ECONOMIC GROWTH AND SMART FARMING: EXAMPLES FROM TÜRKİYE AND THE WORLD

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DOI: 10.53478/TUBA.978-625-8352-17-7.ch37

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Abstract

Agriculture is of critical importance for all countries. Developments such as the increasing world population, rapid consumption of resources, climate change, political tensions between countries and epidemics have begun to seriously affect the food sector. These issues have led to the foreground of agriculture, which lagged behind by industry and service sectors. Technological activities affect many developments in the world, as well as agricultural developments. Especially with Industry 4.0, technological developments in the agricultural sector have started to be experienced visibly. In order to obtain higher yield and diversity from small areas, countries have begun to integrate technology into the agricultural field at a high rate. The IoT has far-reaching implications for analysis, data collection, forecasting and increased efficiency and productivity. This article discusses the effects and importance of smart agriculture with examples. In addition, due to the fact that Türkiye became a party to the Paris Agreement on November 10, 2021 and the EU Green Deal principles, the use of agricultural technologies for the traceable agricultural production process and the correct use of chemical products such as pesticides came to the fore. Along with the examples given around the world, it has been demonstrated that higher productivity and profit can be achieved in relatively small agricultural areas with smart farming methods. In addition, it is stated that the tests of solutions such as soilless farming methods, spraying with unmanned aerial vehicles and some examples of smart agriculture have started to be implemented in Türkiye. As a result, it is emphasized that despite various difficult issues, significant profits and productivity are achieved through smart farming practices. Along with the contributions of these applications, there is an increase in GDP of the countries. The aim of this study is to explain the technologies and applications in this field with examples after mentioning the effect of technological developments in agriculture on economic growth.

Keywords
Economic growth, Smart agriculture, The internet of things, Agricultural technology, Green deal

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1. Introduction

Today, one billion people are undernourished. According to the report published by the Food and Agriculture Organization (FAO) in 2015, the world population is predicted to be 9.7 billion people by 2050 in the future. In order to feed this population, an increase of at least 70% in the world's agricultural production is required. Considering the decrease in agricultural lands and the rapid increase in migration from the village to the city, this increase can only be achieved by increasing the productivity in agriculture, that is, the agricultural production obtained from the unit area. To increase productivity in agriculture, it is necessary to integrate technology with agriculture. One of the concepts that comes to mind regarding agricultural technologies is smart agriculture.

Smart Agriculture (Precision Agriculture) or Agriculture 4.0 refers to the digitalization of production as in Industry 4.0. Therefore, it will be possible to obtain more output with less input (such as water, fertilizer, fuel and medicine) in production with this process. In other words, smart agriculture technologies (precision agriculture) can be used in almost every period of plant production, from tilling to harvesting. Soil analysis, tilling, planting, fertilization, spraying, monitoring of crop conditions and harvesting processes in agricultural lands are techniques that aim to obtain more products with less input by using advanced information and control systems.

Smart agriculture technologies aim to:

- Making regional variable rate applications on the same land by reducing the costs of chemicals such as fertilizers and pesticides,
- Reducing environmental pollution by minimizing harmful chemicals that mix with soil and air by using excessive inputs,
- Providing high quantity and quality products,
- Providing ease of labor,
- Reducing energy costs,
- Implementation of the best decisions for the business quickly and effectively,
- Preventing economic fluctuations by establishing a registration system in agriculture.

Some issues need to be developed in order for smart agricultural technologies to become more widespread both in Türkiye and in the world. Briefly, the first of these is the technology competencies of our farmers, whose average age is high, need to be improved. Most of the agricultural equipment used in our country has a low level of competence in terms of digital technology. It is necessary to make this equipment more compatible with digital technology or to renew the equipment that has completed its economic life. In some rural areas, communication and technology infrastructure needs to be developed. Finally, agricultural data should be securely collected in a large pool and this information should be analyzed and presented to agricultural equipment manufacturers. If these issues are developed, smart agriculture technologies will become widespread both in global and Türkiye and will provide high efficiency in production.

2. Theories of Economic Growth

Economic growth is the measured as observable increase in a country's production capacity or real GDP over a year. The increase in GDP over the preceding period is used to quantify economic growth, one of the most significant economic policy goals for governments. In other words, economic growth means expanding manufacturing capacity and producing more goods and services. The economic growth rate of countries varies based on their resources and other variables (Agwu, 2015, p. 487). In terms of scope, economic growth and development concepts differ from one another. While economic growth only refers to gains in a country's national income or per capita income, economic development includes social, political and cultural progress as well as growth.

Since the Mercantilists, numerous economic schools and thinkers have emphasized economic growth and its factors. Mercantilists have wanted to increase the stock of precious mines in foreign trade because they assess growth in the country's precious minerals. According to physiocrats, the agricultural sector is the primary source of capital accumulation essential for economic growth (Müller, 1978). The Physiocrats took a stand on tax policy, proposing that rising government debt was stifling the growth of productive resources, notably in agriculture, by maintaining a prosperous class of tax farmers and privileged monopolists (Gleicher, 1982, p. 357). They opposed the mercantilist system, also known as the commerce system, favoring an agricultural system to boost a country's economy (Yong, 1994, p. 5).

Population growth, technological development, labor division and capital accumulation are the main variables used by classical economists to explain economic growth. According to classical economic theory, savings demonstrate capital accumulation, which is the most important source of economic growth (Brewer, 2010, p. 4). According to A. Smith, who is considered one of the founders of classical economics, one of the most significant sources of economic growth is specialization in economic activities. Capital accumulation is, of course, one of the critical determinants of economic growth, according to Smith. Profit and savings are claimed to be the primary sources of capital accumulation (Berber, 2006, p. 59). On the other hand, Ramsey's classic work "A Mathematical Theory of Saving," published in 1928, is the origin of modern growth theory. He describes the growth theory regarding household consumption functions through time (Ramsey, 1928).

Growth, as well as consumption, savings decisions and investment, are all addressed in Keynesian economics. According to Keynes, investment expenditures raise the income level and thus the level of savings. Of course, the rise in savings enhance the capital stock through investments, which boost growth. To put it another way, in order to attain the necessary level of growth, savings-investment equality must be achieved (Berber, 2006, p. 103-104). Although Harrod's (1947) and Domar's (1959) growth models are primarily based on Keynesian analysis, they explain economic growth through capital accumulation and savings. According to this model, constant growth necessitates continuous net investments. However, the process will be disrupted if the rise in output due to investments is not balanced by demand. In other words, if the investment saving and supply-demand balance are achieved, the long-term growth process continues (Acemoglu, 2007, p. 25,73; Agwu, 2015, p. 487-488; Snowdon and Vane, 2005, p. 600-601).

Solow (1956), a key contributor to the neoclassical approach, explains the growth in terms of technological progress and population growth. These variables take place in the model externally. There is causation between population growth rate and technological development in the model. The long-term steady-state growth rate is determined by technological development based on scientific ideas and innovations. Solow (1956) and Swan (1956) propose two main predictions in their studies. To begin with, a country with more savings be more prosperous than one with fewer savings. However, this increase in savings does not affect the economic growth rate and only creates a level effect. Second, there is the convergence hypothesis, which states that developing countries will catch up to rich countries due to their faster growth (Acemolu, 2007, p. 25, 73; Agwu, 2015, p. 487-488; Cameron, 2003; Jones, 2015, p. 7-8, 19-20).

In opposition to the neoclassical model, the endogenous growth theories developed by P. Romer (1986) and R. Lucas (1998) first objected to the idea of technology being handled externally. Furthermore, Lucas (1998) claims that the premise that capital's marginal productivity declines is incorrect and that because human capital is incorporated in the model, it can produce long-term growth. Endogenous growth models predict that growth be sustained, owing to the evaluation of technical innovations in economic activities. Romer (1986) claims that, in addition to the internalization of technology, the information created by one company has 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) states it as financial markets. In other words, elements including R&D activities, human capital, new production methods, patents and copyright, new ideas, technology, international trade and capital inflow need all be considered for growth to continue according to endogenous economic growth theories (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 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), according to the Granger causality test results 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. In addition, they use the vector error correction model (VECM) to assess the impact of agriculture on economic growth in Nigeria (Sertolu, Ugural and Bekun, 2017, p. 551) and they find that agriculture is critical to Nigeria's economic growth.

To sum up, conventional and modern and contemporary growth theories approach the concept of growth differently. Traditional growth theories define growth as 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 primary data for growth (Koç, 2013, p. 242). As a result of planning and strategy proportional to a country's level of affluence, it is possible to supply the fundamental food needs of the population. All nations do not possess sufficient resources for self-sufficiency. The requirement and reliance on overseas suppliers are unavoidable. In this regard, one of the objectives of the national technical initiative should be to develop innovative, sustainably based production and supply initiatives for food and agricultural production resources.

3. Agriculture and Technology

The agriculture sector is critical to economic growth and development. Agriculture is vital because it influences economic growth, improves the income level of the generally low-income section of the agricultural workforce, provides input to other sectors of the economy and stimulates demand for these sectors. Agriculture makes a significant contribution to economic growth, especially in developing countries, because it employs so many people.

On the other hand, development in technology is the application of technological advances to improve the efficiency of a product or service's manufacturing processes. Today, it is widely acknowledged that the phenomenon of growth is related to a country's technological level. According to an economist, technology is a tool that helps countries improve their well-being and standard of life, as well as a measurement technique that connects production inputs and outputs. Furthermore, according to an engineer, it is a set of processes utilized to produce a good. In other words, technology is a source of information that can be used to improve the manufacturing and marketing efficiency of existing goods and services as well as create new ones (Kılıçarslan and Dinç, 2007). Technology is a dynamic criterion used in country classification. In industrialized countries, technology determines industrialization and economic policies. The widely accepted belief in the international community is that there is a strong link between countries' advanced technology output, economic growth and development. According to this perspective, economic growth policies judged independently of technology changes be inadequate.

Furthermore, there are various reasons for the agricultural sector's low production; technical advancement is one of the most critical components in resolving this issue. Agricultural production operations such as irrigation, cultivation, harvesting, fertilization, storage of crops and pesticide application can benefit from advanced technology. Besides, the absence of advanced agricultural equipment, particularly in less developed nations, prohibits obtaining the desired production level (Taban and Kar, 2016, p. 94-97).

Agriculture is accepted to be an essential component of economic growth in the literature. According to Golin, Parente and Rogerson (2002, p.160), agriculture is indispensable for economic growth. Their research culminates in a structural transformation model that includes agriculture in a one-sector neoclassical growth model. Thirtle, Lin and Piesse (2003, p. 1973) also show that increasing agricultural productivity significantly impacts reducing poverty. They claim that inequality increases poverty and slows GDP growth per capita. Another study finds that the agricultural sector is a driving force behind economic growth, based on "data on 15 emerging countries and transition economies in Africa, Asia and Latin America" (Awokuse, 2009, p. 20).

All social, economic, environmental and institutional dimensions of sustainable development are positively impacted by increased production in the manufacturing and agriculture sectors, resulting in increased growth (Behun et al., 2018, p. 23). With the development of elements such as productivity, technology, innovations, raw material supply and enhancement of the quality of the workforce, the manufacturing industry and agricultural sector contribute more to GDP (Kopuk and Meçik, 2020, p. 264). Correspondingly, 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, p. 272).

Self and Grabowski (2007, p. 395) suggest that agricultural technology advancements are a requirement for long-term growth and significantly impact it. Using these proxy measures of agricultural productivity, their empirical findings show that advanced agricultural technology in the 1960s had a positive and meaningful influence on growth from 1960 to 1995 and "the measures of agricultural modernization seem to have statistically significant positive effects on human development." (Self and Grabowski, p. 403, 2007). Muhammad Azhar Khan, Muhammad Zahir Khan, Khalid Zaman and Muhammad Mushtaq Khan indicate in their article (2013, p. 2007) that agricultural technology is a crucial component in reducing rural poverty in Pakistan. They examine annual data in Pakistan from 1975 to 2001 by using variance decomposition, cointegration theory and the Granger causality test.

4. The Path to Agriculture 5.0

Changes in agriculture in England in the middle of the 1600s as a result of meeting food demands sparked the First Industrial Revolution and agricultural fields became more structured and well-run. Batch manufacturing and the use of electricity led up to mass production and increased mechanization in agriculture during the Second Industrial Revolution. Afterward, the introduction of computers and digital materials ushered in the Third Industrial Revolution (Klavuz and Erdem, 2019). The "Green Revolution" refers to the changes in the agricultural sector during this period. It "describes the development of wide yielding varieties for numerous major food crops vital to developing countries" (Hazell, 2009). The stages of agriculture are characterized 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

In the agriculture sector, technology is becoming increasingly noticeable. With Industry 4.0, technologies that facilitate farmers' labor by enhancing profit, productivity and quality in agriculture have gotten smarter. While the globe is rapidly adopting the 4th Industrial Revolution, one of the outcomes of Industry 4.0 is the interaction between agricultural machinery, which aims to boost speed and production. These tools can help farmers employ conscious knowledge, reduce expenses, enhance output and make their jobs easier.

Since the early 2000s, the agriculture sector has been evolving in tandem with Industry 4.0. The application of smart technologies such as microprocessors, sensors, cloud-based information, autonomous decision systems and communication technologies in the agriculture sector is referred to as "Agriculture 4.0, Smart Agriculture, Digital Agriculture" (Saygılı et al., 2019). The goal is 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" through the contribution and use of the IoT (Elijah et al., 2018).

5. The Need for Transformation in Agriculture

Countries are competing in a digital transformation race to create added value. Consumer demands and widespread privatization are among the elements of this process; the significance of data and new business models; resource limits and sustainability; and the shift to a qualified workforce (TÜSİAD, 2017). Furthermore, "the globalization of the value chains of agriculture and food products provides a global division of labor in food production". While these developments provide significant opportunities for countries that can effectively use the possibilities offered by advances in production technologies and integrate them into global value chains, they force countries that can't keep up with various challenges, primarily in terms of increased foreign dependency, sustainability and low value-added production (Tümen and Özertan, 2020).

Along with digital transformation, the advancement of communication infrastructure, combined with recent technological developments, has enabled the use of digital technology in agriculture and other sectors. Because of rising population, climate change, global warming and shrinking agricultural lands, agricultural sectors in industrialized countries are pursuing R&D and field studies to reap the benefits of digitalization. Such advances push governments to rethink their current and traditional agricultural policies, focusing on R&D activities, digitization, productivity/added value and agricultural technologies (Tümen and Özertan, 2020).

Agriculture is crucial to every society and is one of the most pressing global challenges. The fundamental goal of agriculture is to enable the sustainable use of natural resources while also providing adequate and balanced nutrition for society. According to the OECD-FAO Agricultural Outlook 2019-2028 report, population growth is expected to increase demand for agricultural products by 15% between 2019 and 2028 (OECD-FAO, 2019) and 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).

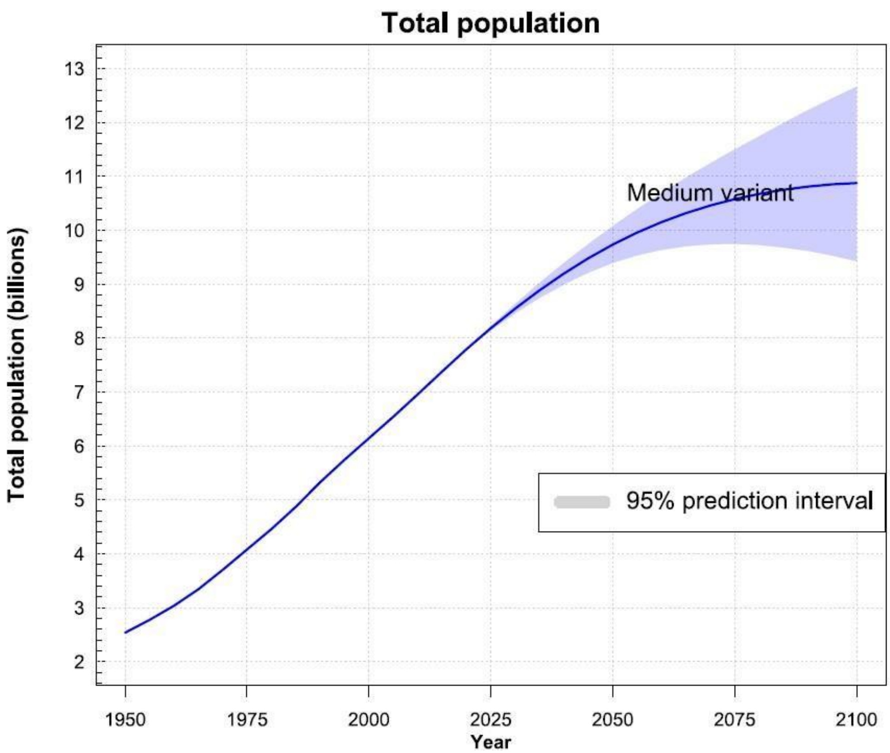

Figure 1. *The global population predictions towards 2100*

Source: https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf

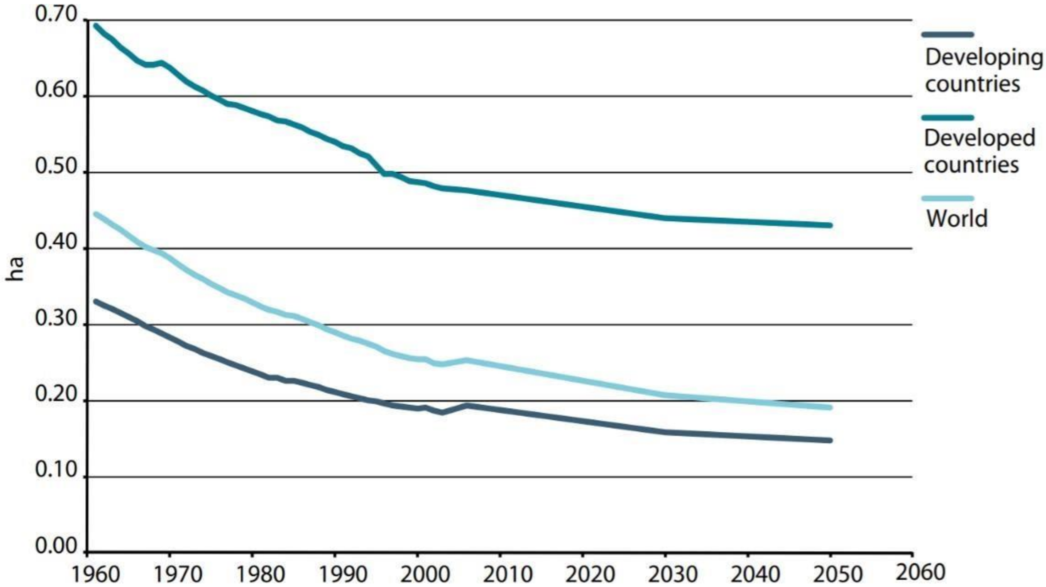

Figure 2. *Arable land per capita*

Source: http://www.fao.org/3/ap106e/ap106e.pdf

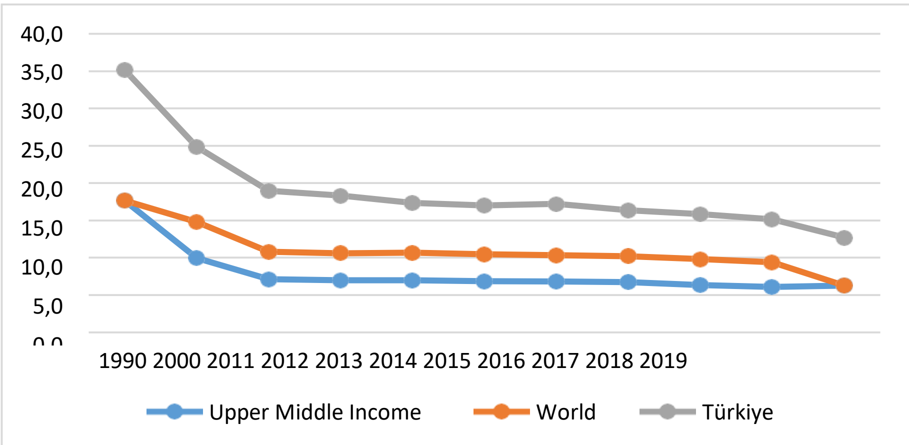

Figure 3. *Agriculture value-added (Billion USD and % of GDP)*

Source:
https://databank.worldbank.org/reports.aspx?source=2&series=NV.AGR.TOTL.ZS&country=UMC ,WLD,TUR#

Apart from the importance of agriculture for a country's survival, the agriculture value-added (billion USD) is increasing in upper-middle-income countries worldwide, unlike Türkiye. Since agricultural productivity has grown significantly and steadily (Figure 3), new agricultural methods have resulted in a progressive growth in agriculture value-added (billion USD). On the other hand, the global percentage of agriculture value-added in GDP appears to be falling. Agriculture's share of GDP is continuously diminishing as other sectors such as services and industry have grown significantly and become important factors in the economy. The percentage of agriculture in GDP is constantly decreasing as other sectors such as services and industry have grown considerably and become important factors in the economy. The comparison of the two graphs reveals that, while the value-added agriculture rate in GDP is decreasing, the productivity and value-added in billions of dollars are increasing. As shown in both graphs (Figure 3), Türkiye's agriculture value-added (billions of dollars) has dropped compared to upper-middle-income countries and the global average. In terms of GDP, it also displays a comparable rate of fall in agriculture value-added. Although upper-middle-income countries, such as Türkiye (The World Bank, 2021), have an increased rate of agriculture value-added (billions of dollars), Türkiye does not. This rate is projected to rise when smart agriculture techniques are used.

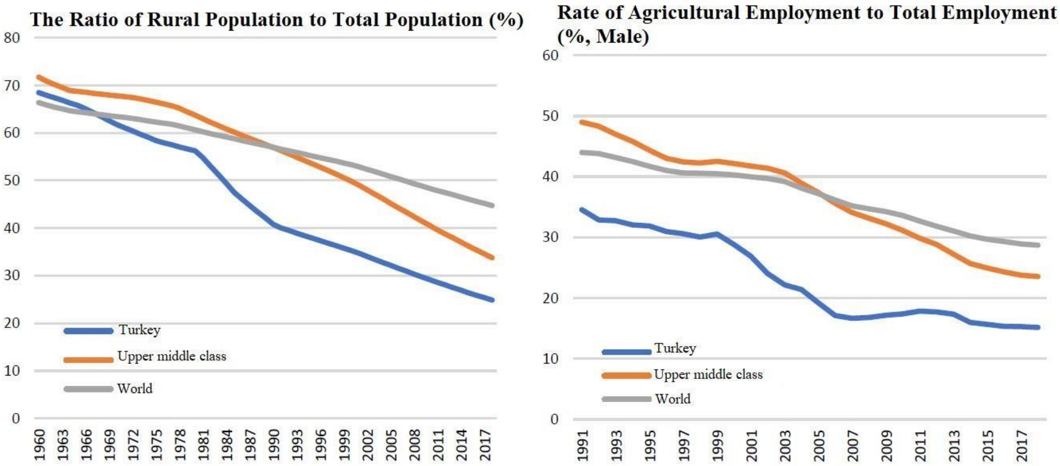

Figure 4. *The ratio of rural population to the total population (%) and the rate of agricultural and employment to total employment (%, male)*

Source: https://databank.worldbank.org/reports.aspx?source=2&series=SL.AGR.EMPL.ZS&country=UMC,WLD,TUR#

There is a need to boost productivity due to the global fall in growth rate and arable land (Figure 2), as well as the decrease in rural population and agricultural employment (Figure 4). Each country's agricultural capacity defines the path to achieving this goal. The advancement of satellite, drone and sensor technologies, referred to as Remote Sensing Systems, has enabled the advancement of IoT (Internet of Things) and technological breakthroughs in communication infrastructures such as 4.5G and 5G, allowing them to be used in farmlands and fields.

6. Smart Agriculture

Smart farming is defined as modern agriculture technology and techniques that enable better soil and crop management and resource efficiency. It reduces environmental damage while increasing agricultural output by providing the infrastructure for the agricultural industry to use advanced technologies such as the cloud, big data and the internet of things (IoT) for tracking, automating and analyzing activities. Smart farming, often known as precision agriculture, is software-managed and sensor-monitored." (Bernstein, 2019; Demirel Atasoy, 2019). Smart agriculture is also known as climate-smart agriculture (CSA), which 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". It has three primary goals: lowering and/or eliminating greenhouse gas emissions, adapting to climate change and creating resilience and if possible, boosting agricultural productivity sustainably

The following items can be highlighted to list the most important objectives of smart farming (Internet of Things Türkiye, 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 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/

Sensing technologies, communications systems, software applications, telematics and positioning technologies, hardware and software systems and data analytics solutions are the six components of smart farming. "A technology that uses sensors to acquire information by detecting the physical, chemical, or biological property quantities and convert them into readable signals" is how sensing technologies are defined (Yokogawa, n.d.). It collects data 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). "The interaction between actors on top of a common technological platform resulting in a cohesive set of ICT (information and communication technology) products or services" is how software applications are defined (Kruize et al., 2016). Communication systems are also critical 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 systems could easily connect, collaborate and establish working online and offline platforms 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., 2019).

Soil fertility is predicted to rise as the internet of things spreads in the agricultural sector, resulting in a profit for farmers. People will also have no problems with the things they buy because healthy products are produced. Advanced technology will conserve natural resources and harmful compounds in the soil will be easily detected, green energy will be produced, remote operations will save time and most significantly, environmental damage will be avoided.

As technology advances, the need to lower the cost and environmental impact of agricultural inputs gradually increase. Physical and geographical variations, environmental and crop characteristics, non-uniform soil, the environmental impacts of inputs and cost increase these pressures. Smart agriculture aims to maximize economic efficiency while minimizing environmental impact by utilizing inputs efficiently (in the required quantity). Furthermore, agricultural technology data drives decisions not just at the farm level but also for input and equipment producers (Coble et al., 2018). It is possible to attain product quality uniformity under these conditions. In this regard, the goals of smart agriculture might be summarized as follows (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 and
- Establishment of the registration order in agriculture.

Data collection has begun in the technological development of smart agriculture and data analysis impacts business development decision-making operations (Atasoy, 2019). Agricultural data is strategically essential. Drones, sensors, satellites, weather stations and soil analysis tools are all used to collect measurable production and agriculture data. Projections and predictions can be made using technologies like machine learning, artificial intelligence and deep learning from large volumes of agricultural data, as well as disease and pest prediction, substantial advancements and early warning systems in agricultural control. The number of devices collecting agricultural data is predicted to reach 75 million by the end of 2020 (TÜSİAD, 2020).

6.1. 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 through 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). Other variables that affect food security include increasing population, decreasing arable land, climate change and natural resources; as a result, the utilization of the IoT has become a crucial concern in order to meet future food demands.

Agricultural techniques have been enhanced throughout human history by combining them with technology to reduce work. Although agriculture is required to support human food demands, not all countries are able to achieve their vital food needs due to the uneven distribution of fertile land. Furthermore, agricultural land is influenced not only by climate and land patterns around the world but also by economic and political challenges, as well as population density, "while rapid urbanization is constantly posing threats to the availability of arable land" (Ayaz et al., 2019).

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 attempts to unite the physical and virtual worlds through the internet, which serves as a connecting and information-exchanging medium (Elijah et al., 2018). It is feasible to collect and evaluate data and turn it into action by combining these worlds and tools with automated processes (Burgess, 2018).

IoT has lately begun to touch a variety of businesses and sectors, ranging from manufacturing to energy and communications to agriculture, in order to reduce unproductivity and improve performance across the board. "This is due to the capabilities offered by IoT, which include basic communication infrastructure (used to connect smart objects—from sensors, vehicles and user mobile devices—using the internet) and a range of services, including 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, robotics and sensor networks, as well as techniques for linking variables to appropriate farming management actions, has paved the way for IoT applications in agriculture" (Vermesan et al., 2015, p. 51). Because of their potential to combine several technologies, these systems are predicted to alter the agriculture sector by enhancing efficiency and productivity.

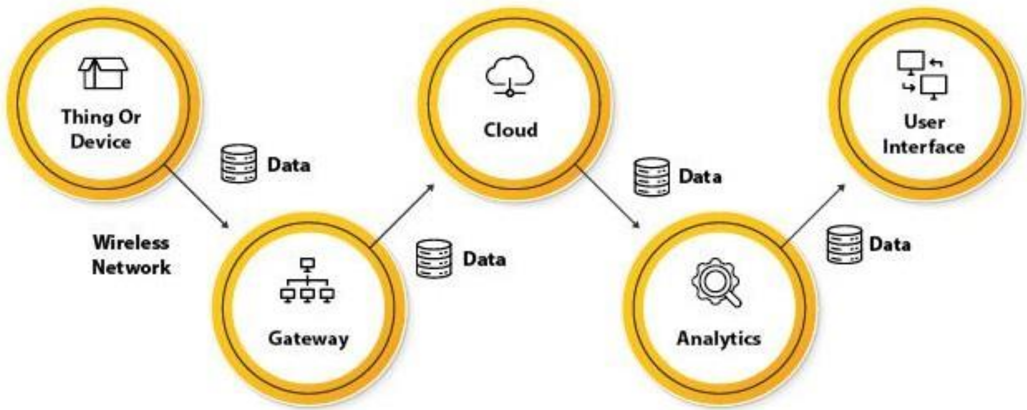

Figure 6. *The components of the internet of things*

Source: https://www.rfpage.com/what-are-the-major-components-of-internet-of-things/

IoT components include an object or gadget, a gateway, analytics, a cloud and a user interface (NewGenApps, 2018). Devices and sensors collect data first, then send it to the next layer. A gateway is another component that manages "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 et al., 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 sophisticated "high-performance network of servers optimized to execute high-speed data processing of billions of devices, traffic control and accurate analysis". Analytics is a means of converting analog data from billions of digital devices and sensors into useful information that can be examined and used for extensive study. Finally, a user interface is "the visible, tangible element 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: Elijiah et al., (2018)

"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," according to numerous indicators (Coble et al., 2018, p. 79). Sensors are now installed in practically all agricultural devices, from agrimotors to crop tools. The IoT allows machines to communicate with one another throughout the manufacturing process. Farmers benefit from agricultural equipment and fields equipped with digital sensors because they can see how much and what sort of fertilizer is needed, the weather conditions, the minerals that plants require, the soil condition and the projected harvest time in real-time. Compared to traditional ways, it is hoped that farmer's work would be made easier and more efficient. Agricultural machinery will save costs and reduce workload.

Agriculture will be more fertile and people will produce the greatest quality products swiftly and affordably with the agricultural revolution followed by Industry 4.0, commonly referred to as Agriculture 4.0 (Türkiye'nin Endüstri 4.0 Platformu, 2019). The IoT solutions in agriculture are expected to constitute a cycle that includes analysis and planning, sensor monitoring and smart control, all of which are linked by a wireless network connected to a cloud service (Andrew, Bogatinoska and Malekian, 2018). With the implementation of smart agriculture methods such as irrigation, drought response, pest control, land appropriateness and yield optimization, the IoT may also produce and develop answers to many difficulties that the agricultural industry faces (Ayaz et al., 2019).

Its goal is to maximize productivity by employing the IoT concept, which has begun to be used in the agricultural sector. Natural resources are not misused thanks to numerous smart agricultural techniques, resulting in cost savings. Products become more profitable under these conditions and the environment is safeguarded. It is hoped that smart agriculture will lessen the risk of water shortage, affecting many countries worldwide in recent years because farmers will know where and how much water they should use and thus will not waste it. Some of its applications are automation, disease and pest management, water quality, agricultural and livestock and irrigation systems, weather monitoring, etc.

6.2. 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

6.3. Challenges

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

6.4. Application examples of countries

Many countries have recently prioritized start-ups focused on developing smart agriculture technologies. Producers have begun to obtain decreased costs, higher output, monitoring and other opportunities in the same field by merging agricultural techniques with the IoT. As a result, countries that profit from these practices can boost their agricultural value-added and thus their GDP. Examples and data on key countries that foster agricultural start-ups in the world are shown in Figure 7. The United States is the biggest agricultural exporting country, with advanced and early-stage start-ups. Despite its smaller area compared to other major countries, Israel is the country that invests the most. In terms of arable land and agricultural exports, Holland is the foremost example. Because of its enhanced agricultural equipment, it is one of the leading countries in terms of agricultural exports despite its smaller surface area.

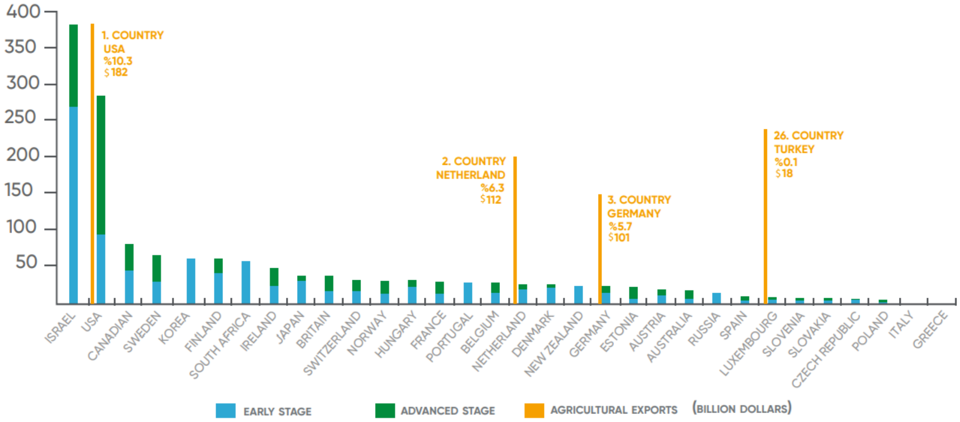

Figure 7. *Smart farming start-ups around the world*
Source: https://assets.kpmg/content/dam/kpmg/au/pdf/2016/powering-growth-realising-potential-agtech-australia.pdf, Accessed on: May, 2022 (Currently, the link is unavailable)

Huawei and Carrier Telia collaborate in Norway on several innovative projects to improve smart farming infrastructure. For instance, "the IoTcan provide smart irrigation systems, where sensors are utilized to extract data to track crops, soil and the air in real-time"; as a result, farmers can monitor the efficiency of farming equipment and forecast weather patterns. In addition, the "Gjeteren" project places a tracking module on sheep in Norway's Rogaland summer farm, allowing farmers to detect and monitor the sheep remotely. Through mobile IoT, Norway will soon be able to track and see everything "from animals, ships, containers and moving things" (HUAWEI, n.d.).

In Spain, Telefonica, which is a Spanish telecommunication company, provides an automated irrigation system that connects meters, level meters and hydraulic valves by utilizing GPRS on 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 enabled farmers to use computers and mobile phones to create an irrigation schedule that worked for them" (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

According to the Ministry of Agriculture, Food and Rural Areas' Annual Report of Food, Agriculture and Rural Areas (2018), the implementation of structural reforms in distribution and processing, the reduction of input costs in agriculture policies and the establishment of a strategic export system all play critical roles in Japan. The most essential aspect of lowering input prices is agricultural technology. As a result, the focus is on increasing production, skill transfers, product quality and the scale of the farming enterprise. For example, self-driving tractors and GPS-based leveling machines from Hokkaido are employed at farming partitions in Moseushi Town as part of an infrastructure development project to increase streamline soil management and leveling accuracy (Ministry of Agriculture, Forestry and Fisheries, 2019). In Kyoto, Japan's Spread Company operates an automated lettuce factory. The company sells lettuce grown automatically under controlled temperature, humidity and light conditions. Every year, 7.7 million lettuce heads are produced. The new factory's design aims include keeping it ecologically benign by reusing 98 percent of water and decreasing labor expenses by 50 percent through automation (Demaitre, 2015).

6.5. National Technology Initiative and Examples of Smart Agriculture Applications in Türkiye

TABİT Smart Farming is implementing Vodafone Smart Village Project to raise awareness of innovative agricultural technologies. Information and communication technology (TABİT, n.d.) combines advanced technology with conventional farming methods to boost production efficiency. To expand technical knowledge in rural regions, training needs analyses and data have been collected in about 12.000 villages since 2004. The smart model used in Vodafone Smart Village promises to reduce agricultural production costs by 22%, animal production expenses by 20% and overall productivity by 10%.

ForFarming is an agricultural technology product powered by artificial intelligence algorithms that is IoT-based, observable, reportable and controlled. It introduces smart soilless agriculture solutions that allow individuals and businesses in the food industry to produce their products. It is one of the efforts of the Commercialization Center of İstanbul, which is one of the associates of the İstanbul Chamber of Commerce and is sponsored by the İstanbul IT and Smart City Technologies Inc. (İSBAK), which is one of the associates of the İstanbul Metropolitan Municipality. ForFarming's fully automated technology ensures controllable and sustainable production by allowing remote access via the internet from a tablet, smartphone, or computer and smart product control.

Turkcell provides farmers with smart farming solutions such as Filiz in order to safeguard the world's scarce water resources and promote efficient agriculture (TURKCELL, 2019). Filiz, a mobile application that works with a soil-weather station to provide real-time data about the user's field, assists farmers in making irrigation and disinfection decisions based on soil and weather conditions to boost output. Farmers may also use the sera monitoring solution to remotely monitor temperature and humidity levels in agricultural areas, as well as maintain the proper heat level by controlling air conditioning equipment without having to go to the greenhouses. As a result, it aims to boost productivity.

6.6. The Applications within the Framework of the Agricultural Credit Cooperatives of Türkiye

The Agricultural Credit Cooperatives of Türkiye (ACC) operates as an independent institution in Türkiye. With 17 Regional Associations and 1625-unit cooperatives, it serves 830.000 farmer members. Its mission is to meet all its members' and Turkish farmers' needs by providing secure, timely, high-quality and affordable goods and services, as well as market their products and ensure that Turkish agriculture is environmentally sustainable, friendly and the most productive sector in the country. It has 13 subsidiaries under its umbrella, all of which are involved in various aspects of agriculture, such as irrigation systems, fertilizer and animal feed. The following are examples of smart farming applications from two firms of the ACC.

Tarnet, a subsidiary of the Agricultural Credit Cooperatives, focuses on smart agricultural applications such as electrostatic spray application and drone disinfection. With the old technology, electricity, time, gasoline, plant protection materials and personnel requirements are all reduced. Tarnet is currently putting drones to the test in paddy fields. Manisa, for example, makes 1.2 L profit per decare and 50% profit in medicine. The latter technology allows for a higher rate of drug adsorption on plants (up to 90%), as traditional methods only allow for around 25%. The electrostatic spraying method can result in a 9-fold decrease in residue on plants, as well as 70 percent medicine, 90 percent water and 50 percent fuel savings.

There are many advantages of agricultural spraying drone (ZIHA) technologies. In general, these advantages can be listed as follows:

1. Protects the environment and gets effective results by using less drugs.

2. Due to its effectiveness in weed control, paddy develops more and the producer buys more products.

3. Since it does not crush the product with the tractor, it does not cause product loss.

4. Since the people making the application are not in the sprayed field, they protect human health.

Since spraying drones (ZIHA) can work autonomously, labor-saving is achieved and it becomes possible to apply pesticides even at night. In addition, with the automatic steering technology implemented by Tarnet:

- 10% in total cost,
- 9% in fuel usage and
- It has been shown that 17% of time can be saved.

GÜBRETAŞ, a subsidiary of the Agricultural Credit Cooperatives, has been producing the Türkiye Soil Fertility Map since 2005 and conducting innovation-oriented initiatives and R&D in recent years. Over 50 thousand farmers have been educated in 14 years to take applied soil samples and plant nutrients in the field. Soil samples were gathered and examined from 11 thousand of farms throughout 81 provinces. In order to expand conscious agricultural output, model test fields/gardens are also being built. The goal of these studies, which are being conducted with pioneer farmers, is to achieve maximum production with minimal fertilizer use (GÜBRETAŞ, 2016, p. 65). The trial fields' target and obtained fertility data are listed below.

Table 2. *The Target and Generated Fertility Data of the Trial Fields*

Plant	Location	Türkiye 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**
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**

Source: Gönay Akbaş, G. and Bağcı, A. (2021). Economic growth and smart farming. Gazi İktisat ve İşletme Dergisi, 7(2), 104-121

7. Conclusion

To summarize, despite their drawbacks, smart farming applications are said to provide a significant increase in profit and productivity. Agriculture has always been and will continue to be an important sector because it is vital to each country's survival. In addition, when considering the deterioration in the supply value chains of the countries and the increase in energy prices due to the war that started between Russia and Ukraine after Covid-19, productivity in the agricultural sector has gained importance. Besides, due to the fact that Türkiye became a party to the Paris Agreement on November 10, 2021, the use of agricultural technologies for the traceable agricultural production process in compliance with the European Green Deal principles and the correct use of chemical products such as pesticides came to the fore. Therefore, Türkiye has published the Green Reconciliation Action Plan, which aims to ensure its adaptation to the policies to combat climate change, which has gained momentum in international trade in recent years. It is a roadmap that will strengthen Türkiye's competitiveness in exports. There are 11 actions under the title of sustainable agriculture goals in the deal. This action plan aims to make the agricultural production chain traceable, produce by taking environmental factors into account and disseminate technologies that reduce carbon emissions. As a result, in addition to the growing importance of other sectors such as boosting productivity, industry, services and profit is vital due to the global fall in growth rate, rural population, arable land and agricultural employment. In addition, the growth of IoT and connectivity has led to smart farming, which has become a necessity in agriculture to boost profit and productivity. Türkiye's National Technology Initiative in agriculture, as in every field, continues on its way with the goals of local production and embracing innovation. There are many instances of smart farming applications linked to IoT, both in global and Türkiye, that attempt to mitigate the disadvantages of declining agricultural employment and arable lands, as well as climate dependency and these applications are predicted to develop through time. In agricultural production, applying advanced technology infrastructure at all supply chain stages will significantly boost productivity while lowering losses.

References

Acemoğlu, D. (2007). *Introduction to Modern Economic Growth.* Massachusetts Institute of Technology. Retrieved from https://www.theigc.org/wp-content/uploads/2016/06/acemoglu-2007.pdf

Agwu, C. (2015). Factors that contribute to economic growth in Nigeria. *International Journal of Management and Commerce Innovations, 2*(2), 487-495.

Andrew, R. C., Bogatinoska, D. C. and Malekian, R. (2018). IoT solutions for precision agriculture. *2018 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, 377-381. DOI: 10.23919/MIPRO.2018.8400066

Awokuse, Titus O. (2009). Does agriculture really matter for economic growth in developing countries?, *The American Agricultural Economics Association Annual Meeting,* Milwaukee, WI, July 28, 2009.

Ayaz, M., Ammad-uddin, M., Sharif, Z., Mansour, A. and Aggoune, e.-H. M. (2019). Internet-of-Things (IoT) based smart agriculture: towards making the fields talk. *The Institute of Electrical and Electronics Engineers*, 129551-129583. doi: 10.1109/ACCESS.2019.2932609

Behun, M., Gavurova, B., Tkacova, A. and Kotaskova, A. (2018). The impact of the manufacturing industry on the economic cycle of European Union countries. *Journal of Competitiveness, 10*(1), 23-39.

Berber, M. (2006). *İktisadi büyüme ve kalkınma* (3. ed.). Trabzon: Derya Kitabevi.

Brewer, A. (2010). *The making of the classical theory of economic growth.* London: Routledge.

Burgess, M. (2018). *What is the Internet of Things? WIRED explains*. Retrieved 10 July 2020, from https://www.wired.co.uk/article/internet-of-things-what-is-explained-iot

Calderone, L. (2019). *Monitoring & growing, precision farming*. Retrieved 26 June 2020, from https://www.agritechtomorrow.com/

Cameron, G. (2003). Why did UK manufacturing productivity growth slowdown in the 1970s and speed up in the 1980s? *Economica*, *70*(1), 121-141.

Canbay, Ş., Kırca, M. (2020). Relationships between industrial and agricultural sector activities and economic growth in Türkiye: an analysis of Kaldor's growth laws. *Journal of the Human and Social Science Researches. 9*(1), 143-170.

Coble, K. H., Ferrell, S., Griffin, T. and Mishra, A. K. (2018). Big data in agriculture: a challenge for the future. *Applied Economic Perspectives and Policy, 40*(1), 79-96. doi: 10.1093/aepp/ppx056.

Demaitre, E. (2015). *Japan's Spread Co. builds the biggest automated lettuce farm*. Robotics Business Review. Retrieved 11 June 2020, from https://www.roboticsbusinessreview.com/agriculture/japans_spread_co_builds_the_big gest_automated_lettuce_farm/.

Demirel Atasoy, Z. (2019). *Türkiye'de akıllı tarımın mevcut durum raporu.* Ankara: Tarım ve Orman Bakanlığı Bitkisel Üretim Genel Müdürlüğü.

Derso, D. and Ejiro, E. (2015). the contribution of information and communication technologies to the Ethiopian agricultural extension system: a review of literature on agriculture knowledge management. *African Journal of Agricultural Science and Technology (AJAST), 3*(9), 407-411.

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), 3758-3773.doi: 10.1109/JIOT.2018.2844296

Folkens, J. (2015). *Building a gateway to the Internet of Things.* Texas: Texas Instruments.

Folnovic, T. (n.d.). *High-Tech farm revolution triggered by crop sensing technology*. Retrieved 15 May 2020, from https://blog.agrivi.com/post/high-techfarmrevolution-triggered-by-crop-sensing-technology

Food and Agriculture Organization of the United Nations. (n.d.). *Climate-Smart Agriculture*. Retrieved from http://www.fao.org/climate-smart-agriculture/en/

Gleicher, D. (1982). The historical bases of physiocracy: an analysis of the "tableau economique". *Science & Society. 46*(3), 328-360.

Gollin, D., Parente, S.and Rogerson, R. (2002). The role of agriculture in development. *The American Economic Review*, *92*(2), 160-164.

Gönay Akbaş, G. and Bağcı, A. (2021). Economic growth and smart farming. *Gazi İktisat ve İşletme Dergisi, 7*(2), 104-121

Guoqiang, S., Yanming, C., Chao, Z. and Yanxu, Z. (2013). Design and implementation of a smart IoT gateway. *2013 IEEE International Conference on Green Computing and Communications and IEEE Internet of Things and IEEE Cyber, Physical and Social Computing.* 720-723. doi: 10.1109/GreenCom-iThings-CPSCom.2013.130

GÜBRETAŞ. (2016). *2016 annual report.* İstanbul. Retrieved from https://gubretas.com.tr/wp-content/uploads/2019/04/GUBRETAS_2016FR_TR_LOW.pdf

Harrod, R. (1947). "*Keynes the Economist" in the New Economics ed. S.E. Harris*. New York: Alfred A. Knopf.

Hazell, P. B. (2009). *The Asian green revolution.* Washington DC: International Food Policy Research Institute. Retrieved 10 July 2020, from https://core.ac.uk/download/pdf/6257689.pdf

Heacox, L. (2008). *Time for telematics*. CropLife. Retrieved 10 July 2020, from https://www.croplife.com/precision/time-for-telematics/

HUAWEI. (2017). *The connected farm: a smart agriculture market assessment.* Retrieved 10 July 2020, from https://www-file.huawei.com/-/media/corporate/images/pdf/v2-smart-agriculture-0517.pdf?la=en

HUAWEI. (n.d.). *Smart agriculture progress in Norway*. Retrieved 3 January 2020, from https://www.huawei.com/en/technology-insights/industry-insights/outlook/mobile-broadband/wireless-for-sustainability/cases/smart-agriculture-progress-in-norway

Internet of Things Türkiye, (2017). *Tarımın geleceği: akıllı tarım sistemleri*. Retrieved from https://ioTürkiye.com/2017/06/tarimin-gelecegi-akilli-tarim-sistemleri/

IoT Agenda, (n.d.). *Smart farming*. Retrieved 13 May 2020, from https://internetofthingsagenda.techtarget.com/definition/smart-farming

Izuchukwu, O. O. (2011). Analysis of the contribution of agricultural sector on the Nigerian economic development. *World Review of Business Research, 1*(1), 191-200.

Jones, C. I. (2016). *"The Facts of Economic Growth" in Handbook of Macroeconomics Volume 2ed. John B. Taylor and Harald Uhlig.* North Holland. doi: 10.1016/bs.hesmac.2016.03.002

Khan, M.A., Khan, M.Z., Zaman, K. and Khan, M.M. (2014). The evolving role of agricultural technology indicators and economic growth in rural poverty: has the ideas machine broken down?. *Quality & Quantity, 48*. 2007-2022.

Kılavuz, E. and Erdem, İ. (2019). Dünyada tarım 4.0 uygulamaları ve türk tarımının dönüşümü. *Social Sciences (NWSAENS),* 14(4), 133-157.Retrieved 6 March 2020, fromhttps://dergipark.org.tr/tr/download/article-file/840914

Kılıçarslan, O. and Dinç, O. (2007).Türkiye ekonomisinde teknolojive veri transferi, *GAU J. Soc. & Appl. Sci., 3*(5), 73-75.

Koç, A. (2013). Beşeri sermaye ve ekonomik büyüme ilişkisi: yatay kesit analizi ile AB ülkeleri bir değerlendirme. *Maliye Dergisi, 165*, 241-252.

Kopuk, E. and Meçik, O. (2020). Türkiye'de imalat sanayi ve tarım sektörlerinin ekonomik büyüme üzerine etkisi: 1998-2020 dönemi analizi. *Yönetim ve Ekonomi: Celal Bayar Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, *27*(2), 263-274. doi: 10.18657/yonveek.693387.

Kruize, J., Wolfert, J., Scholten, H., Verdouw, C., Kassahun, A. and Beulens, A. (2016). A reference architecture for farm software ecosystems. *Computers and Electonics in Agriculture, 125,* 12-28. doi:10.1016/j.compag.2016.04.011

Ministry of Agriculture, Forestry and Fisheries. (2019). *Summary of the annual report on food, agriculture and rural areas in Japan.* Ministry of Agriculture, Forestry and Fisheries. Retrieved 3 January 2020, from https://maff.go.jp/e/data/publish/attach/pdf/index160.pdf

Mohamed, A. K.W. (2013). *Analysis of telematics systems in agriculture.* Master's thesis, Department of Machinery, Utilization, CULS, Prague Retrieved from https://www.bu.edu.eg/portal/uploads/Agriculture/Agricultural%20Engineering/1222/publications/Ahmed%20Khaled%20Abd%20ElWahab%20Mohamed_Ahmed%20Khaled%20Abd%20El-Wahab%20Mohamed.pdf

Müller, A. (1978). Quesnay's theory of growth: A Comment. *Oxford Economic Papers, 30*(1), 150-156.

NewGenApps. (2018). *IoT ecosystem components: the complete connectivity layer*. Retrieved 28 May 2020, from https://www.newgenapps.com/blog/iotecosystem-components-the-completeconnectivity-layer/

OECD-FAO. (2019). *OECD-FAO Agricultural Outlook 2019-2028.* Paris/Food and Agriculture Organizations of the United Nations, Rome: OECD Publishing. doi:10.1787/agr_outlook-2019-en

Ramsey, F. P. (1928). A mathematical theory of saving. *The Economic Journal, 38*(152), 543-559.

RF Page. (2018). *What are the Major Components of Internet of Things?* RF Page. Retrieved 10 January 2020, from https://www.rfpage.com/what-are-the-major-components-ofinternet-ofthings/

Sarker, M. N., Wu, M., Chanthamith, B., Yusufzada, S., Li, D. and Zhang, J. (n.d.). Big Data Driven Smart Agriculture: Pathway for Sustailable Development. *2019 2nd International Conference on Artificial Intelligence and Big Data (ICAIBD)*, 60-65. doi:10.1109/ICAIBD.2019.8836982

Saygılı, F., Kaya, A. A., Tunalı Çalışkan, E. and Erdölek Kozal, Ö. (2019). *Türk tarımının global entegrasyonu ve tarım 4.0.* Retrieved from https://itb.org.tr/img/userfiles/files/ITB%20TARIM.pdf?v=1550751511711

Schriber, S. (n.d.). Smart agriculture sensors: helping small farmers and positively impacting global issues. *Mouser Electronics*. Retrieved 13 May 2020, from https://www.mouser.com.tr/applications/smart-agriculture-sensors/

Self, S. and Grabowski, R. (2007). Economic development and the role of agricultural technology. *Agricultural Economics, 36*, 395-404.

Sertoğlu, K., Ugural, S. and Bekun, F.V. (2017). The contribution of agricultural sector on economic growth of Nigeria. *International Journal of Economics and Financial Issues, 7*(1), 547-552.

Snowdon, B. and Vane, H. R. (2005). *Modern macroeconomics: its origins, development and current state.* Cheltenham: E. Elgar.

Solow, R. M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics, 70*(1), 65-94.

Swan, T. W. (1956). Economic growth and capital accumulation. *The Economic Record, 32*(2), 334-361.

Szostak, R. (2009). *The causes of economic growth: interdisciplinary perspectives.* Heidelberg: Springer.

Taban, S. and Kar, M. (2016). *Kalkınma ekonomisi.* Bursa: Ekin Yayınevi.

TABİT. (n.d.). *Vodafone Smart Village Project*. Retrieved from http://en.tabit.com.tr/projelerimiz/

The World Bank. (July 2021). World Bank Country and Lending Groups. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups (Accessed: August 4, 2022).

Thirtle, C., Lin, L. and Piesse, J. (2003). The impact of research led agricultural productivity growth on poverty reduction in Africa, Asia and Latin America. *Contributed paper for the 25th conference of the International Association of Agricultural Economists*. Durban.

TURKCEL. (2019). *Dijital Tarımda Yerli ve Milli Ürün "Filiz"*. Retrieved 10 July 2020, fromhttps://medya.turkcell.com.tr/bulletins/dijital-tarimda-yerli-ve-milli-urun-filiz/

Tümen, S. and Özertan, G. (2020). *Katma değerin artırılması, inovasyon ve dijital tarım.* İstanbul: TÜSİAD.

Türkiye'nin Endüstri 4.0 Platformu. (2019). Retrieved 10 July 2020, from https://www.endustri40.com/endustri-4-0la-birlikte-gelen-akilli-tarim/

TÜSİAD. (2017). *Türkiye'nin sanayide dijital dönüşüm yetkinliği.* İstanbul: TÜSİAD. Retrieved from https://tusiad.org/tr/yayinlar/raporlar/item/9864-tusiad-bcg-Türkiye-nin-sanayide-dijital-donusum-yetkinligi

TÜSİAD. (2020). *Tarım ve gıda 2020: sürdürülebilir büyüme bağlamında tarım ve gıda sektörünün analizi.* İstanbul: TÜSİAD. Retrieved from https://tusiad.org/tr/yayinlar/raporlar/item/10544-tarim-ve-gida-2020-surdurulebilir-buyume-baglaminda-tarim-ve-gida-sektorunun-analizi

United Nations Department of Economic and Social Affairs. (2019). *World Population Prospects 2019.* New York: United Nations. Retrieved from https://population.un.org/wpp/Download/Standard/Population/

Vermesan, O., Friess, P., Guillemin, P., Giaffreda, R., Grindvoll, H., Eisenhauer, M., Serrano, M.,Moessner, K., Spirito, M., Blystad, L. and Tragos, E. Z. (2015). *"Internet of Things beyond the hype: research, innovation and deployment" in building the hyperconnected society: IoT research and innovation value chains, ecosystems and markets. ed. O. Vermesan and P.Friess*. Aalborg: River Publishers.

Yokogawa. (n.d.). *Definition of sensor and sensing technology*. Retrieved 14 May 2020, from https://www.yokogawa.com/special/sensing-technology/

Yong, Ronald A. (1994). *Physiocracy: A viewpoint of the role of agricultural production in a macroeconomic system.* Master's thesis, University of Montana. Retrieved 7 February 2021 from https://scholarworks.umt.edu/cgi/viewcontent.cgi?article=9709&context=etd

Zambon, I., Cecchini, M., Egidi, G., Saporito, M. G. and Colantoni, A. (2019). Revolution 4.0: industry vs. agriculture in a future development for SMEs. *Processes, 7*(1). doi: https://doi.org/10.3390/pr7010036

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Dr. Ahmet Bağcı has been appointed as Counsellor for Environment and Urbanization at the Permanent Mission of the Republic of Türkiye to European Union since August, 2022. He served as Deputy General Manager of Agricultural Credit Cooperatives of Türkiye between 2018-2022. He also served as Chairman of the Executive Board of TARNET Tarim Kredi Bilişim ve İletişim and Deputy Chairman of the Board of GÜBRETAŞ A.Ş. He received his Ph.D. degree in 2017 with the thesis titled "The Relation between Savings, Financial Development and Growth: The Case of Türkiye's Economy". He served as an Assistant Expert at the Ministry of Culture and Tourism between 2004-2007 and in the Financial Crimes Investigation Board between 2007-2008. In 2008, he served as a Member of Profession at the Turkish Court of Accounts. He completed the European Union Basic and Specialization Training at Ankara University European Communities Application and Research Center. He worked as a Consultant at the Ministry of Youth and Sports in 2013-2014 and served in the Secretariat General of the Presidency in 2014-2017.