Journal of Information Systems Engineering and Management
2025, 10(28s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Digital Agriculture and Sustainability Practices in Rural Türkiye: A Review on the Villages of Tomorrow Project

Merve Ozdemir [1*], Elifnaz Sevim [2]
[1] Student, Merve Ozdemir, ISG Portfolio, United Nations Development Programme, Ankara, Türkiye
[2] Student, Elifnaz Sevim, ISG Portfolio, United Nations Development Programme, Ankara, Türkiye
Email: [1] merve.ozdemir@undp.org, [2] elifnaz.sevim@undp.org
Orchid Id: [1] 0000-0002-7750-1976, [2] 0009-0005-4050-6684.
**Corresponding Author: Merve Ozdemir*

ARTICLE INFO

Received: 30 Dec 2024

Revised: 05 Feb 2025

Accepted: 25 Feb 2025

ABSTRACT

Digital agriculture technologies offer significant opportunities to increase agricultural productivity, utilize water and soil resources efficiently, and improve farmers' incomes. This article examines the impact of these technologies on sustainability in Türkiye's rural areas and the role of the "Villages of Tomorrow" project. In partnership with the United Nations Development Programme (UNDP) and Trendyol, the project aims to promote the adoption of digital agriculture technologies in rural areas and foster sustainable development. The project focuses on disadvantaged groups and promotes gender equality. Climate stations, soil moisture monitoring devices, automatic irrigation systems, pest tracking cameras, crop observation cameras and consultancy services are provided to farmers to ensure the efficiency of these technologies. By 2028, the project aims to establish ten "villages of tomorrow" across various regions of Türkiye, equipping them with digital agriculture equipment. Prioritizing low-carbon solutions and aiming for carbon neutrality, the project adopts circular economy models in the agricultural industry and integrates technologies such as machine learning and AI. According to the project's 6-month data, 20% savings in labor, 15% in fertilizer, 25% in pesticides were achieved with the agricultural climate station. Additionally, 25% savings in pesticides were achieved with the digital pest trap, 15% in electricity with the soil moisture station and irrigation automation, and 20% in fuel with the tractor tracking device. During the same period, 881 people attended trainings, majority being women and students. In conclusion, the project offers a model for the adoption of digital agriculture and achieving sustainability goals in Türkiye's rural areas.

Keywords: Rural Development, Artificial Intelligence, Climate-Smart Agriculture, Smart Farming, Villages of Tomorrow.

INTRODUCTION

The continuous increase in the world population leads to a rapid rise in food demand. Approximately 100 million people are added annually to the global population every year, and according to research, the world population is expected to reach 10 billion by 2050 [1]. With this increase, efforts to combat hunger and improve nutrition conditions gain importance. According to FAO estimates, by 2050, food demand is expected to increase by approximately 70% [2].

The World Bank's March 2024 report emphasizes that healthy, sustainable, and inclusive food systems are essential global development goals. Agricultural development is expressed as a key strategy for alleviating extreme poverty, improving social welfare, and feeding 10 billion people by 2050. It is also noted that the goal of ending global hunger by 2030 remains a distant prospect. High food prices, climate change, and conflicts are increasing food and nutrition insecurity, which puts millions of people at risk of extreme poverty [3].

The United Nations Commission for Social Development emphasizes the growing importance of digital technology to overcome poverty, ensure sustainable development, and build a better life for all [4]. Starting from the information sector, the efficient use of digital technologies is a driving force for sustainable economic development, including agriculture, which provides key employment opportunities in rural areas [5]. With the integration of digital technologies into the agricultural sector, the concept known as Digital Agriculture (DA), also referred to as Smart Farming, Precision Agriculture, or Agriculture 4.0, has emerged [6].

This concept, revolutionary in the agricultural sector, includes the use of drones, robotics, mobile applications, wireless network, and IoT-based automation to monitor and assess weather, water, and soil conditions [7] [8]. These technologies optimize decision processes and production practices throughout the entire agricultural production chain. Over the past few years, DA has made significant progress in increasing agricultural productivity, reducing food insecurity, improving farmer incomes, finding low-carbon solutions, and protecting biodiversity [9] [10] [11]. Moreover, the use of DA technologies has the potential to reduce climate change effects, improve the efficient use of natural resources, and enhance agricultural productivity [12].The effective adoption and implementation of these technologies will shape the future of agriculture by enhancing flexibility, productivity, and ecological balance in the agricultural sector. However, there are also challenges inherent in the technological transition, such as insufficient digital literacy and skills, digital infrastructure, economic and financial difficulties, and issues related to privacy and data security [13]. More effective strategies and policies can be developed to maximize the advantages offered by DA and to address existing challenges. [6].

The agricultural sector also plays a critical role in economic growth and employment. Agriculture, which accounts for 4% of global GDP, can represent more than 25% of GDP in some of the least developed countries [14]. According to TURKSTAT data, in 2023, the share of agriculture in Türkiye's GDP was 4.4% and has decreased by 2% since 2021 [15]. According to TURKSTAT labor statistics, 4 million 695 thousand people are employed in the agricultural sector, a decrease of 171 thousand compared to the previous year [16]. Türkiye, with a land area of 785,350 km^2, has agricultural lands that make up approximately 50% of the total land area [17]. Türkiye's rural regions are the main centers of agriculture, meeting a large portion of the country's food production. However, these issues in the agricultural sector are lowering production efficiency.

FAO and the World Bank published Türkiye's DA profile in 2021 and stated that the problems in the agri-food system are related to low productivity levels, lack of transparency in value chains, inefficient public support, and regional water scarcity. It was expressed that DA could play an important role in solving these problems. It was emphasized that Türkiye has strong digital infrastructure and promising technologies for the agri-food system; These technologies include database technologies, smartphone applications, risk assessment models, advanced analytics, digital contracts, IoT, and blockchain. However, low digital literacy and limited access to value-added services are the main obstacles to the adoption of DA. It is suggested that start-ups be supported, digital inclusion and data management capacity be strengthened, and the beneficial effects of digital transformation within the agri-food system be maximized to address these issues [17].

In response to all these opportunities and risks and to achieve the 2030 agenda, the "Villages of Tomorrow" project, implemented in collaboration with the United Nations Development Programme (UNDP) and Trendyol, has been launched. The project was implemented with a triple helix model consisting of an international organization, local public partners, and a private sector entity. UNDP Türkiye carries out various projects to reduce inequalities in Türkiye's rural regions and develop local economies, actively operating in a significant number of provinces. Trendyol, Türkiye's leading e-commerce platform, has a strong background and expertise in product development, marketing, warehousing, and logistics and stands out as a proven actor in social responsibility and sustainability efforts. Local project partners represent the public sector in the field. The project has also involved the academic community in the process, forming a strong network to reach target audiences through this quadruple helix model. This quadruple helix model has created a strong network to reach target audiences. The project has emerged as an initiative aimed at promoting economic and social development in rural areas by encouraging the adoption of digital technologies. Designed with digital value chains to enhance inclusive growth, the project aims to establish model centers integrating modern technologies in rural areas within the framework of the digital village concept, to provide a wide range of services by turning digital centers into training and mentoring hubs, and to focus on disadvantaged groups (such as women, youth, children, and people with disabilities) to promote gender equality and inclusivity. The project's focus has been expanded to empower different segments of the community, not limited to just young individuals and women. As part of one of the project's priority themes, "digitalization in agriculture," demonstration areas have been created in the gardens of digital centers, and DA equipment has been installed in pilot villages' fields for practical application. In these areas, infrastructure for data-driven spraying, irrigation, planting, and analysis has been established. The project, which works to increase the use of climate-friendly DA solutions, prioritizes low-carbon solutions in agricultural and logistical terms and aims to make carbon neutrality the focal point of the digital village approach. Aiming to establish ten "villages of tomorrow" in various regions of Türkiye by 2028, the project started its activities with a comprehensive strategy consisting of three main stages. This article aims to examine the adoption process of DA technologies, the effectiveness of equipment and training, and the impact on sustainable development goals during the project's initial 6-month phase (October 2023 - March 2024).

METHODS AND METHODOLOGY

In this study, the districts of Kürkçüler in Sarıçam, Adana and Ulamış in Seferihisar, İzmir were selected as pilot areas to evaluate the effectiveness of DA applications in different regions of Türkiye. The core methodology of this research, conducted in collaboration with the Sarıçam Municipality of Adana and İzmir Metropolitan Municipality, is based on field applications of digital farming equipment, data collection, and analysis of these data.

Identification of Pilot Regions:

The pilot regions identified in the study are located in the provinces of Adana and İzmir, which are of strategic importance for agricultural production. The province of Adana stands out for its citrus production, while İzmir is notable for its mandarin production. These regions were selected considering their climatic conditions and the intensity of agricultural activities. Within the scope of the study, two areas in Sarıçam district of Adana province were identified: a 10,000-decare farmer area located at 36°58'49.6"N 35°29'20.7"E, at an elevation of 67.1 meters above sea level, and a 50-decare experimental area at 36°58'58.6"N 35°30'36.9"E, at an elevation of 64.5 meters above sea level. In Seferihisar district of İzmir province, the identified pilot regions include a 10,000-decare farmer area located at 38°15'17.6"N 26°49'13.6"E, at an elevation of 49.7 meters above sea level, and a 45-decare experimental area located at 38°04'57.4"N 26°56'48.7"E, at an elevation of 8.8 meters above sea level. The satellite images of the locations where DA applications were implemented are provided in Fig 1 and Fig 2.

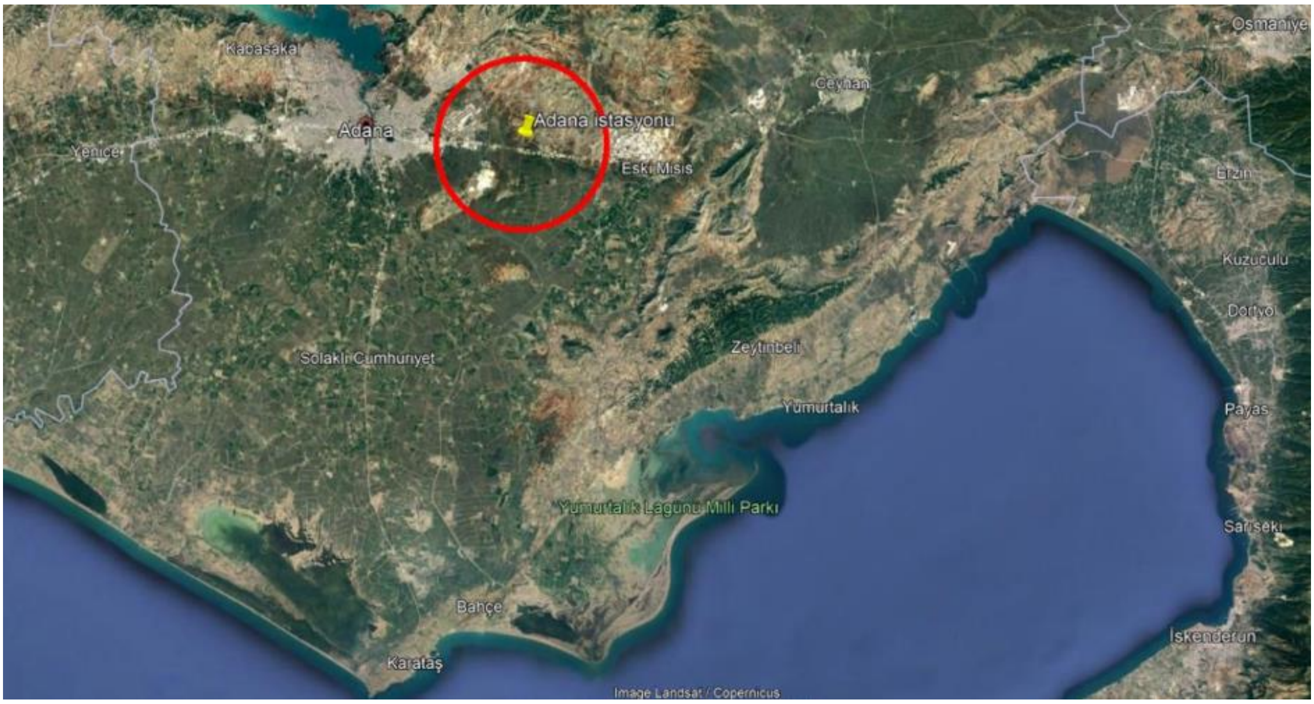

Fig 1. Satellite image showing the DA Station locations and coverage areas in the central Sarıçam district of Adana.

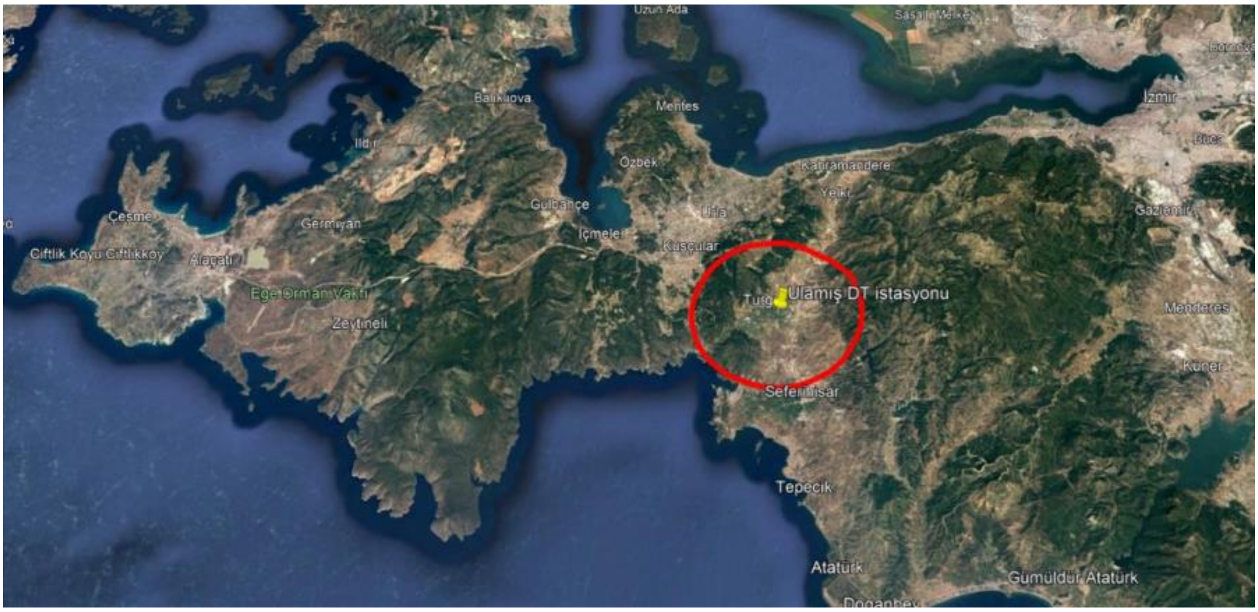

Fig 2. Satellite image showing the DA Station locations and coverage areas in the central Seferihisar district of Izmir.

Installation of Digital Agriculture Equipment:

In the selected pilot villages, the installation of DA equipment was carried out as part of the project. This included the integration of several advanced technologies provided by METOS TR®. Specifically, the entry-level nMETOS100 climate and weather station, equipped with NB-IoT technology, was set up. Additionally, the iSCOUT® Pheromone pest monitoring camera, which features an integrated electronic structure and sticky plate traps, was installed. Also, GPS-based iMETOS® Trackers, which automatically monitor the movements of agricultural machinery and other objects, were deployed to track tractor activities. The number of devices installed in the selected regions is shown in Table 1.

Table 1. Number of Digital Agriculture Equipment in Adana and İzmir Provinces

Province	District	Neighborhood	Station (quantity)	Smart Irrigation (quantity)	Camera (quantity)
Adana	**Sarıçam**	**Yurekli Nhd**	**1**	**2**	**1**
Adana	**Sarıçam**	**Yurekli Nhd**	**-**	**2**	**1**
İzmir	**Seferihisar**	**Ulamıs Nhd**	**1**	**-**	**1**
İzmir	**Seferihisar**	**Urkmez Nhd**	**-**	**-**	**1**

Data Collection and Analysis:

The data collected from the installed DA equipment were analyzed using AI (artificial intelligence) software and NB-IoT technology. This data was gathered through the FieldClimate.com online platform for use at various stages of agricultural production. The data includes parameters such as chilling requirements, temperature stress, local precipitation, local evapotranspiration measurement (plant water consumption), soil moisture, plant disease, pest forecasting, and early warnings. The collected data were evaluated by local public institutions and relevant experts.

Training and Awareness Programs:

To effectively implement digital agriculture applications, training programs were organized for local producers and agricultural engineers. The training programs focused on the use of DA equipment, data analysis methods, and environmental sustainability. The training included practical applications and interactive workshops on how to use digital tools in field management. Additionally, educational programs were prepared for children to encourage farming. Demographic data, such as the number, gender, age group, and educational background of participants, were collected through participant forms filled out at the beginning of the training programs.

RESULTS

In this study, the effectiveness of DAA was evaluated based on parameters such as chilling, temperature stress, localized rainfall, localized evapotranspiration measurements, soil moisture, plant diseases, pest prediction, and early warnings in selected regions. This assessment was conducted through a detailed analysis of data collected from digital agricultural tools deployed in the Adana and İzmir regions. The impact of digital agricultural tools on pesticide use is presented in Table 2, their impact on harvest yield in Table 3, and other savings achieved are listed in Table 4.

Table 2. Pesticide Data Obtained from Areas Covered by Digital Agricultural Devices in Adana and İzmir

Province	District/ Neighborhood	DAA Area	Crop Used	Current Number of Pesticide Applications	Number of Applications with Predictive and Early Warning System (PEWS)	Amount Saved (Ton)
Adana	Sarıçam/ Yürekli Nhd	Pilot Area	Citrus	6	3	30
Adana	Sarıçam/ Yürekli Nhd	Farming Area	Citrus	6	3	6.000
İzmir	Seferihisar/ Ulamış Nhd	Pilot Area	Mandarin	4	2	18
İzmir	Seferihisar/ Urkmez Nhd	Farming Area	Mandarin	4	2	4.000

Table 3. Harvest Data Obtained from Areas Covered by Digital Agricultural Devices in Adana and İzmir

Province	District/ Neighborhood	DAA Area	Dekare	Harvest (Ton)	Yield Increase with PEWS (Ton)	Reduction in Losses with PEWS (Ton)
Adana	Sarıçam/ Yürekli Nhd	Pilot Area	50	200	40	10
Adana	Sarıçam/ Yürekli Nhd	Farming Area	10.000	39.000	7.800	1.950
İzmir	Seferihisar/ Ulamış Nhd	Pilot Area	45	180	36	9
İzmir	Seferihisar/ Ürkmez Nhd	Farming Area	10.000	40.000	8.000	2.000

Table 4. Savings Data Obtained from Areas Covered by Digital Agricultural Devices in Adana and İzmir

Province	District/ Neighborhood	DAA Area	Amount Saved with DA Tools (%)				
			Fertilizer	Water	Labor	Electricity	Fuel
Adana	Sarıçam/ Yürekli Nhd	Pilot Area	15	44	20	15	20
Adana	Sarıçam/ Yürekli Nhd	Farming Area	15	44	20	15	20
İzmir	Seferihisar/ Ulamış Nhd	Pilot Area	15	-	20	15	20
İzmir	Seferihisar/ Ürkmez Nhd	Farming Area	15	-	20	15	20

Pesticide Usage Savings:

The images showing pest detection via the pest monitoring camera are presented in Fig 3. In both İzmir and Adana, the forecasting and early warning systems of digital agricultural tools have reduced the frequency of spraying for the Mediterranean fruit fly by 25%. In İzmir, while under normal circumstances four sprayings are required, with DA, only two sprayings were sufficient, resulting in a 25% pesticide savings. Similarly, in Adana, the six required sprayings were reduced to three, achieving the same percentage of savings. These results align with findings in the literature, where precision agriculture technologies have led to pesticide use reductions of 20-50% [18]. By preventing unnecessary pesticide applications, digital agriculture technologies also minimize environmental impact.

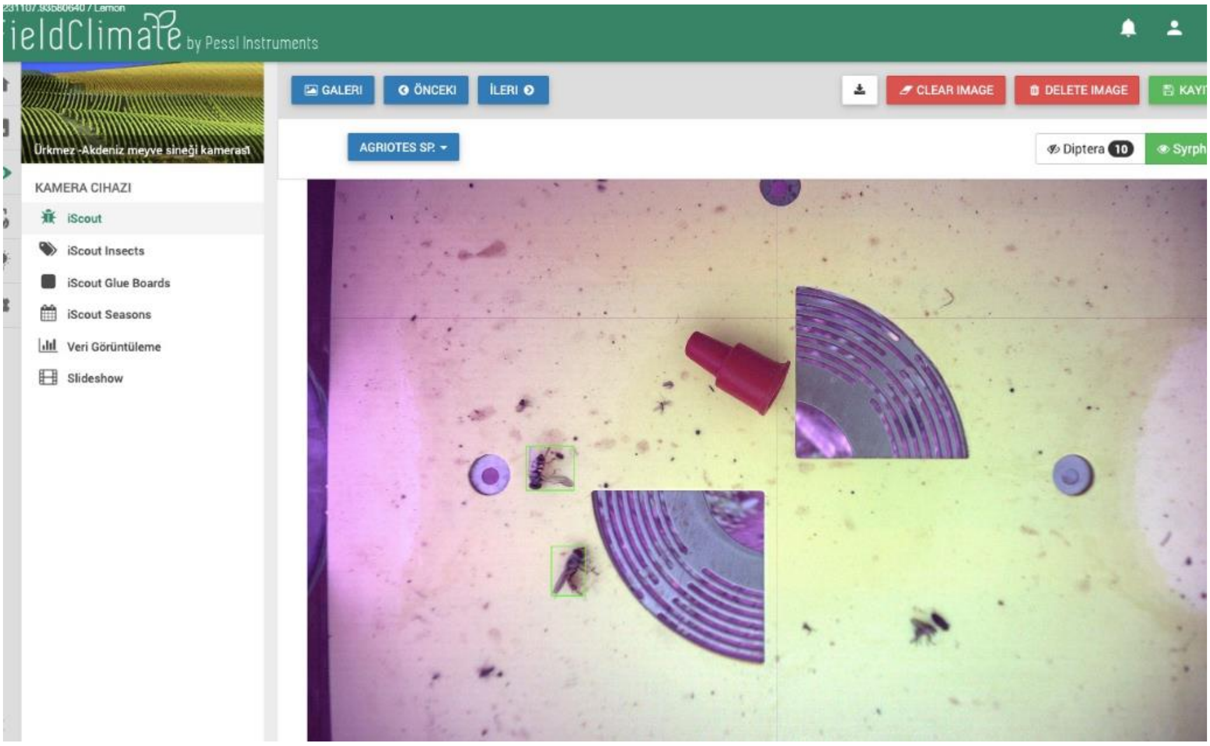

Fig 3. The detection of the Mediterranean fruit fly

Fertilizer and Water Savings:

In İzmir and Adana, a 15% reduction in fertilizer use has been observed. Literature reports a 5-40% decrease in fertilizer use with the use of remote sensing equipment [19]. Additionally, in Adana, water usage has been reduced by 44%. Literature suggests that smart irrigation systems developed in Spain can achieve 30-60% water savings [20]. DA equipment enhances the efficient use of water, reducing costs and contributing to sustainable agricultural practices.

Labor and Fuel Savings:

In the experimental areas of İzmir and Adana, labor and fuel costs were reduced by 20%. These findings are consistent with literature reporting reductions of 50% in labor and 6-80% in fuel consumption with the use of automated tractors and agricultural equipment [21]. Automation and AI-supported systems significantly lower labor costs and enhance operational efficiency.

Crop Yield and Loss Reduction:

The images of harvest tracking conducted with DA tools are shown in Fig 4. In İzmir and Adana, 20% of the harvest was achieved through the accurate use of DA tools, with crop losses reduced by 25%. Notably, the use of AI-assisted crop monitoring and forecasting systems led to a 15-25% increase in crop yield [22]. This demonstrates the potential of DA technologies to reduce crop losses and increase farmers' income.

Fig 4. Harvest tracking application and harvest guidance

Training and Information:

In the study, the participant profiles of individuals who attended the DA training programs were determined, and the suitability of the project for the targeted audience was evaluated. As a result of this evaluation, the number of participants categorized by gender and age groups is shown in Fig 5.

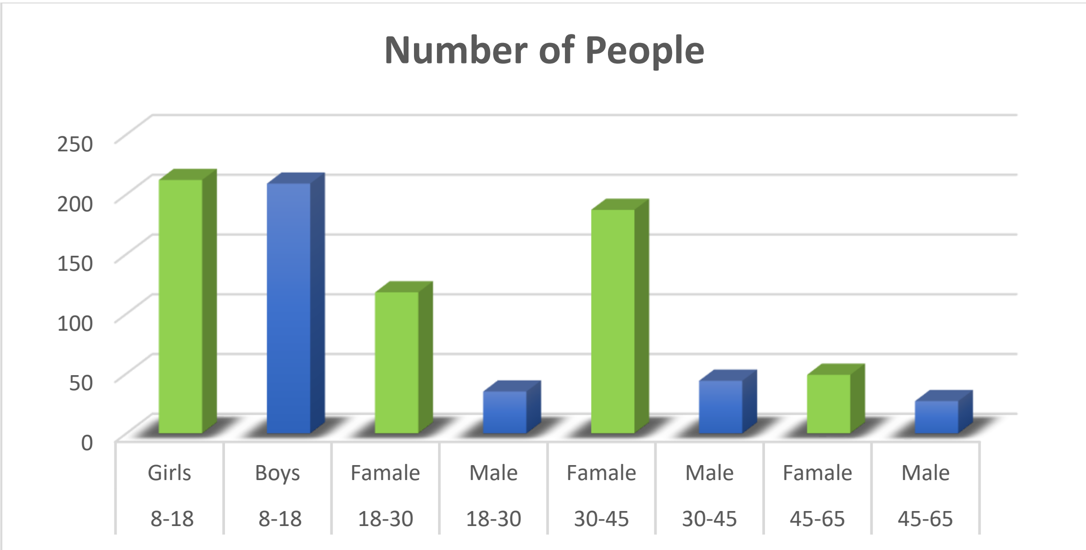

Fig 5. The gender, age range, and number of participants in the DA training programs

The data from the table indicates that the training programs have a broad reach across different age and gender groups. Over the 6-month period, a total of 881 individuals participated in the DA training held in İzmir and Adana. Among the participants aged 8-18, girls (212) and boys (209) were almost equally represented. In the 18-30 age group, the number of female participants (118) was significantly higher than that of male participants (35). For the 30-45 age group, the participation of women (187) was notably higher than that of men (44). In the 45-65 age group, the participation rates of women (49) and men (27) were lower compared to other age groups. There are no studies in the literature specifically showing participation and gender differences in rural DA training. However, a systematic literature review on the adoption of DA highlights that digital literacy and skills are primary factors influencing the adoption of DA in rural areas [13].

CONCLUSION

This study has thoroughly examined the impacts of the "Villages of Tomorrow" project on the adoption of DA technologies and sustainability in Türkiye's rural areas. The effectiveness of the project's DA applications was assessed through various parameters obtained from rural pilot regions in Adana and İzmir. The trials conducted in İzmir and Adana validate the potential of the DA technologies established under the project to reduce costs, minimize environmental impacts, achieve economic savings, enhance resource efficiency, and improve agricultural productivity. These findings are consistent with similar studies in the international literature and demonstrate that DA offers a significant solution for sustainability and efficiency.

The training programs successfully reached the target audience and accelerated the adoption of DA practices in rural areas by increasing digital literacy skills. Consequently, the "Villages of Tomorrow" project, conducted in collaboration with UNDP and Trendyol, supports sustainable development and minimizes environmental impacts through integrated DA technologies. Additionally, the project highlights the contribution of DA to sustainable farming practices and presents an effective model for rural areas.

REFERENCES

[1] The World Bank, World's population will reach nearly 10 billion by 2050. 18 June 2018; [Online]. Available: https://datatopics.worldbank.org/world-development-indicators/stories/world-population-will-continue-to-grow.html.

[2] FAO, How to Feed the World in 2050. High-Level Expert Forum. Food and Agriculture Organization of the United Nations. 12-13 October 2009; [Online]. Available: https://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf.

[3] The World Bank, Agriculture and Food. 15 March 2024; [Online]. Available: https://www.worldbank.org/en/topic/agriculture/overview#1.

[4] United Nations Commission for Social Development. Economic and Social Council, Report on the sixty-second session. 2024.

[5] Sovetova NP, Rural Territories' Digitalization: from Theory to Practice. Economic and Social Changes: Facts, Trends, Forecas. 2021; 14[12]: S105-S124.

[6] Dibbern T, Romani LAS and Massruhá SMFS, Main drivers and barriers to the adoption of Digital Agriculture technologies. Smart Agricultural Technology. 2024; 8: 100459.

[7] Basso B and Antle J, Digital agriculture to design sustainable agricultural systems. Nature Sustainability. 2020; 3: S254–S256.

[8] Sparrow R and Howard M, Robots in agriculture: prospects, impacts, ethics, and policy. Precision Agriculture. 2021; 22: S818-S833.

[9] MacPherson J, Voglhuber-Slavinsky A, Olbrisch M, Schöbel P, Dönitz E, Mouratiadou I and Helming K, Future agricultural systems and the role of digitalization for achieving sustainability goals. A review. Agronomy for Sustainable Development 2022; 42: 70.

[10] Palwak K and Kołodziejczak M, The Role of Agriculture in Ensuring Food Security in Developing Countries: Considerations in the Context of the Problem of Sustainable Food Production. Sustainability. 2020; 12 [13]: 5488.

[11] Queiroz DMde, Coelho ALdeF, Valente DSM and Schueller JK, Sensors applied to Digital Agriculture: A review. Revista Ciência Agronômica. 2020; 51: Special Agriculture 4.0, e20207751.

[12] Balasundram SK, Shamshiri RR, . Sridhara S and Rizan N, The Role of Digital Agriculture in Mitigating Climate Change and Ensuring Food Security: An Overview. Sustainability. 2023; 15: 5325.

[13] Gumbi N, Gumbi L and Twinomurinzi H, Towards Sustainable Digital Agriculture for Smallholder Farmers: A Systematic Literature Review. Sustainability. 2023; 15[16]: 12530.

[14] The World Bank, Agriculture and Food. 15 March 2024; [Online]. Available: https://www.worldbank.org/en/topic/agriculture/overview.

[15] Turkish Statistical Institute (TURKSTAT), Quarterly Gross Domestic Product, Q4: October-December and Annual, 2023. 29 February 2024; [Online]. Available: https://data.tuik.gov.tr/Bulten/Index?p=Donemsel-Gayrisafi-Yurt-Ici-Hasila-IV.-Ceyrek:-Ekim-Aralik-ve-Yillik,-2023-53756.

[16] Turkish Statistical Institute (TURKSTAT), Labor Force Statistics, 2023. 25 March 2023; [Online]. Available: https://data.tuik.gov.tr/Bulten/Index?p=Isgucu-Istatistikleri-2023-53521.

[17] FAO and The World Bank, Digital Agriculture Profile •Turkey. The World Bank. 2021; CB3954TR/1/04.21.

[18] Ørum JE, Kudsk P and Jensen PK, Economics of site-specific and variable-dose erbicide application. Precision Agriculture. 2017; S93-S10.

[19] Argento F, Anken T, Abt F, Vogelsanger E and Liebisch F, Site-specific nitrogen management in winter wheat supported by low-altitude remote sensing and soil data. Precision Agriculture. 2021; 22: S364-S368.

[20] Damas M, Prados AM, Gómez F and Olivares G, HidroBus® system: fieldbus for integrated management of extensive areas of irrigated land, Microprocess. Microsyst. 2001; 25: S177–S184.

[21] Petrović B, Bumbálek R, Zoubek T, Kuneš R and Smutný L, Application of precision agriculture technologies in Central Europe-review. Journal of Agriculture and Food Research. 15: 101048.

[22] Padhiary M, Saha D, Kumar R and Sethi LN, Enhancing precision agriculture: A comprehensive review of machine learning and AI vision applications in all-terrain vehicle for farm automation. Smart Agricultural Technology. 2024; 8: 100483.