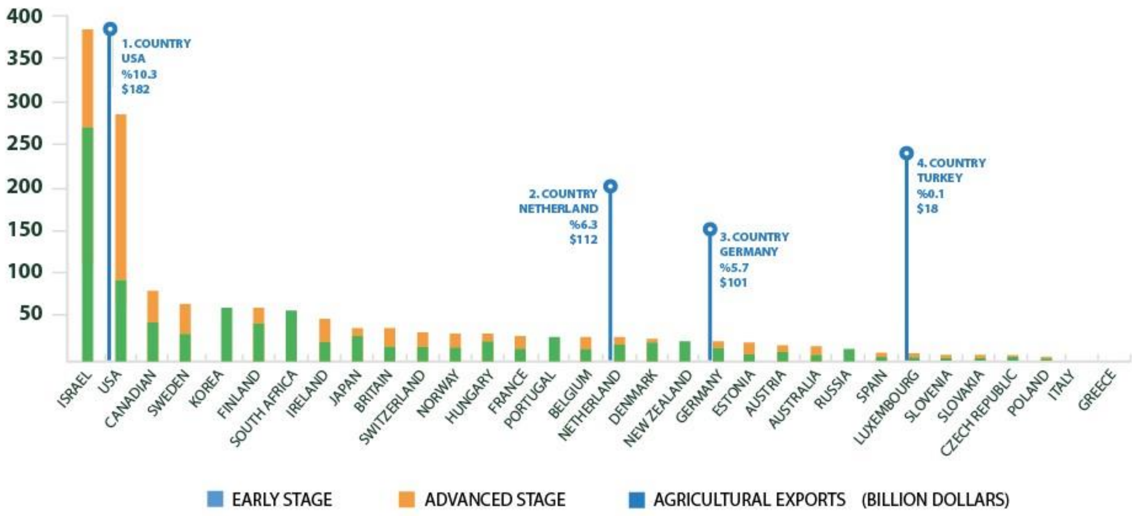

Figure 7. Smart Farming Start-ups around the World. Source: https://assets.kpmg/content/dam/kpmg/au/pdf/2016/powering-growth-realising-potential-agtech-australia.pdf

In Norway, Huawei and Carrier Telia are working on several innovative projects in order to improve smart agricultural infrastructure. For example, Internet of Things (IoT) is capable of providing smart irrigation systems, where sensors are used to retrieve data to track crops, soil, and the air in a real-time manner" (HUAWEI, n.d.); therefore, farmers are able to monitor the efficiency of farming equipment and forecast weather patterns. Also, the project called the "Gjeteren" sticks a tracking module on sheep in Norway's Rogaland summer farm to allow farmers to locate the sheep and screen their well-being remotely. Soon, Norway will be capable of tracing and observing everything "from animals, ships to containers and moving objects through mobile IoT" (HUAWEI, n.d.).

In Spain, Telefonica which is a Spanish telecommunication company, provides an automated irrigation system, connects meters, level meters, and hydraulic valves by utilizing GPRS in several farms. A single farm has 21,000 hectares, making it difficult for farmers to operate the irrigation valves manually. "Telefonica and ABB provided the remote irrigation system which helped farmers to incorporate computers and mobile phones in setting up a suitable irrigation schedule" (HUAWEI, 2017, p. 11). The benefits of the case are stated as follows:

- Savings – 47 hm^3 of water per annum
- 25% increase in farm profits
- 30% reduction in electricity bills

In Japan, according to the Annual Report of Food, Agriculture and Rural Areas (2018) published by the Ministry, the reduction of input costs in agriculture policies, the implementation of structural reforms in the distribution and processing, and the establishment of a strategic export system play an essential role. Agricultural technologies are seen as the most important factor in reducing input costs. Therefore, productivity improvement, product quality improvement, skill transfers, and farming business size expansion are the focal points (Ministry of Agriculture, Forestry and Fisheries, 2019). For example, Hokkaido, which are self-driving tractors and GPS-using leveling machines, are used at farming partitions expanded under an infrastructure development project to improve leveling accuracy and streamline soil pudding in Moseushi Town (Ministry of Agriculture, Forestry and Fisheries, 2019). Additionally, Japan's Spread Company runs an automated lettuce factory in Kyoto. The company offers automatically growing lettuce with conditions including automatically controlled humidity, temperature, and light. 7.7 million heads of lettuce are produced per year. The new factory's design goals include keeping it environmentally friendly by reusing 98 percent of water and keeping costs down through automation, cutting the need for human labor by 50 percent (Demaitre, 2015).

5.5. Examples of smart agriculture applications in Turkey

TABİT Smart Farming carries out Vodafone Smart Village Project to increase awareness, use and disseminate innovative agricultural technologies. Smart village is combining advanced technology with traditional farming methods in order to increase the efficiency of production by information and communication technology (TABİT, n.d.). Since 2004, training needs analysis and data have been collected in approximately 12.000 villages to spread technological knowledge in rural areas. With the smart model applied in Vodafone Smart Village, it aims to decrease 22% in crop production costs, 20% in animal production costs, and increase productivity by 10% on average.

ForFarming is an IoT-based, measurable, controllable, and reportable agricultural technology product supported by artificial intelligence algorithms. It presents smart soilless agriculture solutions that provide an opportunity to produce their products for individuals and companies which operate in the food sector. It is one of the initiatives of Commercialization Center of İstanbul, which is one of the associates of İstanbul Chamber of Commerce and supported by İstanbul IT and Smart City Technologies Inc. (İSBAK), which is one of the associates of İstanbul Metropolitan Municipality. ForFarming's fully automated technology provides sustainable and controllable production by providing an opportunity to remote access from a smartphone, tablet, or computer by the internet and control products smartly.

Turkcell offers smart agricultural solutions, like Filiz, to farmers in order to protect the limited water resources in the world and support efficient agriculture (Dijital Tarımda Yerli ve Milli Ürün "Filiz", 2019). The mobile application Filiz, which is used with soil-weather station providing instant data about the user's field, helps the farmer make irrigation and disinfection decisions according to soil and weather conditions in order to increase productivity. Also, with the sera monitoring solution, farmers can monitor the temperature and humidity levels of agricultural areas remotely; maintain the required heat level by operating the air conditioning units without going to greenhouses. Thus, it is aimed to increase productivity.

1.2. The applications within the framework of the Agricultural Credit Cooperatives of Turkey

The Agricultural Credit Cooperatives of Turkey (ACC) work as an independent institution in Turkey. It provides services to 830.000 farmer members with 17 Regional Associations and 1625-unit cooperatives. It aims to answer all the needs of its members and the needs of the Turkish farmers in general by providing the services and goods they require in a timely, secure, high quality, and affordable manner as well as market their products and ensure that Turkish agriculture is environmentally friendly, sustainable and the most productive sector. It has 13 subsidiaries under its roof, and all of these subsidiaries operate in different working areas related to agriculture, such as fertilizer, irrigation systems, animal feed. Below, it is given the smart farming applications examples of the two companies of the ACC.

Tarnet, a subsidiary of the Agricultural Credit Cooperatives, works on smart farming applications by focusing on drone use on disinfecting technologies and electrostatic spray application. The former technology provides a decrease in time, electricity, the use of plant protection materials (depending on the material), fuel, and the need for labor. Currently, Tarnet is testing the application of drone use on paddy fields. For example, 50% profit in medicine and 1.2 L profit per decare are made in Manisa. The latter technology enables a higher amount of medicine (up to 90%) adsorption on plants, while this rate is only around 25% with traditional methods. In applying the electrostatic spraying technique, a 9-fold reduction in residue on plants, 70% medicine, 90% water, and 50% fuel savings can be achieved.

GÜBRETAŞ, which is also a subsidiary of the Agricultural Credit Cooperatives, prepares the Soil Fertility Map of Turkey since 2005 and carries out R&D and innovation-oriented activities in social responsibility activities in recent years. In 14 years, more than 50 thousand farmers have been trained to take applied soil samples and conscious plant nutrition in the field. Soil samples were taken from 11 thousand agricultural lands in 81 provinces and analyzed. Additionally, model test fields/gardens are being created in order to expand conscious agricultural production. In these tests, which are being carried out with pioneer farmers, achieving maximum yield with minimum fertilizer consumption is being aimed (GÜBRETAŞ, 2016, p. 65). The target and generated fertility data of the trial fields are given below.

Table 2

The Target and Generated Fertility Data of the Trial Fields

Plant	**Location**	**Turkey Fertility (kg/da)**	**Province Fertility (kg/da)**	**County Fertility (kg/da)**	**Farmer Fertility (kg/da)**	**Target Fertility (kg/da)**	**Generated Fertility (kg/da)**
Potato	Ödemiş-İzmir	3.347	3.519	3.483	3.000	5.000	**5.000**
Nut	Terme-Samsun	70	57	48	200	400	**380**
Sunflower	Edirne Merkez	245	236	250	270	350	**321**
Sunflower	Zile-Tokat	245	242	252	250	350	**495**

Plant	Location	Turkey Fertility (kg/da)	Province Fertility (kg/da)	County Fertility (kg/da)	Farmer Fertility (kg/da)	Target Fertility (kg/da)	Generated Fertility (kg/da)
Sunflower	Altınekin-Konya	368	414	500	400	above 500	**510**
Corn	Onikişubat-K.Maraş	962	800	1097	1.100	1.500	**1.730**
Potato	Niğde-Merkez	3.358	3.607	3.635	3.500	4.500	**4.600**
Corn	Şehzadeler-Manisa	961	1.156	1.176	1.450	1.800	**1.760**
Pumpkin (Appetizer)	Tomarza-Kayseri	75	52	40	100	150	**162**
Sugar Beet	Çumra-Konya	6.153	7.171	7.645	8.000	10.000	**10.200**
Olive	Gömeç-Balıkesir	164	114	113	30-40 kg/tree	40-50 kg/tree	**60kg/tree**
Cotton	Menemen-İzmir	502	562	549	520	550	**620**
Cotton	Harran-Şanlıurfa	502	450	431	400	550	**525**
Corn (2th sowing)	Ceylanpınar-Şanlıurfa	968	871	896	1.200	1.500	**1.570**

6. Conclusion

To sum up, it is argued that smart farming applications offer a significant rate of productivity and profit despite their challenges. Since agriculture always has vital importance for each country around the world and it is related to survival, it has been a prominent subject, and it will always be. Therefore, besides the increasing importance of other sectors such as services and industry, increasing productivity and profit is critical because of the decline in growth rate, and arable land worldwide, the decrease in rural population, and agricultural employment. Also, the development of IoT and connectedness pave the way for smart farming, which has become a necessity to increase productivity and profit in agriculture. There are many examples of smart farming applications integrated into IoT both around the world and in Turkey, which aims to disadvantages of the decrease in arable lands and agricultural employment, and dependency on climate and these applications are expected to improve in time. The use of advanced technological infrastructure at all stages of the supply chain in agricultural production will significantly increase productivity and reducing losses.

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