Food and Agriculture Organization of the United Nations

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DIGITAL TECHNOLOGIES FOR AGRICULTURE IN TÜRKİYE
A REVIEW

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FAO/Frank Hollinger

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Foreword

Digital technologies are revolutionizing agriculture worldwide, offering immense potential to enhance productivity, resilience and environmental sustainability.

For Türkiye, this digital transformation is both an opportunity, and a strategic necessity. Considered as a regional agricultural powerhouse, Türkiye can harness technologies, such as precision farming, decision support systems based on Internet of Things (IoT) monitoring systems, e-commerce and blockchain for traceability to increase efficiency, enhance value addition, and build climate-resilient agrifood systems.

This review explores how these technologies can address key challenges and unlock new growth opportunities for the sector. Developed through the FAO Investment Centre and the European Bank for Reconstruction and Development (EBRD) partnership, this review reflects our shared commitment to advancing innovation and investment opportunities in sustainable agrifood systems.

It revisits Türkiye's progress in developing an enabling digital agrifood ecosystem, along with remaining challenges and opportunities. A particular focus is on smart technologies at the farm level and on the role of agribusiness companies to support technology uptake.

Through fieldwork and 120+ interviews with farmers, agribusinesses, cooperatives, tech providers, and policymakers, it provides a detailed analysis of the opportunities and challenges in digital agriculture.

The findings are promising. Driven by a supportive environment for digital transformation, the number of Agtech suppliers including domestic start-up has increased in recent years. High-value sectors like horticulture and greenhouse production are showcasing how digital tools can reduce inputs, boost efficiency, and improve product quality, paving the way for broader adoption across Türkiye's agriculture.

However, challenges persist. AgTech providers still struggle to develop scalable business models and attract patient capital to support their growth. Despite the rapid expansion of e-commerce, the adoption of smart technologies among farmers and agribusiness remains uneven. Especially smaller farmers face barriers such as high upfront costs, limited digital literacy, and fragmented supply chains.

Overcoming these obstacles requires tailored solutions, targeted financial mechanisms, and investment in capacity building. Developing farmer-centric digital tools is crucial to ensure benefits are accessible to all.

Collaboration across the public and private sectors, including partnerships between government bodies, AgTech start-ups, Development Finance Institutions, agribusiness, and farmer cooperatives, is key to accelerating this transition.

Each actor has a role – governments can provide supportive policies and infrastructure, start-ups can deliver innovative solutions, and cooperatives can facilitate outreach to small-scale farmers. Agribusiness companies can act as technology brokers testing new technologies and making them available to contracted farmers. Government, DFIs and Impact Investor may develop specific support schemes for AgTechs allowing start-ups to co-develop and field test new solutions with farmers and agribusiness, complemented by patient capital and blended finance. Uptake of digital technologies by small and

medium sized can be fostered through tailored matching grants combined with training and capacity development.

Together, these initiatives can ensure that farmers of all sizes benefit from tailored digital solutions, practical training, and on-the-ground demonstrations, driving adoption and fostering resilience.

This review aims to guide policymakers, investors and practitioners by providing actionable insights into how digital technologies can drive meaningful change and create investment opportunities within Türkiye's agrifood sector. We invite you to explore its findings and apply them to foster growth and innovation.

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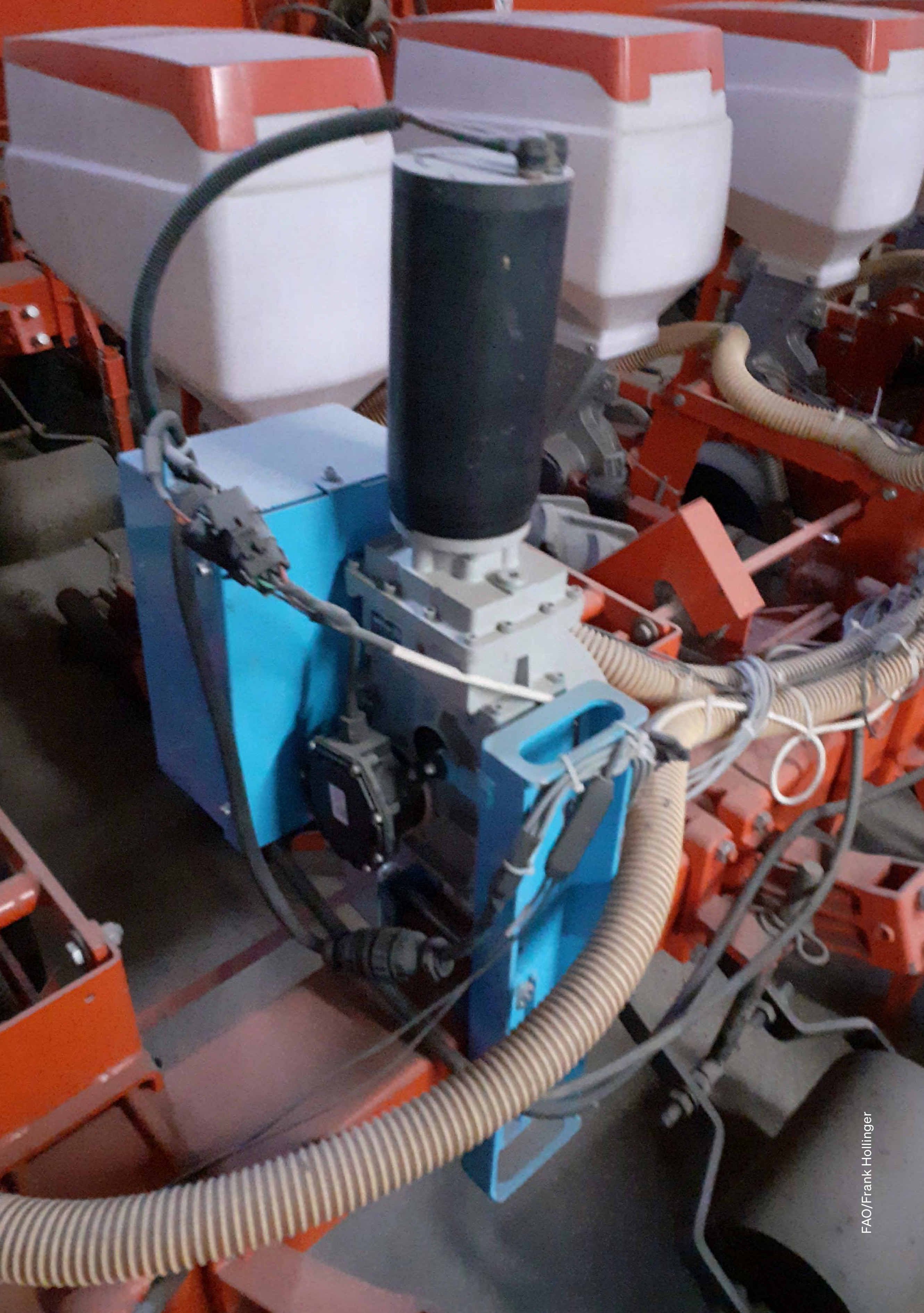
Abbreviations

ACCU	Australian Carbon Credit Unit
AgTech	agricultural technology
AI	artificial intelligence
B2B	business to business
B2C	business to consumer
BDDK	Banking Regulation and Supervision Agency
BTK	Information Technologies and Communications Authority of Türkiye
CBDDO	Digital Transformation Office of the Presidency of the Republic of Türkiye
ÇKS	Farmer registration system
CMCC	Euro-Mediterranean Centre on Climate Change
CRM	customer relationship management
CT	communication technology
EIT	European Institute of Innovation and Technology
EO	earth observation
EOPOWER	Earth Observation for Economic Empowerment project
ERP	enterprise resource planning
ESG	environmental, social and governance
EUR	euro
EWA	Empowering Women in Agrifood
FAO	Food and Agriculture Organization of the United Nations
GAP	good agricultural practice
GDP	gross domestic product
GIS	geographic information system
GSM	global system for mobile communication
ICT	information and communication technologies
IoT	internet of things
IPARD	Instrument for Pre-accession Assistance for Rural Development
IT	information technology
ITTM	İzmir Agriculture Technology Center
ITU	Information Telecommunication Union
KKB	Kredi Kayıt Bürosu (Türkiye's Credit Bureau)
KKYDP	Rural Development Investment Support Programme
KOSGEB	Small and Medium Enterprises Development Organization
MoAF	Ministry of Agriculture and Forestry of the Republic of Türkiye
MoIT	Ministry of Industry and Technology
MoEUCC	Ministry of Environment, Urbanization and Climate Change
MSME	micro, small and medium-sized enterprises
N	nitrogen
NGO	non-governmental organization
NRI	Network Readiness Institute
PLF	precision livestock farming
R&D	research and development

SaaS	software as a service
SME	small and medium enterprises
TAD PORTAL	Agricultural Land Evaluation and Management Automation Portal
TAGEM	General Directorate of Agriculture Research and Policies
TARBIL	Agricultural Monitoring and Information System
TARDES	Turkish Agricultural Loan Analysis system
TKDK	Agriculture and Rural Development Support Institution
TRY	Turkish lira
TTGV	The Turkish Technology Development Foundation
TUCSAP	Türkiye Climate Smart and Competitive Agricultural Growth Project
TÜBİSAD	Türkiye's Informatics Industry Association
TÜBİTAK	The Scientific and Technological Research Council of Türkiye
TÜİK	Turkish Statistical Institute
TÜRKVET	Animal registration system
USD	United States of America dollar
VC	venture capital
VRA	variable rate application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Executive summary

Advances in digital technologies are transforming every sector of the economy including agriculture and the food system. Digital technologies offer great potential to enhance resilience, efficiency and greening of agrifood systems, from production, processing, logistics, retail and trade to support services and finance. Still, questions remain about how quickly such technologies will evolve and be adopted, what the most compelling use cases will be, and who will benefit. Despite the promise and excitement about digital technologies and their many potential use cases in agriculture, there is limited evidence about adoption levels in practice, in Türkiye and elsewhere. Too little is known about drivers for and barriers to adoption by different segments of farmers and other food system actors, as well as about users' perception about benefits and challenges.

This study aims to shed some light on these issues by reviewing the current state of digital technologies in agriculture in Türkiye. Rather than focusing on specific value chains and technologies, it takes a broader, exploratory approach. Following a brief review of key trends and challenges in the agriculture sector, the study starts by describing the ecosystem for digital transformation and the current technology supplier landscape. The study then identifies key digital technologies in agriculture and their most prominent use cases, main user groups and adoption levels, as well as practical challenges facing users and the potential for expansion in the short to medium term. The main focus is on smart farming technologies used by farmers, cooperatives and agribusiness companies working with contracted farmers. Other prominent use cases in the agrifood system such as e-commerce, traceability, agricultural finance and public extension services are also covered to some extent. The report targets a broad audience ranging from policymakers to investors, farmers and their organizations, agribusiness companies, and other practitioners in the sector.

Given the scarce literature and secondary data on digital agriculture in Türkiye, the study draws on the results of over 120 key informant interviews conducted with a wide range of stakeholders, including digital technology providers, users, researchers, and public sector institutions. Primary data collection has been complemented by intensive web search literature review.

TURKISH AGRICULTURE: KEY FEATURES, TRENDS AND CHALLENGES

Türkiye is an upper-middle-income country with a population of 84 million, a quarter of which lives in rural areas. Agriculture accounts for 5.5 percent of Türkiye's gross domestic product (GDP) and provides 17 percent of total employment. Türkiye has strong agrifood industries, including beverages, tobacco, textiles, forestry, paper, and leather. The country is a major manufacturer and exporter of agricultural machinery, especially tractors and irrigation equipment. As a leading agricultural exporter in Europe and Central Asia, Türkiye exported USD 21 billion worth of agricultural products in 2021, twice its agricultural imports. After two decades of strong economic growth, macroeconomic conditions have worsened in recent years and the country is grappling with macroeconomic instability, high inflation, and volatility of prices for agricultural inputs and products.

Türkiye's agriculture is highly diverse in terms of its climatic, topographic, and soil conditions as well as its farming systems and farm size

structure. According to the latest available survey data (2016), farmers own on average 5.9 plots of 1.3 ha each (7.7 ha per farmer). However, these averages mask significant differences between regions and value chains. While the majority of the 2.2 million registered farms are small, there are important segments of medium and large farms including corporate investors, especially in orchards, greenhouse and livestock production.

Livestock and aquaculture account for over one-third of total agricultural output, followed by cereals, fruits and vegetables, each accounting for 12 to 15 percent in value term. The area under greenhouse production has increased to 85 000 ha in 2021. Agriculture is highly mechanized and chemical inputs are widely used. Despite some growth, the application of good agricultural practices (GAP) and organic agriculture cover less than 2.5 percent of total cropped area combined.

Exacerbated by climate change and a volatile macroeconomic environment, the sector is facing multiple challenges ranging from land degradation and increasing water scarcity, to soaring input costs, environmental pollution, pesticide residues, and labour shortages. Türkiye's agriculture must shift to a more sustainable and resilient production model, as recognized in recent policy documents such as the Green Deal Action Plan (2022). This requires smarter use of agri-inputs including water and energy, improved labour and land productivity, and better adaptation to climate change, including through improved early warning and decision support tools. Digital technologies could play an important role in addressing the challenges facing Turkish agriculture and contribute to its transformation.

CONTEXT AND ENABLING ENVIRONMENT FOR DIGITAL TECHNOLOGIES IN AGRICULTURE

Overall, the enabling environment for rural digital transformation is sufficiently well developed in Türkiye. The country has a strong and growing information and communications technology (ICT) sector, especially in software development. In international rankings examining overall digital transformation capabilities, Türkiye ranks high among upper-middle-income countries but below the European Union average. Its mobile connectivity and related physical infrastructure and internet access are on par with the European and Central Asian averages. In rural areas, the use of smartphones and access to fast, reliable internet are widespread enough to enable farmers to access digital technologies in most parts of the country. The Ministry of Agriculture and Forestry (MoAF) has digitized its systems and offers a range of e-government services. MoAF hosts extensive databases, but interoperability is very limited.

Türkiye's start-up support ecosystem has flourished in the last decade, with a plethora of public and private incubators, accelerators, technoparks, and innovation initiatives. Still, there is a gap in the start-up ecosystem in terms of support for (pre-)seed stage agricultural technology (AgTech) start-ups to test and improve their products in response to customer needs and local conditions, considering the great majority of incubator and accelerator schemes are sector agnostic and the same applies to angel and venture capital (VC) investors. However, AgTech start-ups need longer time frames, for example, to test products and train algorithms in a sector that is subject to biological processes and diverse site-specific conditions. Growth rates and returns of start-ups in smart agricultural technologies therefore tend to be lower compared to peers in other sectors. Hence, despite the strong growth in VC investment in recent years, only a small number of AgTech start-ups managed to attract such

investments. This suggests that AgTech start-ups need specialized support programmes combined with patient capital investors taking into account the specificities of the agriculture sector.

Mature agribusiness companies have access to a range of research and development support programmes from national organizations (e.g. TÜBİTAK and Türkiye's Small and Medium Enterprises Development Organization, known as KOSGEB), along with sub-national initiatives which can be used for digitization purposes. Investment support for farmers, farmer organizations and agribusiness small and medium enterprises (SMEs) is available through the MoAF's Rural Development Investment Support Programme (KKYDP), and through the European Union's Instrument for Pre-accession Assistance for Rural Development (IPARD) programme. However, most digital technologies have only recently been included in KKYDP and require further promotion, as envisaged under the World Bank funded the Türkiye Climate Smart and Competitive Agricultural Growth Project (TUCSAP). While some banks have started introducing specific financing products for internet of things (IoT) devices such as digital weather stations, digital technologies can be financed through mainstream agrilending products including agricultural credit cards and medium-term equipment loans offered by many banks. In addition, the state-owned Ziraat Bank offers a range of concessional loans for agricultural mechanization, irrigation modernization, and greenhouse development which can also be used for eligible digital technology investments.

DIGITAL TECHNOLOGY SUPPLIERS

The number of domestic and international AgTech providers has increased, especially in the last five years. Broadly, five types of AgTech providers can be distinguished: (i) domestic AgTech start-ups, (ii) domestic information technology (IT) companies diversifying into AgTech, (iii) agricultural input providers, (iv) farm machinery and equipment suppliers, and (v) international AgTech companies.

There are about 35 AgTech start-ups in smart and precision agriculture, supply chain management and agrifinance; more than 30 e-commerce and food delivery start-ups including decacorns such as Getir, Yemeksepeti and Trendyol; and more than 60 agri-related start-ups in biotechnology, indoor farming, and alternative proteins. Half of these start-ups were founded in the past five years, and most are in an early development stage (concept/pre-seed).

AgTech start-ups are struggling to find paying customers, expand their customer base, and develop scalable products, services, and business models. Those start-ups that were created as subsidiaries of existing IT companies tend to have a faster growth trajectory capitalizing on existing technologies, commercial networks and cash flows of their parent companies. Given the difficulty of selling services to individual farmers, start-ups partner with mobile operators; banks; large agribusinesses, agriscience and input companies; agricultural machinery manufacturers; as well as public sector entities. After some initial growth, start-ups often look beyond Türkiye for faster growth and relocate abroad. Founders of AgTech start-ups mainly hold degrees in electrical engineering or IT and only few have a background in agriculture.

Local AgTech start-ups often seek to enter the market with cheaper and more localized technologies given that established international brands are often considered too expansive by users. Some lower-cost precision agriculture technologies are developed in collaboration with domestic machinery and equipment manufacturers to be retrofitted onto existing technologies used by small and medium farmers. However, insufficient quality

control of newly launched digital products (including low-cost imports) has led to mixed user-experience and some established suppliers perceive this as a threat for further market development by eroding customers' trust in such technologies.

There are few international AgTech providers with direct presence in Türkiye. Most are working with local distributors, as the Turkish market is not an easy target due to the farm size structure, language barriers, and price-sensitive customers. Agriscience and input companies, both domestic and international, are increasingly introducing digital solutions, through own research and development (R&D) or in collaboration with start-ups. While digital services are mainly used to support sales of conventional products for the purposes of customer relationship management (CRM), standalone digital products are also emerging that mirror global market trends.

USE OF DIGITAL TECHNOLOGIES IN PRACTICE

Despite the increase of promising use cases of digital technologies for farmers, agribusinesses, and public entities, overall adoption levels in Türkiye are still low, especially at farm level. While internet and social media use for accessing weather and price information or e-government services is quite common among farmers, only a small minority has purchased specific smart farming technologies or pays for related services. Such early adopters are mainly larger farmers with high educational levels and good access to information on new technologies. Some of these farmers partner with domestic AgTechs to co-develop, test and refine digital solutions.

Agribusiness companies, cooperatives and public entities such as local branches of the MoAF, municipalities, and chambers of agriculture also play important roles in testing and adopting digital technologies and providing services to farmers. Prominent examples of such multifarm uses of digital technologies include early warning systems for pests, diseases and extreme weather events and related agronomic advisory services. The integration of digital technologies in early warning systems and advisory services increases their speed and precision and allows reaching large numbers of farmers at marginal incremental costs.

Some agribusiness companies have been using digital technologies and services to support contracted farmers in order to better meet product quality and volume requirements, or to meet and monitor their environmental, social and governance (ESG) targets. Other corporate users such as input and machinery manufacturers as well as banks have been using app-based technologies – supported by remotely-sensed and crowdsourced data – as part of their CRM strategies to complement their core products and services and strengthen their market position, and to better understand market potential.

Most large agribusiness companies engaged in primary production or in sourcing from contracted farmers have started digitalizing their field operations, raw material sourcing, quality management and traceability systems but are still at an early stage of digitization. Companies are taking an incremental approach, piloting different technologies and suppliers on a small scale to test their viability under field conditions. As such, they play an important role as technology brokers, eventually expanding technology-enabled services to contract farmers. Agribusiness and other corporates (e.g. agriscience companies and banks) also provide a launchpad for domestic AgTech start-ups to commercialize and refine their product and services.

Agribusinesses often start with digital weather stations and remote sensing, which provide large area coverage at low cost. Eventually, the number

of IoT devices is increased to improve coverage and accuracy levels. Leading companies have successfully integrated IoT devices and other field technologies into their enterprise resource planning (ERP) systems, enabling integrated production monitoring and traceability.

Overall, digital technology adoption has progressed most in higher value crops such as orchards, greenhouse production and field crops with high input costs where the cost benefit ratio is strongest. IoT devices such as digital field climate stations, insect traps and soil moisture sensors have seen rapid growth among public and private users due to a range of use cases and proven benefits in terms of reduced input use and improved production management. Satellite-based remote sensing has been underutilized compared to the broad range of potential use cases; and some quality issues have been reported at the field level. There is potential for expanding the use of remote sensing, especially for additional use cases beyond farming targeting agribusiness, banking, insurance, and the public sector.

The use of precision agriculture technologies is currently limited to assisted steering systems for large-scale field crop farmers, while the use of variable rate applications is in its infancy. Lower-cost innovations that are retrofitted on existing machinery and equipment and new delivery models through local service providers show some promise. Precision livestock technologies are currently used by large dairy producers (more than 100 milking cows), but recent entry of new providers and lower-cost solutions may lead to some expansion towards medium and smaller farms. Automation has been confined to modern greenhouses, tractor steering, and large-scale poultry and dairy production, with some potential in irrigation of field orchards. Despite growing interest in the use of drones, particularly for spraying, the potential for expansion is moderate and mainly limited to specific crops such as maize or paddy where drones offer the clearest advantage over conventional spraying. Advances in precision spraying could expand the use of drones. There is also some progress in business-to-business agricultural platforms and agrifinance solutions, but most are at an early stage and no major platform has emerged.

CHALLENGES AND OPPORTUNITIES IN AgTech EXPANSION

Digital technologies can play a critical role in enabling Türkiye's transition to more sustainable and resilient agricultural production. However, there are a number of constraints that need to be addressed.

The first set of constraints is related to scale: the majority of crop and livestock farms in Türkiye are small and many of these small farms are not sufficiently profitable to invest in digital technologies. Moreover, the value added of many current technologies (e.g. remote sensing, variable rate applications) is limited on small farms which can easily be inspected manually and have limited intra-field heterogeneity. There are also technical path dependencies for certain digital technologies that have to be hooked onto specific hardware (e.g. irrigation automation, variable rate technologies, blockchain), which are only available to few farmers and agribusinesses.

A second set of constraints is related to limited awareness, knowledge and skills regarding digital technology applications in agriculture, linked to demographic and cultural factors. The average age of Turkish farmers is above 55 and their technical literacy levels remain limited. The age profile of many extension staff is in a similar range and their awareness of and exposure to digital technologies is often limited. Even large farms and agribusiness companies lack knowledge about the range of digital technologies and providers available given the fast changes in the AgriTech landscape, partially

due to the limited presence of international providers in Türkiye, language issues, and limited field presence of AgTech providers in general. The lack of "human touch points" and limited availability of field support and after sales services act as further constraints. Most digital technologies require specific skills to install, calibrate and operate software and equipment, analyse, and interpret data generated by IoT devices or remote sensing images, and convert these into actions. The combination of the above-mentioned factors illustrates the risk of a digital divide in rural areas. In addition, a large gender gap has been observed, with the vast majority of AgTech providers and users being men.

A third set of constraints is linked to quality issues and trust in digital technologies. User feedback on available AgTech solutions suggests that technologies do not always live up to their promises. Reasons include limited field testing, calibration and validation of technologies, especially by start-ups, exacerbated by the diversity of agroecological and farming conditions in the country. Further reasons include limited field presence of AgTech providers and the cultural divide between AgTech providers (often with IT and engineering background) and farmers. Last, contrary to farm machinery, equipment or agrochemicals, there is no well-established testing and quality assurance mechanism in place for digital technologies. This leaves the burden of risk and "trial and error" to users, which may discourage many farmers, especially under current economic conditions.

The fourth set of constraints is related to the high cost of digital technologies, especially if imported, in combination with some uncertainties about their benefits. In addition to the initial investment costs, many technologies require periodic licence or subscription fees in addition to costs for network connectivity, etc. Farmers are generally reluctant to pay for digital services or equipment unless tangible benefits are fully demonstrated. The strongest driver for adoption is neighboring farmers using a technology successfully and achieving tangible benefits. Hence, as technologies spread more broadly and costs decline, demand and willingness to pay are likely to grow.

Last, private AgTech providers are struggling to find business models allowing them to service small farmers given the limited willingness and ability to pay for digital technologies and related services. So far, either public entities or private companies have been paying for these services in most cases.

Despite these challenges, there is considerable potential to expand the use of digital technologies in agriculture, especially when economic conditions stabilize. Climate change, rising input and energy costs, environmental pollution, pesticide residues, consumers' food quality and safety concerns, and the environmental footprint of food are among the key macro drivers for AgTech adoption. Export-oriented farms, including higher-value orchards and greenhouses, are more eager to use AgTech solutions for disease and frost early warning and traceability to prevent quantitative and qualitative loss in their agricultural production. Digital technologies can also be instrumental in achieving Türkiye's commitments under the Green Deal Action Plan and the Paris Agreement for green transformation.

Of the technologies examined, IoT devices and remote sensing applications show the greatest potential for expansion in the short to medium term. This could be through farm level adoption or through multifarm use depending on farm size and use case. IoT devices have clear and proven use cases in supporting climate change adaptation, reducing input use, and improving management, monitoring, and traceability at the farm level and along value chains. The more granular and real-time the data feeding AI, and

the larger the amount of data feeding the algorithms, the easier it is to develop dependable actionable advice and decision support to farmers.

Satellite data is also underutilized relative to its potential. As higher resolution becomes available at lower cost, the range of use cases and quality of service will increase. For drone-based analytics, the market potential seems more limited due to high costs, limited coverage and regulatory constraints. However, multifarm solutions may increase the use of drone-based analytics. In spraying, drones have a clearer role, especially in large pest outbreaks.

The scope for precision agriculture technologies is also more limited due to high investment costs and the scale requirements mentioned above. Similarly, the potential for precision livestock farming is mainly limited to medium and large dairy farms. Automation is currently used in modern greenhouses. Geothermal greenhouses and new agro-industrial zones offer opportunities for the proliferation of fully automated greenhouses.

RECOMMENDATIONS FOR FASTER AND MORE INCLUSIVE DIGITIZATION

There are several ways for public and private stakeholders to enhance the pace, inclusiveness and impact of digital transformation of Turkish agriculture. The study recommends several interventions led by public and private actors although most require collaborative efforts.

Public sector-led interventions

To better align with farmer needs, domestic AgTech providers should be given the opportunity to develop robust solutions through tailored support schemes. These schemes should address the specific needs and challenges of agriculture, beyond the current sector-agnostic incubator and accelerator programmes. In addition, blended finance instruments in the form of patient capital should be made available to AgTech start-ups. This will help to overcome the slower pace of product development and commercialization of smart agricultural technologies. Such efforts could build on the Tech-InvesTR Programme offered by the Scientific and Technological Research Council of Türkiye (TÜBİTAK). In addition, development and impact finance could be mobilized for AgTechs offering solutions that target specific needs of smaller farms, women and micro, small and medium-sized enterprises (MSMEs) in agrifood chains, and/or can make important contributions to greening, climate change mitigation and adaptation.

Data governance frameworks, protocols and networks for data sharing and interoperability should be improved. Interoperability of MoAF databases can reduce data silos and optimize the use of data for planning, policy monitoring and services to farmers. Among private AgTech suppliers, an open inter-operability network with common standards should be developed for agricultural applications including smart agricultural machinery, sensor systems and data analysis tools as part of an enabling ecosystem to advance innovative data-driven agriculture. In the public-private continuum, the broadest possible agricultural data repositories, integrating both public and private data, could provide a new boost to research and innovation for smart agricultural solutions. Regulators should promote an open data approach and define standards for data quality, ownership, sharing, privacy protection, along with protocols for fair sharing of benefits from big data between farmers, private technology providers, and the public sector.

Farmers' and other agricultural value chain actors' trust in digital solutions should be strengthened. To this end, testing protocols and quality assurance/accreditation of smart technologies should be ensured in line with

international best practices. In addition, a grievance mechanism can allow farmers and other users of digital technologies to report underperforming digital solutions in a drive towards increased consumer protection. Further independent research on use cases, costs and benefits of different technologies should be conducted including cost-benefit analyses for various settings to better document returns on investments. From the users' perspective, knowledge sharing platforms can help farmers and other users share their experiences with different technologies and providers.

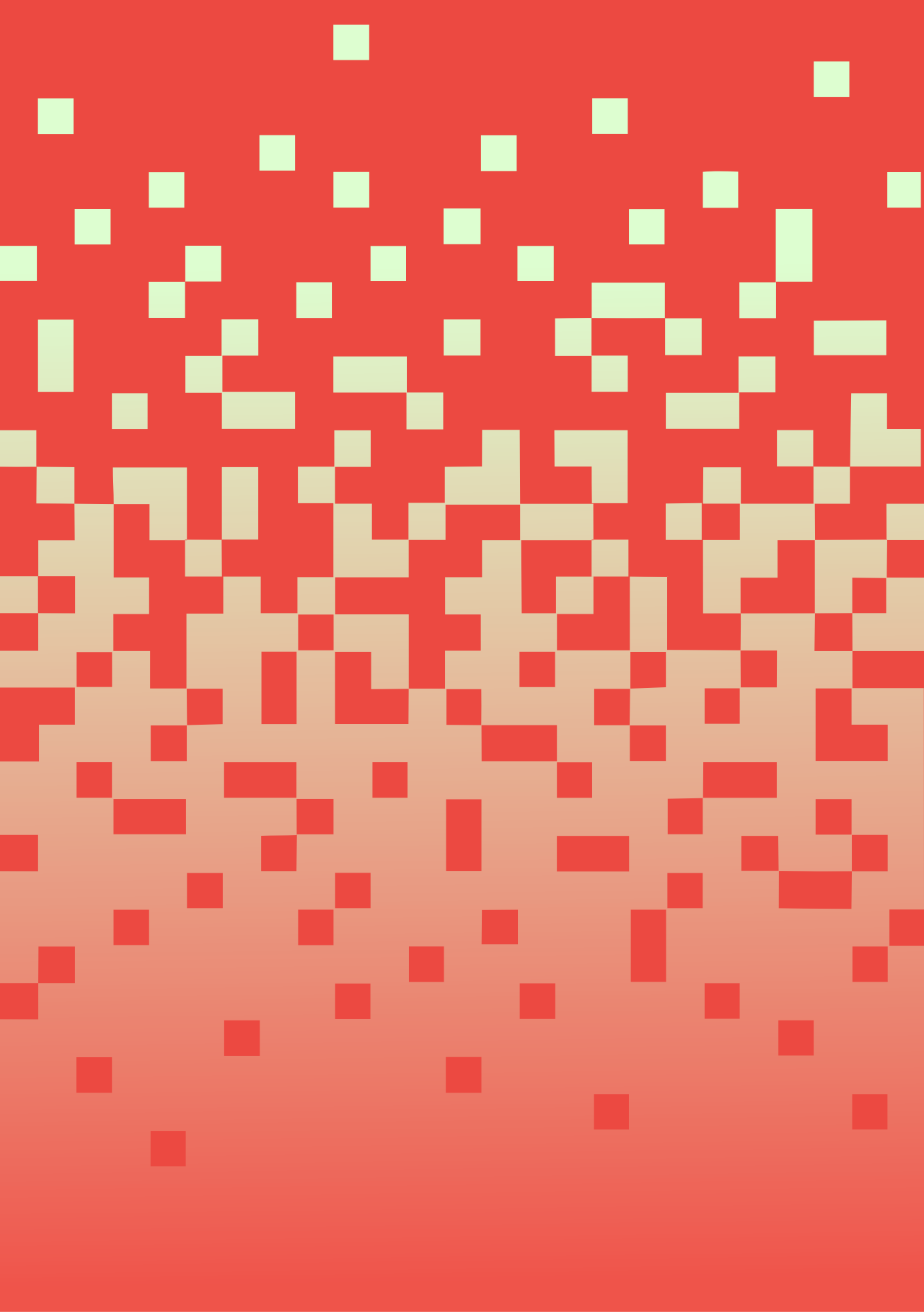
The ability of farmers and other agricultural value chain stakeholders including key staff of public entities to use and promote digital technologies should be strengthened, through awareness creation and capacity development. This can be achieved through various means including formal trainings, e-learning modules, technology demonstrations through fairs and field days, and horizonal knowledge exchange among current and potential AgTech users. To facilitate the AgTech adoption, awareness creation should be complemented by financial support in the form of matching grants and concessionary loans. Such incentives could focus on: (i) sharing risks of early adopters of frontier technologies with limited field track record; (ii) promoting multifarm use of technologies with proven environmental co-benefits via cooperatives, rural organizations and service providers; and (iii) complementary technical assistance and advisory services, on a cost-sharing basis, for better identification of needs, the right products and adoption processes.

Private sector-led interventions

Client-centric approaches should be applied for designing new digital products, services and delivery mechanisms. Involving end-users, such as farmers, farmer organizations, agribusiness and local extension staff in co-creation, field testing and product refinement can help ensure that services better respond to the needs of users and that user interfaces are easy to understand and navigate.

Initial orientation training and in-person after-sales support services for users should be provided complementing remote technical support via hotlines or bots. Local support networks and qualified staff are essential as "human touch points" conducting technology demonstrations, initial user training, technical backstopping and support.

Innovative partnerships and business models among farmer organizations, chambers of agriculture, AgTech companies, local dealers and distributors can boost rural outreach. Joint ownership, shared use and service provider models can make technologies such as precision agriculture, drone services and decision support systems available to larger number of farms, including smallholders.



Introduction

Rapid advances in digital technologies are transforming every sector of the economy including agriculture and the food system. The range of digital technologies and their use cases in agriculture have been expanding tremendously in recent years, fostering a transition towards Agriculture 4.0.[1] Remote sensing data based on satellite imagery is becoming increasingly available at higher resolutions and lower costs. Likewise, the use of sensors and other internet of things (IoT)[2] devices allows for constant real time measurement and monitoring of key parameters determining the performance of crop and livestock production, storage, transformation, and sales. Advances in artificial intelligence (AI) and machine learning (ML) combined with increased data availability and big data analysis are improving the accuracy for various use cases ranging from analytics and decision support systems to precision farming and automation.

While there is no doubt that digital technologies will lead to far-reaching transformations in agricultural production, processing, logistics, retail and trade, the question is how fast these technologies will unfold, what the most compelling use cases will be, and who will benefit. On the one hand, advances in digital technologies show great promise in contributing to a more efficient, sustainable and resilient agrifood system through improved decision making and risk management, better responses to climate change, lower and more efficient use of inputs, and improved access to knowledge, markets, and support services. On the other hand, there are risks related to increasing the "digital divides" at various levels – among countries and among producers. Concentration of market power based on data (also termed as "new oil") leads to an uneven playing field: on the supply side between tech giants and smaller companies/start-ups, and on the demand and user side, as many digital technologies have an inherent bias towards large-scale and industrial farming.

1 Agriculture 4.0 is a commonly used term in Türkiye. It encompasses the coordinated use of new information and communication technologies to optimize decision-making for the collection, analysis, and evaluation of data which can enable farmers and other stakeholders in the agricultural value chain to improve production and value addition and increase their efficiency and effectiveness (Araújo *et al.*, 2021).

2 IoT devices comprise hardware for data capture (e.g. sensors) and connectivity (e.g. wireless sensor networks), along with data processing and analytics and user feedback through decision support or automation. Most providers sell hardware together with cloud-based analytics and services. Subscription fees apply for continuous access to analytics and services or for access to a broader range of services.

Despite the great promise of digital technologies and the excitement about technological advances in agriculture, there is limited empirical evidence about their uses and adoption levels in practice.[3] Too little is known about drivers for and constraints to adoption by different segments of farmers and other food system actors. There is also limited evidence on user feedback about benefits and challenges of different technologies. This report examines the current use of digital technologies in agriculture in Türkiye. It is one of three country assessments carried out within the European Bank for Reconstruction and Development (EBRD)/FAO partnership, which also covers Ukraine and Serbia. While the companion studies focus on specific value chains and technologies, this study on Türkiye takes a broader and more exploratory approach, given the huge diversity of agroecological zones, production systems and value chains in this country. The study reviews the key trends and challenges in the agriculture sector and the broader digital transformation landscape, identifying the main technologies in use today. It highlights prominent use cases, user groups, and adoption levels, while exploring the drivers and barriers to adoption. The study also addresses practical challenges and assesses the potential for expanding these technologies in the short to medium term.

Given the limited availability of secondary data and literature on digital agriculture in Türkiye, the study is mainly based on interviews with a broad range of stakeholders, including providers and users of digital technologies, as well as other actors of the technology ecosystem such as researchers and public sector entities. In order to gain deeper insights into the drivers for adoption of digital technologies, the most commonly used technologies and use cases were identified through interviews with different food system actors, along with the main benefits and challenges experienced in practice. In total, approximately 120 stakeholders were interviewed remotely and during field visits in several batches between 2020 and 2022 (Annex 6 contains a complete list). The main focus has been on smart farming technologies used by agribusiness companies and farmers. Other prominent use cases of digital technologies such as e-commerce, traceability, agricultural finance and public extension services have also been covered to some extent. This review does not attempt to be exhaustive but exploratory, to be followed by more detailed and focused reviews of specific technologies, value chains and user groups.

3 The bulk of the evidence is written by suppliers and promoters of digital technologies. Yet, empirical data on adoption levels and benefits to different farmer segments is limited. This even applies to evidence on the profitability of digital technologies such as precision agriculture mainly used in advanced agricultural settings. Studies are often context-specific, and conclusions are not easily generalizable. For a detailed literature review, see: Kehl, Meyer, and Steiger, 2021.

The report is structured as follows:

Chapter 1 sets the scene by first providing an overview of Türkiye's agriculture including its key features, trends and challenges. This is followed by a description of the broader ecosystem for digital technology development and adoption including a review of the state of the ICT infrastructure; an overview on the technical and financial instruments to support technology development by start-ups, established companies and farmers.

Chapter 2 provides an overview on the main types of digital technology providers in Türkiye, including start-ups, other domestic technology providers, international companies, and the main technologies provided. It also looks at the maturity of the suppliers, their business and distribution models and features a number of examples.

Chapter 3 delves into the practical use cases and adoption of digital technologies across various agrifood system actors. It begins with a review of limited quantitative evidence on farmer technology adoption before examining adoption patterns among agribusinesses, farmers, and the local public sector. Additionally, it briefly discusses the rapid growth of e-commerce. Annex 7 offers a detailed analysis of the current digital technologies used in Türkiye's agriculture, including promising use cases, adoption levels, user feedback, challenges, lessons learned, and potential for expansion.

Chapter 4 summarizes the main findings and conclusions regarding technology adoption and use, main barriers and constraints, potential for expansion and provides recommendations for a faster and more inclusive digitization of the sector.

The report targets a broad audience ranging from policymakers to investors, farmers and their organizations, agribusiness companies, and other practitioners in the sector. Different readers may be interested in specific topics at varying levels of detail. In order to help readers navigate through the report, key highlights and findings are summarized in bullet points at the beginning of each chapter.

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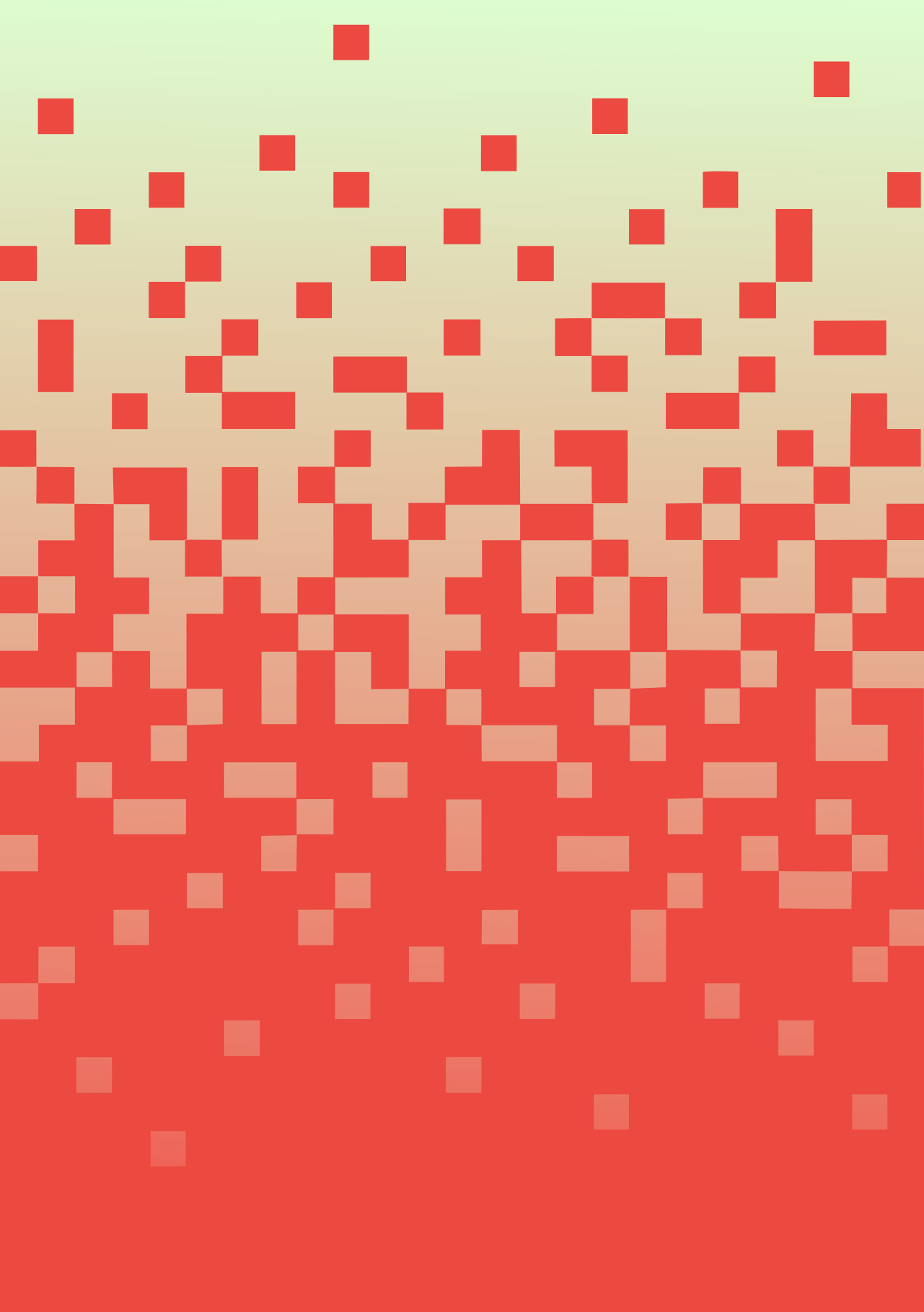


Chapter 1
Turkish agriculture and enabling environment for digital technologies

Key highlights

- Türkiye is an upper middle-income country with a population of 84 million – one-quarter of which live in rural areas. Agriculture is an important sector accounting for 5.5 percent of Türkiye's GDP and 17 percent of total employment.
- Türkiye has a strong agrifood industry and is also an important manufacturer and exporter of farm machinery such as tractors and irrigation equipment.
- The country is one of the largest agricultural exporters in Europe and Central Asia. In 2021, total agricultural exports amounted to USD 21 billion, almost double agricultural imports.
- One-third of cropped land is irrigated. Of this, 29 percent is under pressurized irrigation systems. Agriculture is highly-mechanized and chemical inputs are widely used.
- Türkiye's agriculture is highly diverse due to its variety of climatic, topographic and socioeconomic conditions. The average farm size of 7.7 ha masks huge differences between regions and value chains.
- The majority of the 2.2 million registered farms are small but there is a sizable medium and large farming sector, especially in fruit orchards, livestock and greenhouse production.
- Livestock and aquaculture account for 35 percent of agricultural output, followed by fruits, cereals and vegetables (between 12 and 15 percent, each).
- Key challenges of the sector include: i) land degradation and increasing water scarcity exacerbated by climate change; ii) spiraling input costs and food prices; iii) environmental pollution; iv) pesticide residues; and v) labour shortages.
- Digital technologies can help tackle these challenges in many ways including through smarter use of agrochemicals, water and energy; improved early warning and decision support systems at all levels; and increased productivity, contributing to a more sustainable, resilient and efficient agrifood system.
- Overall, the enabling environment for rural digital transformation is well developed in Türkiye. The country boasts a strong and growing ICT sector especially in the area of software development.
- In international digital transformation rankings, Türkiye scores relatively high among upper middle-income countries but at the lower end if compared with European Union countries.

- In terms of mobile connectivity, Türkiye's physical infrastructure, satellite coverage and internet access are on par with regional averages.
- A high percentage of farmers with smartphones and overall satisfactory internet access in rural areas provide a solid basis for widespread access to digital technologies.
- The MoAF has digitized its systems and services including e-government and a large number of databases. However, interoperability remains limited and is exacerbated by data quality issues.
- Türkiye's start-up support ecosystem has been expanding in the last decade with public and private incubator and accelerator programmes, technoparks and innovation platforms.
- There has been strong growth in venture capital (VC) investments especially since 2019, but the economic downturn following the pandemic curtailed the investments significantly.
- AgTechs and FoodTechs rank lowest among invested categories, with a total of 18 VC investments worth USD 18 million in 2020–2023.
- The large majority of incubator and accelerator schemes are sector agnostic. The same applies to Angel and VC investors.
- There is a gap in the support environment for (pre)-seed stage start-ups for testing and improving their products according to client needs and local conditions.
- VC investors focus on more mature companies with well-established products and client base, which offers these investors the promise of high and fast revenue growth. Few AgTechs match these requirements.
- AgTech start-ups would benefit from more specialized support programmes combined with more patient investments, considering the peculiarities of the agriculture sector.
- Established agribusiness companies have access to a range of support programmes for research and technology development, which can be used for digitization purposes. Substantial support for agriculture is available through the MoAF's Rural Development Investment Support Programme (KKYDP), the Agriculture and Rural Development Support Institution (TKDK), and Ziraat Bank's agricultural loans.
- Since digital technologies are new to most farmers, financial support must be coupled with sensitization and capacity development.

1.1 TURKISH AGRICULTURE

Türkiye is an upper middle-income country with strong growth history but currently facing macroeconomic turbulences. The Turkish economy, with a current GDP of USD 9 500 per capita, has seen robust annual growth since 2000. Growth slowed in 2018 and hit a low of -0.4 percent in 2019 but rebounded strongly to 10.1 percent in 2021 after pandemic restrictions eased. Fiscal stimulus-driven pandemic recovery, rising global commodity prices, and heterodox monetary policies restored growth but lead to spiraling inflation and currency depreciation. A return to orthodox economic policies in 2023 sought to improve price stability and investment climate in the country.

Türkiye's economy is dominated by the services sector contributing 53 percent to GDP, followed by industry (31 percent), and agriculture (6 percent). The country has a strong industrial base and 44 percent of its manufacturing exports consist of medium- and high-tech (World Bank, 2022a). Türkiye's population is currently around 84 million. Despite decades of outmigration from rural areas, a quarter of the population (24 percent) still live in rural areas (World Bank, 2019).

1.1.1 Key features and performance

Agriculture remains an important contributor to Türkiye's GDP, employment and foreign exchange. The total value added of agriculture, forestry and fishing amounted to USD 45 billion in 2021. The sector has grown by 2 percent annually on average in the last decade. It creates 17 percent of total employment (15 percent among economically active men and 23 percent among economically active women) (Turkish Statistical Institute, TÜİK, 2022a). Farmers are aging, with an average age of 52 and a share of young farmers (18–39) of only 14 percent (Kredi Kayıt Bürosu, KKB, 2022).

Türkiye's agriculture is highly diverse due to climatic and topographic variability. The country has three distinct macroclimatic regions: 1) Mediterranean climate along the Aegean and Mediterranean coasts; 2) oceanic climate along the Black Sea coast, with high precipitation throughout the year; and 3) continental climate in the interior of the country. In addition, there are seven agroecological regions with marked diversity in terms of agroclimatic conditions, topography, and soil structure. There are also important sociocultural differences across regions, which include the openness towards new technologies. Due to population growth and land conversion, the total agricultural land per capita has decreased from 0.76 ha in 1990 to 0.46 ha in 2018 (Ministry of Environment, Urbanization and Climate Change, MoEUCC, 2021).

In view of low and fluctuating rainfall levels in large parts of the country, agricultural production increasingly depends on irrigation. 6.6 million ha of agricultural land are irrigated – one-third of the area under permanent and temporary crops (Şahin, 2019). 29 percent of irrigated land is equipped with modern irrigation equipment (pressurized systems such as drip, sprinkler and centre pivot), while the rest is under gravity irrigation (DSI, 2021).

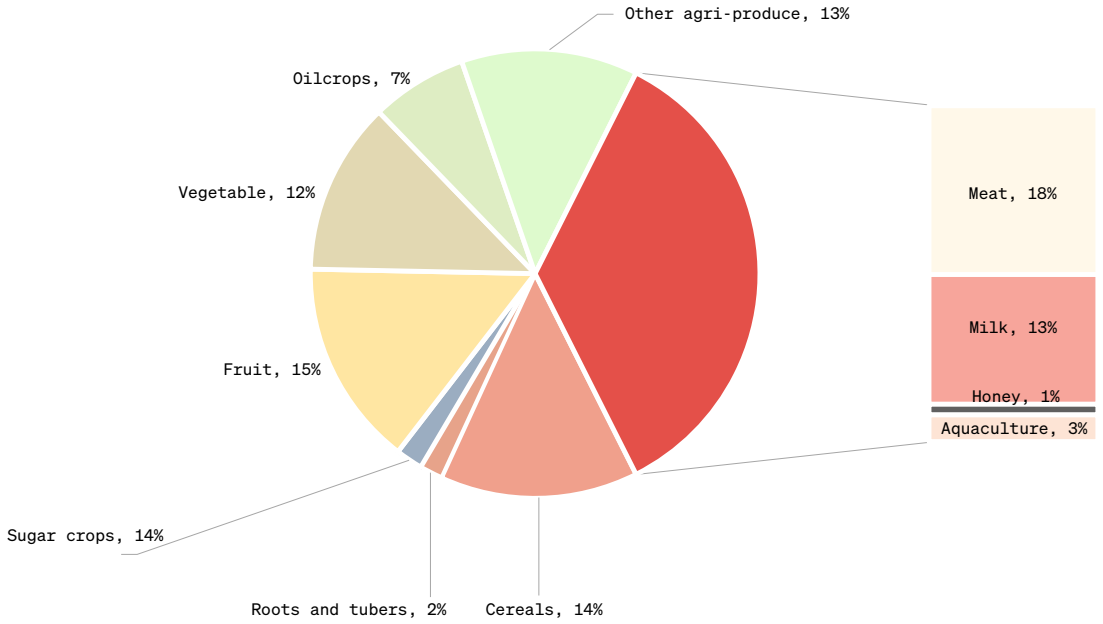
The farm enterprise structure is highly diverse ranging from small family farms to large-scale agribusinesses. There are 2.2 million registered farmers. The 2016 farm structure survey revealed an average farm size of 7.6 ha, up from 5.9 ha in the 2001 agricultural census – a modest trend of land consolidation. Approximately 60 percent of farm holdings operated on less

than five hectares, according to 2016 survey data. However, actual farm sizes are often larger due to land rental and informal land consolidation by pooling land registered under multiple family members under a single operation. Moreover, farms of field crop producers are substantially larger than those of fruits and vegetables producers.

There are various types of farmer organizations that can serve as entry points for digital technologies and related service provisions: cooperatives, producer unions, animal breeder and beekeeper unions, irrigation unions, as well as chambers of agriculture and producer councils. According to a recent survey, 81 percent of responding farmers were members of producer unions or cooperatives (MoAF, 2022a).

Livestock and aquaculture account for 35 percent of agricultural output, followed by fruits, cereals and vegetables in value terms (FAO, 2022a) (Figure 1). Türkiye's field crops are dominated by wheat, tomato, barley, sunflower, and maize. The main orchards are hazelnuts, grapes, pistachios, apples, olives. Türkiye leads the global production in hazelnuts, raisins, figs, dried apricots, and cherry (MoAF, 2022b).

Figure 1
Türkiye's key agriproduct composition in terms of gross production value in 2020



SOURCE: FAO. 2022a. FAOSTAT: Value of agricultural production. Rome. [Cited 22 August 2022.] www.fao.org/faostat/en/#data/QV and FAO. 2022b. FISHSTAT: Fishery and aquaculture statistics. Global aquaculture production value 1984–2021. Rome. [Cited 22 August 2022.] www.fao.org/fishery/statistics-query/en/aquaculture/aquaculture_value

In 2021, total agricultural exports amounted to USD 21 billion, almost doubling agricultural imports (USD 11.5 billion), making Türkiye one of the largest agricultural exporters in the region (FAO *et al.,* 2021). In terms of product groups, agricultural exports are dominated by fruits and vegetables (47 percent), followed by cereals and preparations (18 percent) and fishery products (7 percent). Major export crops are hazelnut, fig, citrus, apricot, apple, grape, peach, sunflower and dried pulses. Agricultural imports are dominated by cereals and preparations (39 percent), followed by feedstuff (18 percent), and fruits and vegetables such as almond, walnut and banana (16 percent). Türkiye has a large trade deficit in plant protection products (Arslan and Çiçekgil, 2018) and fertilizers (UN, 2022), which make the country vulnerable to international price fluctuation shocks and currency devaluation.

Greenhouse production has increased in the last decade, reaching 85 400 hectares of land under protective cover in 2021. Of this, 54 percent was under plastic cover, 25 percent low-tunnel, 12 percent high tunnel and 9 percent glass cover (TÜİK, 2022b). Main greenhouse crops are tomatoes (45 percent), cucumber (12 percent), watermelon (8 percent), and banana (7 percent) in terms of production volume (TÜİK, 2022b). Most greenhouses, especially in the Mediterranean region, use basic technologies for heating and frost protection. Yet, fully climate controlled modern greenhouses with advanced technologies have been expanding, especially in areas with geothermal potential (Tüzel *et al.,* 2020).

Turkish farmers benefit from relatively high levels of border protection and subsidies. During the last decade, 23 percent of gross farm receipts originated from producer support schemes compared to 19 percent in the European Union (OECD, 2022). Approximately two-thirds of the support was in the form of market price support and producer prices were about 15 percent above border prices during 2019–2021.

One-fifth of the farmers are engaged in contract farming mainly in sugar beet as required by law, followed by wheat (9 percent), tomato (9 percent); tobacco (8 percent), corn (8 percent), poppy (7 percent), and sunflower (5 percent).

Agricultural growth has been driven by mechanization, irrigation, and increased use of fertilizer and pesticides. Türkiye also has an important manufacturing base for farm machinery and equipment, including irrigation equipment and greenhouse construction. The country has become a net exporter of agricultural machinery and equipment in the last decade – driven by exports of tractors and tractor components, irrigation equipment, tillage, seeder, fertilizer, and plant care equipment (Tarmakbir, 2022).

Türkiye has a strong agrifood industry including beverage, tobacco, textile, forestry, paper, and leather subsectors. Agrifood industries account for 6 percent of all industrial enterprises and 13 percent of industrial employment. Their contribution to industrial output, value added and exports was 17 percent, 13 percent, and 29 percent, respectively. Major processed crops are sugar beet, tea, hazelnut, sunflower, followed by wheat, milk, tomato, fruits, and meat (Ministry of Industry and Technology, MoIT, 2020).

Food retail is composed of a mix of modern and traditional retail chain with the modern food retailers' market share standing at 53 percent (United States Department of Agriculture, USDA, 2020). Traditional marketing outlets such as bazaars, greengrocers and kiosk shops still prevail for consumers' fresh food shopping. Türkiye's modern food retailers increasingly adopt omnichannel marketing to synchronize marketing and sales channels including brick-and-mortar, e-commerce, social media, and pick-and-collect.

1.1.2. Challenges facing the agriculture sector

Key agricultural challenges in Türkiye include high input costs, impact of climate change and water scarcity, labour shortages, low labour quality, and lower-than-expected product prices, according to the latest farmer survey conducted by the Turkish Credit Bureau (KKB, 2022) and field observations.

Climate change has caused rising temperatures and higher evapotranspiration during hot summers, combined with a reduction in average annual precipitation, more irregular weather pattern, and an intensification of extreme weather events (MoEUCC, 2021). These alter the growing seasons and phenological stages and shift cultivation areas toward higher latitudes and altitudes (Euro-Mediterranean Centre on Climate Change, CMCC, 2021). Climate projections expect lower yields due to heatwaves and droughts; increased groundwater withdrawals, and more pest and disease pressure following reduction of winter frosts (Food & Drink Industry Associations Federation of Türkiye, TGDF, 2017).

Desertification and aridification are long-standing challenges for Turkish agriculture exacerbated by climate change (UN Convention to Combat Desertification, UNCCD, 2016). In terms of desertification risks, 23 percent of Türkiye's land is classified as highly and 51 percent is moderately susceptible, especially in central, southeastern and eastern Türkiye (MoEUCC, 2021). With declining water availability, agriculture already accounts for 74 percent of total freshwater consumption (CMCC, 2021), mainly due to flood irrigation as the dominant practice on 70 percent of irrigated land. Increasing water scarcity and water pollution are threatening Türkiye's river basins. Of the country's 25 river basins, 15 face water availability constraints.

Land degradation has been reducing the production base for agriculture. There are drainage problems on 3 million hectares and salinity and sodicity problems on 1.5 million hectares, which together represent one-third of irrigated land. In addition, 59 percent of agricultural land, 64 percent of pastures, and 54 percent of forests are at risk of erosion (UNCCD, 2016). Climate change is expected to exacerbate land degradation through soil erosion, fertility loss and nutrient depletion, with negative impacts on agriculture and livestock productivity and the soil's capacity to serve as a carbon sink.

Input use of Turkish farmers is often beyond the agronomic optimum. Fertilizer use has increased between 2010 and 2020 (up 51 percent for nitrogen and 33 percent for phosphate) (FAO, 2021). Nitrogen use is particularly high compared to peers, leading to nutrient leaching and pollution, as well as rising input costs. While still around the European Union average in 2020, pesticide use has increased by 41 percent since 2010 (FAO, 2022c). Pesticide residues have become a major concern of domestic consumers and a threat for Türkiye's products entering export markets. The European Commission's Rapid Alert System for Food and Feed (RASFF) has issued 359 border rejection notifications for food products originating from Türkiye in 2021 (European Commission, 2022). Türkiye ranks third in terms of the number of cases, after India and Poland (Kara-Kaşka, 2022). Pesticide residues in fruits and vegetables, and aflatoxins in nuts and seeds remain a major problem.

Inadequate traceability infrastructure hampers food safety in Türkiye. Currently a very limited number of agriproducers and food retailers are using food traceability systems. Nevertheless, Türkiye's Wholesale Market Registration System (HKS), established in 2010 under the Ministry of Trade, serves as a comprehensive database for monitoring trade activities, including

the recording of goods information, trade volume, price levels, and taxation, with fresh food producers and traders mandated to document all wholesale transactions of fruits and vegetables within the system.

Input costs have been soaring since the devaluation of Turkish Lira in 2020, driven by prices for fertilizer, energy, and animal feedstuff. Agriculture is the second most energy intense sector after industry in Türkiye (MoEUCC, 2021). Soaring energy prices increased irrigation-related electricity costs. Labour costs have also increased.

While increasing food prices have been a major challenge for consumers, producers did not benefit much. Generally, adjustments of farm gate prices lag behind increases in retail prices and remain below increases in energy (Demirkılıç *et al.,* 2022) and fertilizer prices. Increasing gap between farm gate and retail prices implies that producers do not receive market price signals due to structural inefficiencies along value chains and limited cross-regional linkages (World Bank, 2020).

The availability of qualified labour is increasingly becoming a challenge in Turkish agriculture. In a nationwide survey, almost one-third of the farmers indicated that they face difficulties in finding agricultural workers (KKB, 2022). Farmers also face challenges in monitoring labour attendance and performance, managing payment transactions, and ensuring occupational safety and health.

Food quality, safety and geographic origin have been growing concerns for urban middle class consumers despite the recent economic headwinds making them more price-sensitive (Tomatis *et al.,* 2022). Still, good agricultural practices (GAP) and organic production have expanded slowly covering only 1.1 percent and 1.6 percent of Türkiye's total agricultural land respectively.

1.1.3. Outlook

Turkish agriculture must switch to a more sustainable and resilient production model. This entails smarter use of agri-inputs including water and energy, improved labour and land productivity, and better climate change adaptation including through early warning and decision support tools. Major trading partners are increasingly sensitive to environmental performance. For example, the European Union Green Deal will affect Türkiye both as it is within the current customs union and as a candidate for full membership. In response, Türkiye ratified the Paris Agreement on 6 October 2021 and set a net-zero emission target by 2053. Türkiye has also published its Green Deal Action Plan in 2021 which seeks to reduce the use of pesticides and chemical fertilizers, improve organic agriculture, promote land consolidation, geothermal powered greenhouses, agricultural circularity, and zero food loss and waste (Ministry of Trade, MoT, 2021).

Digital technologies can play an important role in addressing Turkish agriculture's challenges and contributing to its transformation. Rapid advances in big data analytics through AI combined with improved availability and quality of data from various sources and enhanced internet connectivity set the stage for improved decision support, real time monitoring and predictive analytics, with a range of use cases. These include improved risk management and early warning systems for pest, disease and weather-related risks; site-specific real-time advice to crop and livestock producers; reduced and more tailored use of inputs; improved planning and monitoring of land use and agricultural production based on

better data and forecasts; and improved traceability of products in response to changing market trends and consumer demands. Overall, digital technologies can contribute to improved investment, management and monitoring at all levels, from individual farms and firms to national planning and policymaking. The current status, use cases, avenues of improvement and investment in agricultural digital technologies in Türkiye are reviewed in the following chapters of this report.

1.2 ENABLING ENVIRONMENT FOR DIGITAL TECHNOLOGIES IN AGRICULTURE

1.2.1 Enabling environment for digital transformation

Türkiye boasts a strong and growing ICT sector especially in software development. The sector has reached a market size of USD 30 billion in 2021 (less than 1 percent of the global volume), recording a 7 percent increase from 2020. Communication technologies (CTs) account for more than half of the sector size (USD 17 billion), but the share of information technologies (IT) has been increasing. Software development has contributed almost two-thirds of the overall sector growth. Exports of ICT products and services recently increased strongly, from USD 1.15 billion in 2019 to almost USD 2 billion in 2021. Total employment in the sector reached 185 000 in 2021, with a growth of 14 percent per annum. Women accounted for 27 percent of the ICT workforce (Deloitte and Türkiye's Informatics Industry Association, TÜBİSAD, 2022).

While ICT hardware is mainly imported, IT software and services are mostly provided by domestic suppliers. Software companies work mainly on decision support systems, banking and finance applications, web technologies, enterprise resource planning modules, and cyber security (Deloitte and TÜBİSAD, 2022).

Several indices assess Türkiye's digital transformation status vis-à-vis other countries:

- ***The Network Readiness Index (NRI) ranks Türkiye 45th out of 130 economies*** (Network Readiness Institute, NRI, 2021). The country performs better on variables such as tertiary education enrollment, mobile internet access, international internet bandwidth; e-government services; gross expenditures on R&D by private enterprises as percentage of GDP; use of robots in industrial production; computer software spending; cyber security; and e-commerce legislation. It ranks lowest in handheld prices; investments in emerging technologies; regulatory quality; legal frameworks adaptability to emerging technologies; privacy protection by law content; gender gap in internet use; and rural gap in use of digital payments.
- According to the ***Digital Transformation Index***, developed by the Informatics Industry Association of Türkiye (TÜBİSAD), ***the country performs well in terms of affordability of services and in digitalization of society***, i.e. the use and quality of e-government applications and the use of ICT in education (TÜBİSAD, 2021). The index highlights key underperforming areas such as (i) digitalization of the economy (patent applications in ICT, number of employees in knowledge-intensive and telecommunications sectors,

exports of ICT products and services); (ii) infrastructure (international bandwidth per internet user, number of secure internet servers, share of investments in telecommunications, ICT investments per company); and (iii) regulatory framework (law enforcement, legal effectiveness in dispute settlement, impartiality of judiciary in cases of dispute with public institutions, prevalence of unlicensed software use).

- ***In the 2022 Global System for Mobile Communications Association (GSMA) Mobile Connectivity Index, Türkiye scores 75 out of 100, on par with the Europe and Central Asia regional average of 77.*** Türkiye scores highest on content and services (online security, availability, and local relevance of content) and infrastructure (network performance and network coverage). Lowest scores are in affordability (prices of smartphones, tax burden, and the level of income inequality), and consumer readiness (especially in gender equality).
- In terms of e-government services, ***Türkiye ranks "very high" in the E-Government Development Index (48th globally)*** and the E-Participation Index (18th globally) (UN Department of Economic and Social Affairs, UNDESA, 2022). As of 30 October 2021, the number of users on the e-Government gateway was 57 million (Department of Digital Technologies, Procurement and Resource Management, CBDDO, 2021). A recent survey found that 74 percent of Turkish population used the e-government application in 2023 (TÜİK, 2023).

Mobile connectivity, internet access and satellite infrastructure

Physical infrastructure and internet access in Türkiye are on a par with regional averages. Mobile phones are the dominant means of internet access. As of the third quarter of 2023, there are 94.3 million internet subscribers including mobile and digital subscriber line and 92.8 million mobile phone subscribers including machine to machine communication. Turkcell is the market leader with 41 percent of subscriptions, followed by Vodafone (31 percent) and Türk Telekom (28 percent) (Information Technologies and Communications Authority of Türkiye, BTK, 2023). Türkiye plans to introduce 5G services in 2025 (Deloitte and TÜBİSAD, 2022). According to the International Telecommunication Union (ITU), 81 percent of the population is using the internet, 20 percent has fixed broadband subscriptions (81 percent of which are above 10 Mbit/s), and the population coverage of the 4G mobile network technology is 92 percent (ITU, 2021).

In the last decade, Türkiye increased its use of earth observation (EO) resources. Türkiye's domestically produced Göktürk-2 satellite, providing satellite imagery for Turkish Armed Forces and for research institutes, was launched in 2012. In June 2016, Göktürk-1 satellite was launched featuring remote sensing technology for monitoring pollution, natural disasters, and law enforcement. Türkiye plans to launch Göktürk-1Y in 2026 and Göktürk-3 in 2028 to capture high-resolution imagery. The GEOPORTAL was established for economic and environmental monitoring through EO services, followed by the European Union Framework Programme 7-funded Earth Observation for Economic Empowerment (EOPOWER) project. Türkiye's National Geographic Data Geoportal has been open to the public since August 2014 (MoEUCC, 2024).

Internet access and smartphone use by farmers

Network coverage and speed is still uneven across rural Türkiye, with rural areas lagging behind. A nationally representative survey conducted by MoAF in 2020 revealed that 82 percent of farmers are using the internet, mainly through smartphones (80 percent). Half of the farmers had access to 3G or above. Only 60 percent of the respondents considered the mobile internet coverage to be adequate, and half of the farmers were satisfied with the internet speed. Internet and smart phone usage decreases with age and increases with educational qualification. There are no significant differences among the seven regions of Türkiye.

Institutional and policy context

Enhancing broadband internet infrastructure, mobile network coverage, e-services outreach in rural areas have been laid out in key policy documents such as the 12th Development Plan, the MoAF's Strategic Plan (2024–2028) and the National E-Agriculture Strategy (2021–2025). In addition, the National AI Strategy (2021–2025) promotes open data and open-source environments within and between businesses and government agencies while considering ethics, privacy and inclusion (CBDDO, 2021). In parallel, Türkiye's Personal Data Protection Law, in force since 2016, aligns national practice with the European Union's General Data Protection Regulation (GDPR). ***Türkiye increasingly regulates cloud-based services.*** The Presidential Circular issued in 2019 regarding Information and Communications Safety stipulated that critical data related to population, health, contact, genetic, and biometric information must be stored in servers physically located in Türkiye (Deloitte and TÜBİSAD, 2022). The regulation requires digital service providers and

users to take additional precautions while working with foreign clients and server providers.

All nationwide digital agriculture programmes in Türkiye fall under the supervision of the Digital Transformation Office under the Presidency of the Republic of Türkiye. The General Directorate of Communications under the Ministry of Transport and Infrastructure supervises the digital communication network infrastructure, and the Information Technologies and Communications Authority (BTK) regulates and supervises the ICT infrastructure and services including mobile and internet subscriptions.

The Science, Technology, and Innovation Board also falls under the Presidential Office, and is tasked with making recommendations in digital agriculture, including entry points for Türkiye into the global start-up ecosystem, and other areas that will improve economic, social and national security to reduce import dependency and increase the competitiveness of the Turkish industry (FAO *et al.,* 2021).

ICT use by the Ministry of Agriculture and Forestry

In recent years, the Ministry of Agriculture and Forestry (MoAF) has digitized its systems and services including e-Government services for stakeholders in the agriculture sector, databases and registry systems as well as services such as agricultural weather forecasting and extension.[4] The largest and most important MoAF systems are described in Table 1 and a more extensive overview is provided in Annex 1.

While MoAF hosts huge amounts of data, interoperability between the different databases and systems remains limited. The various information systems have been established by different departments in the Ministry at different points in time, with different architectures and data coding, by different IT service providers and for different purposes. Currently, large databases such as the Farmer Registry System are not shared with private AgTech developers.

Table 1
Main systems and databases of MoAF

Farmer Registration System (ÇKS)	Operational since 2005, CKS is the main system managing agricultural subsidies and support. It includes farmer demographics, assets and production information. Approximately 2.2 million farmers are registered.
Animal Registration System (TÜRKVET)	Created in 2001, the system is used to identify, record and monitor animal movements and diseases, support the execution of national or regional eradication programmes, and keep records on health, breeding and support payments for cattle, sheep, goat and equines.
Integrated Management and Control System (IACS)	Introduced in 2017, the system monitors the distribution of direct payments to farmers. Although the system is not yet operational, 3 000 staff have been trained.
Agricultural Land Evaluation and Management Automation Portal (TAD PORTAL)	The land information system includes land-use changes, soil survey and analysis data. The portal is for the registered users at the Ministry and is not publicly accessible.

SOURCE: Authors' own elaboration.

4 There are also agricultural databases under other ministries, such as the Land Registry and Cadaster Information System operated by the MoEUCC, and the Wholesale Market Registration System operated by the Ministry of Trade.

MoAF embarked on several ambitious projects to establish comprehensive agricultural information systems but none of these has been implemented successfully. This is partially due to the number, size and diversity of the existing databases, along with concerns about the accuracy of the data in some of the systems. The completion of an agricultural census planned for 2026 will allow the content of these databases to be verified and updated, and will enhance the scope for using this data for a range of digitally-enabled analytics and services, both by the public sector and private AgTech providers.

BOX 1

ATTEMPTS FOR DIGITAL ONE-STOP-SHOPS: E-AGRICULTURE PORTAL AND TARBIL

The **E-agriculture Portal,** launched in August 2020 but currently unreachable, was meant to bring all online services offered by the MoAF to farmers, citizens and companies under one roof. The portal was designed to cover 2.12 million farmers, 33 million agricultural parcels and 64.7 million animals (bovine and ovine) and to offer 138 public services (88 services for farmers and 50 services for citizens and companies). The E-agriculture Portal was online between August 2020 and July 2021. There have been no updates regarding the reasons of inactivity in the annual activity report of the MoAF for 2021.

The **Agricultural Monitoring and Information System (TARBİL)** was initiated in 2015 to establish a one-stop-shop for all agricultural support services including risk-management and early warning, agri-extension, subsidy-allocation, and official statistics. The project envisaged the installation of: i) 1 200 weather stations providing real-time data on 39 parameters such as local wind, soil moisture, and temperature to the data analysis centre in İstanbul Technical University; and ii) a web- and mobile-based platform for data authorization, monitoring and auditing. In total, 42 separate databases were to be integrated within the TARBİL portal. The project has not been completed and its current status is unknown. The MoAF's Activity Report for 2021 and 2022 (MoAF, 2022c; MoAF, 2023) indicates that a working group was established to assess the situation and plan maintenance and development activities concerning the weather stations installed under this scheme. The field work and interviews with farmers and practitioners carried out for this FAO–EBRD report revealed that many of the installed weather stations are currently not functioning.

SOURCE: Authors' own elaboration.

Systematic use of satellite-based remote-sensing technologies for production audits complementing in-person field visits are envisaged under MoAF's Regulation on the Planning of Agricultural Production (Official Gazette, 14 September 2023). The regulation envisages the establishment of a Planning Board to determine the minimum and maximum production targets for each agricultural basin based on a set of socioeconomic, agroecological and environmental factors as well as national policy priorities.

1.2.2. Support ecosystem for technology start-ups

Start-ups[5] play an important role in developing digital solutions and business models for the agriculture sector. Being high-risk ventures, a supporting ecosystem is critical for start-ups to reach scale and become profitable. Start-ups need support in transforming ideas into viable products that address farmers' real problems; test these products under field conditions; find customers and develop a commercialization strategy. Start-up support typically includes incubator and accelerator programmes, access to pre-seed and seed funding, venture capital, as well as mentoring and partnering with established companies.

Türkiye's start-up support ecosystem has been expanding in the last decade with growing numbers of incubators, accelerators, innovation platforms, technoparks, NGOs, and public organizations. There are a number of public programmes providing pre-seed and seed funding to start-ups as well as private angel investor networks and venture capital funds.

Public support programmes and instruments

A key space where technology start-ups are incubated and accelerated are technology development zones, known as technoparks. The Ministry of Industry and Technology (MoIT) oversees technoparks since 2001 to support technology development, commercialization, internationalization, and enhancing market competitiveness in the country. As of August 2023, there are 100 technoparks hosting 9 615 companies with 102 009 employees. Half of the companies focus on computer programming followed by natural sciences and engineering (6 percent), and biotechnology (3 percent) (MoIT, 2023). Technoparks provide start-ups with wage and social insurance premium subsidies for their R&D personnel and comprehensive incentives in customs, corporate and value-added taxes.

The Scientific and Technological Research Council of Türkiye (TÜBİTAK) is implementing the Entrepreneurship Support Programme (BiGG Programme) – the main public incubator programme for idea-stage tech-based entrepreneurs. The programme has been implemented since 2012 in partnership with 147 accredited organizations including universities, technoparks, technology transfer offices, and private entities (TÜBİTAK, 2022a). It comprises three phases starting with idea-stage project applications, team selection, business plan development bootcamps, and mentorship support via the incubation programmes facilitated by the accredited organizations. In the first phase, applicants can receive grants up to TRY 450 000 (USD 15 600 as of 22 November 2023) to establish a company. Start-ups selected for the second phase can receive an additional TRY 900 000 (USD 31 200 as of 22 November 2023) to implement their business plans and develop a minimum viable product (MVP) during an 18-month period. Following an evaluation of the technical and commercial viability of the MVPs, grantees are referred to other TÜBİTAK programmes and commercial investors (phase 3). On average, the programme has allocated approximately USD 8 million in grants per year. Sustainable agriculture and nutrition category accounts for 10 percent of all BiGG grantees (TÜBİTAK, 2021).

5 A start-up can be defined as a young company (less than 10 years of age) founded by one or few entrepreneurs around a unique and innovative product, service or business model, often related to technology, with strong potential for growth and scalability (Baldridge and Curry, 2022).

Since 2018, TÜBİTAK has been implementing the Tech-InvesTR Venture Capital Support Programme in collaboration with the Ministry of Treasury and Finance and technoparks. The programme works with five national and international fund managers[6] to channel VC investments to technology-focused early-stage start-ups (TÜBİTAK, 2022b). Based on the initial plan, a total of TRY 1.7 billion will be mobilized by the five funds, complemented by contributions from the Türkiye's Treasury (TRY 330 million), TÜBİTAK (TRY 27 million) and technology transfer offices (TTOs) (the same amount). Funds will have a lifespan of 12 years, including a five-year investment period. They can invest in early-stage start-ups in any sector, provided that investee start-ups had previously received public support from TÜBİTAK or other sources (TÜBİTAK, 2022b). As of July 2023, the five VC funds had invested TRY 1.3 billion (equivalent to USD 45 million) in 73 early-stage start-ups focusing on financial technology (fintech), competitor price tracking, gaming, logistics, cloud-based call centre, online consultancy, blockchain, AI, wearable technology products, augmented reality in healthcare, and AI-based image analysis (Milliyet, 24 July 2023). The only AgTech start-up that received investment was Tarfin through its transaction with Collective Spark.

The Small and Medium Enterprises Development Organization (KOSGEB) implements the Advanced Entrepreneurship Support Programme which grants up to TRY 375 000 (USD 13 000) to entrepreneurs who have completed the Advanced Entrepreneurship Training and are operating in selected fields including agricultural, manufacturing and ICT-related activities relevant to AgTech start-ups. The grant covers costs of establishing an enterprise; purchase of machinery, equipment and software; mentoring and consulting, as well as operating costs. In 2022, KOSGEB concluded 10 536 transactions worth TRY 636 510 638 equivalent to USD 38.4 million under this scheme (KOSGEB, 2023).

Regional Development Agencies occasionally support local AgTech start-ups such as Ankara Development Agency's TAGTech Programme that focuses on field integration and R&D support for farmers and AgTech start-ups.

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6 Collective Spark, Diffusion Capital Partners, 500 Start-ups İstanbul Fund II Venture Capital Fund, Gedik Portfolio Management, and Boğaziçi Ventures. For further information on the financial modality between TÜBİTAK, technoparks, and the Ministry of Treasury and Finance, see: Ministry of Science, Industry and Technology, 2018.

Turkish start-ups can also apply to international programmes funded by the European Union. The European Institute of Innovation and Technology (EIT) Food undertakes three entrepreneurship programmes: Seedbed Incubator to help launch, EIT Food Accelerator Network to accelerate, and RisingFoodStars to scale agrifood start-ups. Two AgTech start-ups from Türkiye – Windagrotech and Farmlabs – are alumni of these programmes. EIT has two financing streams for alumni: (1) Food Start-up Impact Fund provides funding of up to EUR 500 000 per venture to the promising start-ups that boost sustainability, health and trustworthiness of the global food system; and (2) EIT Food matches investments concluded by FoodSparks, a pan-European FoodTech seed fund managed by PeakBridge. Investment-ready start-ups supported in EIT Food programmes have direct access to the FoodSparks's VC investments of EUR 300 000–EUR 500 000.

BOX 2

THE EIT FOOD HUB IN TÜRKİYE: SUPPORTING WOMEN-LED AGRIFOOD START-UPS

Impact Hub İstanbul, through its Foodback platform, operates as the ***EIT Food Hub in Türkiye.*** Foodback facilitates the EIT Food's local operations, such as the Empowering Women in Agrifood (EWA) Programme, which provides women-led agrifood start-ups with educational tools, mentoring, community building, access to EIT Food resources, and pre-seed finance (USD 5 000–10 000). The EWA supported mostly food innovation start-ups in its 2020 and 2021 rounds.

SOURCE: Authors' own elaboration.

Private incubator and accelerator programmes

There are 56 private accelerator and 38 incubator programmes open to agrifood start-ups. The programme funders and implementers include commercial banks, private universities, telecommunications companies, NGOs and chambers of commerce. However, only a minority of them are currently supporting start-ups in the agrifood system. WorkupAgri, a joint effort by İşbank and Hackquarters is the only agrifood-focused private programme that provides cash support and stakeholder network access to early-stage AgTech start-ups. The programme in its 2021 round featured (i) Soylgel, a start-up producing multifunctional hydrogel supplying water and nutrients for prolonged times, (ii) wiCow, an AI-supported early warning and health monitoring system for cattle breeding, and (iii) BeePlant, a hardware that enables royal jelly to be produced without a beekeeper through utilizing machine learning.

The Turkish Technology Development Foundation (TTGV), a not-for-profit public-private partnership foundation implements two programmes for start-ups. The HIT Enterprise Support Programme accelerates the first customer/sales transaction of technology-based early-stage start-ups. TTGV provides USD 50 000 support for business development activities. If a third-party investor invests in the start-up within five years, TTGV can invest up to USD 1 million additionally based on the investor's valuation. So far, three agrifood start-ups, i.e. FarmLabs, wiCow, and Biolive have benefitted from the HIT programme.

Other private service providers support ecosystem players with designing accelerator programmes such as Kök Projekt. Since 2019, Kök Projekt worked with İşbank in facilitating the İşbank Agriculture Competition (currently called WorkupAgri) and with the Women in Tech Association in organizing competitions to support women-led early-stage AgTech start-ups and idea-stage student entrepreneurs.

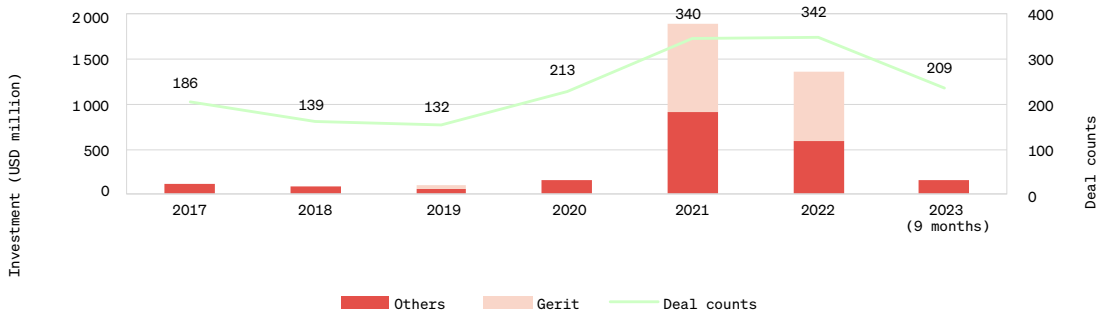
Scale-up investment support for start-ups (seed and early stage)

Angel investment and venture capital (VC) financing are integral to a start-up ecosystem. As of the third quarter of 2023, total VC investment fund size reached USD 1.5 billion by 278 VC investment funds, seven VC investment trusts, and 80 corporate VC funds (Start-ups Watch, 2023). In addition, 521 accredited angel investors and 16 angel investor networks operate in Türkiye (Ministry of Treasury and Finance, 2023). So far, 187 angel investors have invested TRY 28 million (equivalent of USD 1 million) in 59 investment rounds.

Gaming, fintech and delivery start-ups dominate the VC investment scene. The golden years of VC investment in Türkiye were 2021 and 2022, driven by USD 3.2 billion (76 percent of the total amount) invested in six start-ups: Getir (grocery delivery) (USD 1.7 billion), Dream Games (gaming) (USD 460 million), Insider (marketing tech, software as a service or SaaS, AI) (USD 121 million), Tiko (a property technology start-up) (USD 65 million), Colendi (fintech) (USD 38 million), and Libra (gaming) (USD 30 million). With the global recession and the economic downturn in Türkiye, VC transactions slowed in 2023. Excluding the mega deals of Getir and Dream Games, which attracted foreign investors, domestic capital remains critical for the majority of start-ups and smaller deals.

Figure 2

Angel and venture capital investments in Türkiye between 2017 and 2023



SOURCE: Start-ups Watch. 2023. The state of Turkish startup ecosystem 2023 an in-depth analysis and evaluation. In: Startups Watch. İstanbul, Türkiye. https://startups-watch-production.s3-eu-central-1.amazonaws.com/uploads/documents/3760/The_State_of_Turkish_Startup_Ecosystem_2023.pdf?X-Amz-Expires=3600&X-Amz-Date=20240805T114418Z&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIJVM3YYYR2ZQJJSQ/20240805/eu-central-1/s3/aws4_request&X-Amz-SignedHeaders=host&X-Amz-Signature=b90650f07a3604827c876053c15be502239a5d6a637bed53696ee16d79f07fe1

Foreign investor participation first jumped from 8 percent in 2017 to 17 percent in 2022 but then retreated to 10 percent in 2023 (first three quarters) in terms of number of transactions. In value terms, due to Getir and Dream Games mega deals in 2021, foreign investor participation peaked at 89 percent. ***Excluding these mega deals, domestic capital remains critical for the majority of start-ups and smaller deals.*** In international rankings as of the third quarter of 2023, Türkiye ranked 19th in Europe (USD 32 million), with the United Kingdom of Great Britain and Northern Ireland topping the list with USD 4 billion, and fourth in the Near East and North Africa region, after Israel (USD 1.4 billion), United Arab Emirates (USD 236 million), and Saudi Arabia (USD 58 million).

AgTech and foodtech category ranks among the lowest invested categories in 2020–2023 period: 18 VC transactions worth USD 18 million (Annex 2) (KPMG, 2022), with the largest items being Tarfin (USD 8 million), Plant Factory (USD 2.3 million), Fazla Gida (USD 2.8 million), Agrio (USD 1 million), and Farmer Expert (USD 1 million). The recent VC transactions in the agrifood sector are illustrated in Annex 3. Some of the agrifood companies that received VC are introduced in Box 3 below.

Türkiye's main challenge concerns retaining the start-ups in the country. Start-ups often relocate abroad after Series A investment (Start-ups Watch, 2022). The companies owned by Turkish diaspora and/or registered in foreign countries (mainly the United Kingdom and and the United States of America) continue receiving investment from Turkish VC investors. For instance, in 2022, there were a total of 82 diaspora deals with a total volume of USD 1.9 billion (KPMG, 2022) including Getir's USD 1.2 billion acquisition of Gorillas in Germany.

BOX 3

PROFILE OF SOME AGRIFOOD COMPANIES THAT RECEIVED VC INVESTMENT RECENTLY

ForFarming is an İstanbul-based start-up founded in 2018 offering device-agnostic AI-powered SaaS software for indoor farming called the Farmio app, which is currently being used on 140+ farms across 15+ countries. The start-up received its seed VC from Tarvenn Ventures (USD 422 000). In November 2019, the start-up was valued at USD 2 million and received an additional USD 422 000 in private equity capital from a consortium of investors. The company raised an additional USD 450 000 in September 2021 from individual investors with USD 3.2 million valuation. In March 2023, ForFarming raised USD 157 758 investment from Founder One. The company has started working with Getir and CarrefourSA in the domestic market. It has also established a branch in in the United States (Newark, Delaware).

HST Tarım, founded in January 2021 in İstanbul, operates Hasfin which offers deferred payment solutions for farmers' seed, feed and fertilizer purchases. HST Tarım received USD 700 000 investment from Letven Capital and Re-Pie's "First Mixed Technology Venture Capital Investment". Hasfin works directly with farmers and agri-input retailers to commercialize its machine-learning-based fintech product.

Tarfin (see Box 17 for more information) received its seed capital investments from BIC Angels in April 2017 and from a group of international financiers including Wamda Capital

and Collective Spark in September 2018. Later, Elevator Ventures, Syngenta Group Ventures, Collective Spark Fund and Wamda participated in the Series A investment round led by Quona Capital in September 2020. With the pre-Series B investment (USD 8 million) made with the participation of Yara Growth Ventures and other institutional investors, Tarfin has received an investment of USD 14 million cumulatively since its establishment.

AgrioFinans is an İstanbul-based fintech start-up founded in 2020 to provide smart contract and e-wallet solutions for agricultural and food value chains. Financial institutions leverage Agrio as a credit delivery channel and a data system for risk mitigation. Idacapital invested in AgrioFinans in 2021 (USD 700 000). Agrio has recently become one of 30 companies allowed to operate in the Chinese agricultural market in partnership with the European Union and the Government of China.

Biftek.co, founded in 2018 in Ankara, produces micro-organism-based growth medium supplement to grow muscle stem cells. Türkiye's first start-up working on lab-grown meat, Biftek.co is now based in the United States (Newark, Delaware). Valued at USD 12.5 million, Biftek.co received investments from Sankonline, TRAngels Angel Investment Network, Big Idea Ventures, and Canada Cult Food Sciences as of 2021. The company plans to mass produce and commercialize their cultured meat. The start-up was co-founded by the same entrepreneur that co-founded Tarla.io and Iklim.co.

Skysens is an IoT start-up company founded in İzmir Ege University Technopark in 2015 with offices in İstanbul and Austin, Texas, United States. Skysens is an initiative based on low power wide area (LPWA), a low-energy wide network technology addressing the connectivity issues of GSM-based or low-distance solutions. In November 2017, the company received seed investment from ACT Venture Capital. The company exports to 32+ countries. In 2021, Re Pie Asset Management invested in Skysens with USD 5 million company valuation.

Agrovisio, a start-up founded in 2017 in Ankara, helps agricultural commodity buyers and farmers estimate price trends by merging historical and real-time crop supply dynamics through remote-sensing satellites and, where needed, drone imagery. Agrovisio received its first investment from Start-up Wise Guys in January 2021. The company relocated its headquarters to Estonia and introduced a branch in Italy. In November 2021, the start-up received its second round of investment with a valuation of USD 10 million from Start-up Wise Guys, Bora Büyüknisan, Aristo ApS, Cenciarini & Co. Merchant and Investment Banking, Çukurova Investment Platform, Keiretsu Forum Türkiye, Galata Business Angels and EGİAD Angels.

Esular, a start-up founded in 2019 in İstanbul, offers smart irrigation automation solutions through wireless soil moisture sensors and irrigation valves. It received USD 242 thousand investment from fonTAR and fonbulucu in March 2023.

SOURCE: Authors' own elaboration.

1.2.3. Technology support to established companies

TÜBİTAK supports companies, academia and public stakeholders in research and development through 12 schemes where agriculture, food, and the use of digital technologies are identified as priority areas (TÜBİTAK, 2024). Total expenditure across all TÜBİTAK technology and innovation support programmes amounted to TRY 1.3 billion in 2022 (or USD 75.9 million) (TÜBİTAK, 2022c). ICT companies received 29 percent of the grant support, followed by automotive (16 percent) and machinery manufacturing (14 percent) in 1995–2022 period. Food and agriculture received 5 percent of the support in the same period.

TÜBİTAK cooperates with the MoAF's General Directorate of Agriculture Research and Policies (TAGEM) to offer co-funding for R&D projects in agriculture. TÜBİTAK-TAGEM supports agricultural research that enhances food security and sustainability while promoting collaboration between universities, public and private actors. There are two specific calls: (1) Priority Areas R&D Projects Support Programme (up to TRY 2 million or USD 69 000 as of November 2023) for original basic/applied research projects with high impact potential; (2) National New Ideas and Products Research Support Programme (up to TRY 1 million or USD 35 000 as of November 2023) for applied research and/or experimental projects developing products, processes, methods, models that can reduce foreign dependency and/or increase Türkiye's competitiveness.

TÜBİTAK also acts as the national agency for three international R&D support schemes: International Industrial R&D Projects Grant Programme (called EUREKA)), EUROSTARS, and the HORIZON EUROPE programme. The latter is the European Union's key funding window for research and innovation, with a budget of EUR 95.5 billion. One recent example under HORIZON is the ICT-AGRI-FOOD, a project funded by the HORIZON EUROPE which promotes the use of smart digital technologies in the agrifood sector to make European food systems more sustainable, resilient and secure. In the ICT-AGRI-FOOD, TÜBİTAK and TAGEM are consortium members and coordinate Turkish applicants for the joint calls for projects.

TAGEM offers R&D grant support for universities, TÜBİTAK R&D units, NGOs, public institutions, and private companies. As of 2023, the support offers TRY 300 000 for TÜBİTAK's and university's R&D departments (no co-funding), TRY 300 000 for NGOs (maximum 70 percent financing), and TRY 3 million for private companies (maximum 70 percent financing). The calls for R&D grants are thematic: e.g. agricultural economics, pest management or AI-based early warning models. The R&D grants allocated USD 9.7 million for 2022 and budgeted USD 13.2 million for 2023 (MoAF, 2023b).

KOSGEB supports existing SMEs[7] through two major schemes including for agrifood value chains, each of which provide TRY 10 million (or USD 345 700 as of December 2023) per transaction. First, the Business Development,

7 KOSGEB defines SMEs as enterprises employing fewer than 250 people and whose annual net sales revenue or financial balance sheet does not exceed TRY 250 million (USD 13.5 million).

Scaling and Internationalization Scheme supports scaling and cooperation, international incubation and accelerator building, competitiveness, branding, and foreign market access. In 2022, KOSGEB operated 17 351 transactions worth TRY 511 286 901 (or USD 30.9 million) under this scheme (KOSGEB, 2023). Second, the SME Technological Investments and Strategic Product Support Scheme, which supports the production and commercialization of innovative tech products that will contribute to Türkiye's current account balance. In 2022, KOSGEB operated 1 579 transactions worth TRY 228 761 315 (or USD 13.8 million) under this scheme.

Local enterprise support schemes are also provided by regional development agencies, municipalities and public-private partnerships to support agricultural technology developers. One example is İzmir Agriculture Technology Center (ITTM), an AgTech implementation campus being built in the TAGEM Institute in Menemen (İzmir) coordinated by the İzmir Commodity Exchange.

1.2.4. Support for technology adoption in the agrifood sector

There are two major grant schemes that promote technology adoption by agri-SMEs and farmers: (1) the Rural Development Investment Support Programme (KKYDP) funded and operated by the MoAF, and (2) the European Union-funded Instrument for Pre-accession Assistance for Rural Development (IPARD) grant scheme implemented by the Agriculture and Rural Development Support Institution (TKDK). In addition, commercial banks offer subsidized loans to promote technology adoption in the agriculture sector.

Since 2006, the KKYDP supported 16 331 projects of farmers, producer organizations, and agri-SMEs with TRY 22.5 billion (or USD 5.7 billion as per the average exchange rate in 2006–2022 period) (MoAF, 2023). A broad range of investment items related to crop and livestock production, processing, storing and packaging are eligible under the KKYDP. Some digital applications have also been supported, mainly in the form of automated hardware such as greenhouses, automated milking parlours (with integrated cow monitoring systems), and robotics in animal feeding and manure cleaning. Standalone digital and precision agriculture technologies have only recently (2022) been included in the list of eligible investments, such as: i) variable rate sprayers and fertilizer spreaders; ii) automated steering modules; iii) nitrogen sensors in field crop production; iv) farmer information systems (including frost, extreme precipitation, hail, pest warning, fertilization calendar, spraying-irrigation recommendation), harvest and current yield mapping; v) agricultural unmanned aerial vehicles; and vi) cow monitoring systems.[8]

8 The precision livestock farming systems can measure and monitor parameters such as steps and location of cattle, body temperature, heart rate, biomedical data, as well as quantity and quality of milk.

BOX 4

TÜRKİYE CLIMATE SMART AND COMPETITIVE AGRICULTURAL GROWTH PROJECT (TUCSAP)

The TUCSAP project funded via a USD 341 million loan from the World Bank aims to strengthen the capacity for sustainable and competitive agricultural growth and promote the use of climate-smart agriculture in targeted regions of Türkiye. One of the components will support the uptake of digital technologies by farmer organizations, service providers and agribusiness companies working with contracted farmers. The project will combine matching grant support for technology acquisition with sensitization, training and capacity development at all levels. The activities will be piloted in select provinces during the first two years and eventually expanded at national level. Another component aims to strengthen the MoAF's ICT capabilities to improve agriculture sector monitoring and statistics. The project was signed in 2022 and the expected closing date is March 2028.

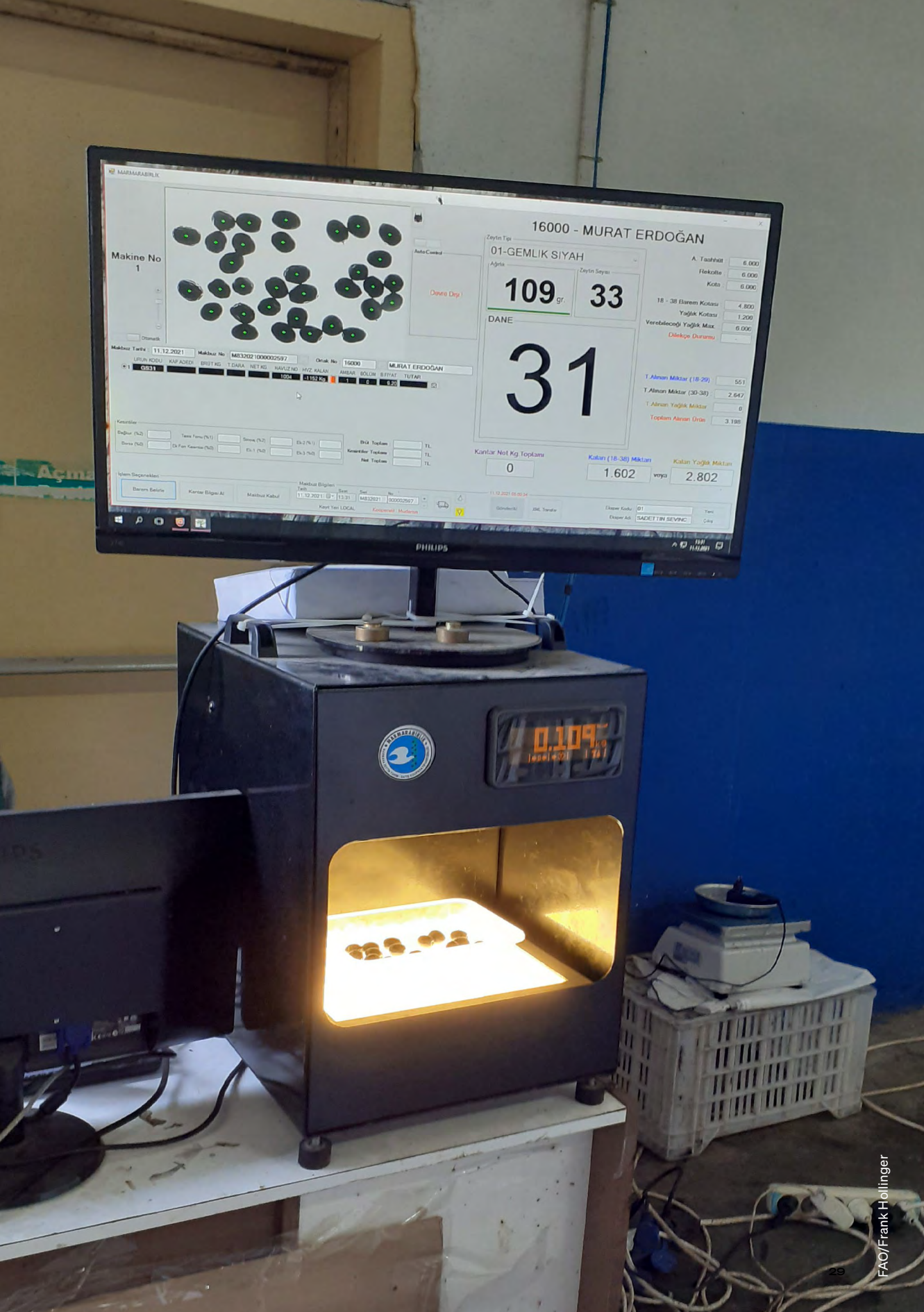
SOURCE: Authors' own elaboration.

The IPARD programme supports agri-SMEs, farmers, cooperatives, and producer unions in 42 provinces co-financing investments in farm assets, processing, marketing, climate adaptation, organic farming, implementation of local development strategies, and diversification of farm activities. While IPARD support does not specifically target smart farming technologies, investments in smart farming equipment are eligible, similar to the KKYDP. In the scope of the IPARD I and II, a TRY 45.4 billion grant has been mobilized for 25 982 projects in the 2011–2023 period (TKDK, 2024).

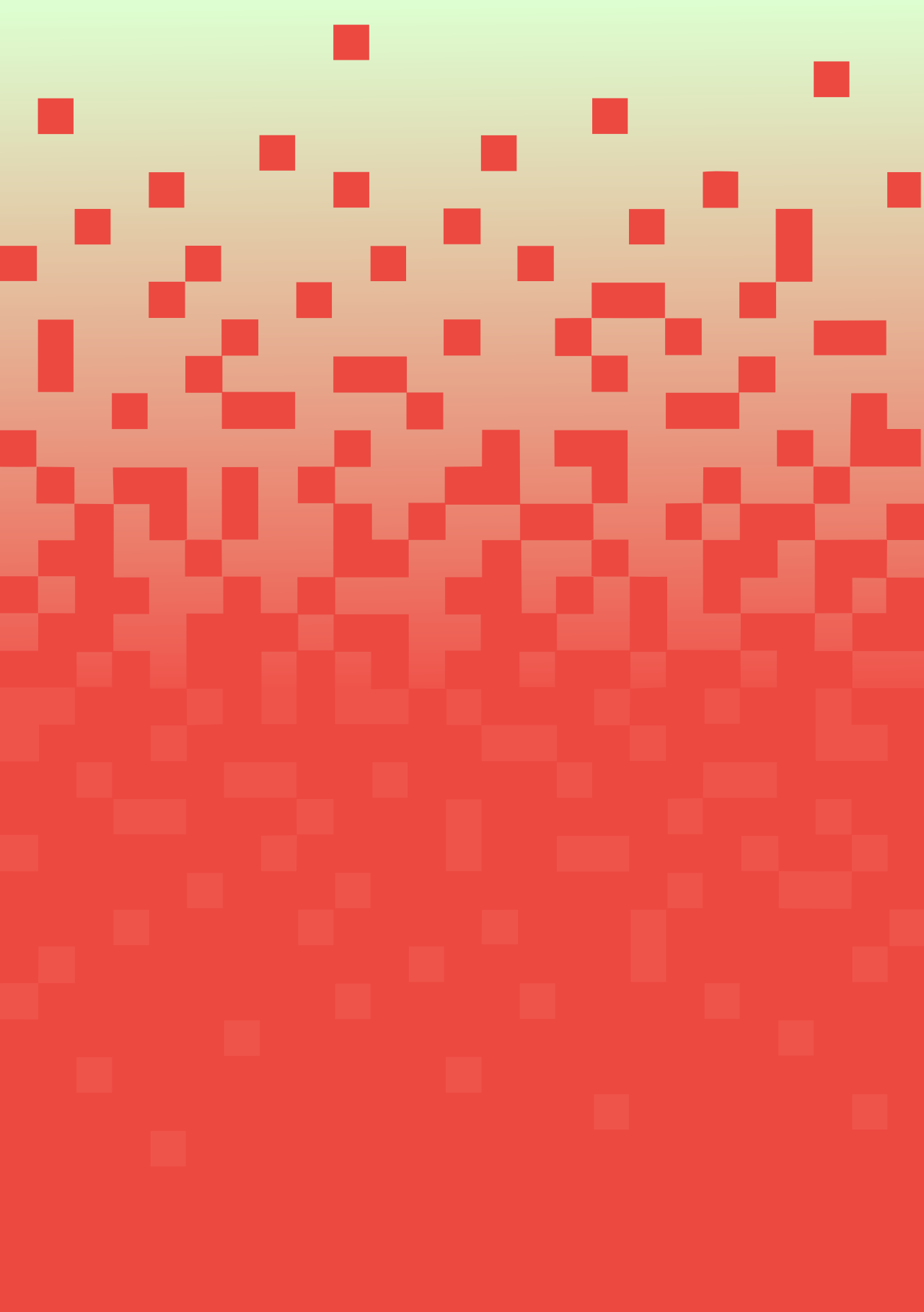
Digital technologies can also be financed through mainstream equipment loans provided by banks. The total volume of outstanding loans in agriculture increased from TRY 10 billion in 2007 (USD 6.9 billion) to TRY 456 billion (USD 15.8 billion) in June 2023 (BDDK, 2023). Ziraat Bank, Türkiye's public agricultural development bank accounts for approximately 70 percent of outstanding loans in the sector mainly catering for small and medium-sized farmers. In 2021, the bank extended an agricultural loan volume of TRY 120 billion (USD 13.5 billion), 74 percent of total agricultural loans disbursed by the banking sector. Ziraat Bank lent to 732 000 producers, one-third of all registered farmers. Ziraat Bank's agricultural loans received interest rate subsidies: for one-third of that portfolio (TRY 32 billion) interest was fully covered by the Ministry of Treasury and Finance; 23 percent of the portfolio carried interest rates of 0.1 to 5 percent, and 43 percent carried interest rates of 5 to 10 percent per annum (Ergin, 2022). "Agricultural mechanization loans" offer subsidized interest rates for digital and precision agriculture products with loan eligibility certificate (Kredi Uygunluk Belgesi).[9] Digital technologies and automation can also be financed through loans for pressurized irrigation systems, construction and greenhouse modernization (Ziraat Bank, 2024).

9 The list of companies and equipment with credit eligibility certificates is available at MoAF, 2024.

Ziraat Bank's loan ceilings allow commercial banks to centre on market segments requiring larger loan sizes. Deniz Bank, İşbank, Şeker Bank, TEB, Yapi Kredi, and KuveytTürk are active agricultural lenders. In general, these banks do not have specific products for financing digital technologies, which can be covered through their mainstream loan products (including equipment loans and agricultural credit cards). Some banks are exploring specific financial solutions to promote specific agricultural technologies that also generate data to better manage climate and other agricultural risks. For example, İşbank has been financing digital field climate stations in collaboration with Vodafone Türkiye and Metos since 2019.



FAO/Frank Hollinger



Chapter 2
Digital technology suppliers

Key highlights

- The number of domestic and international AgTech providers has been growing especially in the last five years. There are approximately:
  - 35 AgTech start-ups in smart and precision agriculture, supply chain management and agrifinance;
  - 30+ e-commerce and food-delivery start-ups including decacorns such as Getir, Yemeksepeti, and Trendyol;
  - 60+ agri-related start-ups working on advanced materials and biotechnology, indoor farming, and alternative proteins.
- AgTech start-ups are struggling to find paying customers, expand their customer base and develop a scalable product and business model for sustained and fast growth.
- Start-ups established as subsidiaries of existing IT companies are making use of pre-existing technologies, commercial networks, and cash flows have better growth prospects.
- After some initial traction, start-ups often move beyond Türkiye to grow faster.
- Many SmartAgri start-ups seek to produce lower-cost and localized versions of established (mainly foreign) products that can be retrofitted on existing machinery and equipment.
- Given the difficulty of selling services to individual farmers,start-ups are collaborating with corporates such as mobile operators, banks, large agribusinesses, farm machinery manufacturers, agriscience and input companies, as well as with public sector entities.
- Few founders of AgTech start-ups have an agricultural background, with most coming from electrical engineering or IT backgrounds.
- There are few international AgTech providers with direct presence in Türkiye, which is perceived as a challenging market due to farm size structure, language barriers, and price-sensitive customers. Most international brands are available through local distributors.
- WAgriscience and input companies are increasingly adding digital products to their portfolios. In some cases, there is a shift in the use of digital technologies from supporting sales of conventional products towards developing standalone digital products.

The number of domestic and international AgTech providers offering digital solutions has been growing, especially in the last five years. Broadly, five types of AgTech providers can be distinguished: (i) domestic AgTech start-ups, (ii) domestic IT companies diversifying into AgTech, (iii) agricultural input providers, (iv) farm machinery and equipment suppliers, and (v) international AgTech companies. Table 2 provides some examples, and the remainder of this chapter provides a brief overview of each category.

Table 2
Main types of AgTech providers

Type of AgTech provider	Examples
AgTech start-ups	Tarla I.O., Doktar, Agrovisio, Provea, Teknokurgu, Farmer Expert
Domestic IT companies diversifying into AgTech	Ankaref, Geosys (Farmlabs), Topraq, Softtech (Imece)
Agricultural input providers	Bayer, Syngenta, Hektas, Toros
Farm machinery and equipment providers (including irrigation)	TürkTraktör, Teta Teknik, Gea
International AgTechs	Metos (Pessl Instruments), Trimble, Topcom, Sentek

SOURCE: Authors' own elaboration.

2.1. AGTECH START-UPS

There are approximately 35 AgTech start-ups in Türkiye in the areas of smart and precision agriculture and related fields such as supply chain management and agrifinance. This number is relatively low given the size of the country and its agriculture sector and considering the number of start-ups in other sectors. Another important agrifood-related segment is e-commerce and food delivery, with another 30+ start-ups. This includes some mature start-ups valued more than USD 10 billion, and therefore now considered as decacorns, which experienced notable growth in the last five years such as Getir, Yemeksepeti, and Trendyol. However, most of the other and more recent start-ups in e-commerce, are small seed-stage ventures focusing on business-to-consumer (B2C) transactions. These start-ups are mainly targeting niche markets such as natural or organic products, higher quality food product and products from specific regions or producers. Other agri-related segments include advanced materials and biotechnology, with approximately 35 start-ups; indoor farming (approximately 15 start-ups); and alternative proteins (16 start-ups) according to the last ecosystem map (Kök Projekt, 2021).

Analysing the start-up landscape is challenging due to the rapid changes, with new ventures being established and others ceasing to operate. The start-ups included in this study were drawn from the 2022 Türkiye Agriculture Ecosystem map prepared by Kök Projekt and complemented by information collected through web research and meetings with approximately half of the start-ups. During the interviews, it turned out that some of the companies are not start-ups in the strict sense as they were either created as AgTech subsidiaries of established IT companies or are acting as distributors of established brands. Annex 4 provides an overview on the AgTech start-ups in Türkiye in smart farming and related themes including traceability, business-to-business (B2B) e-commerce and agrifinance.

2.1.1. Stages of development

While the first domestic AgTech companies were founded 10 years ago, the segment gained traction only recently, with more than half of the start-ups being established between 2019 and 2021. Most smart farming start-ups are at very early stages of development (mostly idea/pre-seed), with few paying customers. However, maturity and age of start-ups are not necessarily correlated, with some newcomers developing quickly, while some of the oldest start-ups not able to gain much traction. Those start-ups that were created as subsidiaries of established IT companies tend to have a faster growth trajectory. Overall, 16 start-ups are classified as idea/pre-seed stage, with few paying customers. Roughly the same number are classified as seed stage. These companies have an established track record in the market with a larger customer base, more refined products, and prospects to attract seed funding. However, only a small number of these have been able to attract seed or early-stage funding from angel investors and venture capital funds (Annex 3). Most start-ups are staying afloat through cash flow generated internally or from other income sources of their owners/founders, but with limited growth.

Many of the companies interviewed are located in university technoparks and received support from public programmes during and after incubation stage or through accelerator programmes. Accelerator programmes have helped start-ups to gain visibility (even internationally), expand their networks, develop additional products, and – in some cases – attract seed funding. In several cases, start-ups developed their initial products or refined them through research grants from TÜBİTAK and TAGEM, sometimes in collaboration with universities or public research institutes. This financial and technical support has been instrumental for ground truthing and field validation of digital solutions.

2.1.2. Technologies and services

Overall, AgTech start-ups are struggling to find paying customers, expand the customer base and develop scalable products and business models to put them onto a sustainable growth trajectory. For this reason, there has been very limited VC funding pouring into the sector, even at the seed stage. The most successful example (apart from the e-commerce start-ups) is Tarfin, which provides agricultural inputs on a credit basis and has been able to raise many rounds of commercial funding from the capital market to fund and expand its operations (Box 3 in Chapter 1). Several start-ups expressed the view that the most promising areas for developing scalable business models based on digital solutions are agricultural finance and insurance, carbon offsetting, and other activities related to corporate environmental, social and governance (ESG) targets, such as nature-positive or regenerative agriculture. Others see potential in combining data from satellites and other sources to conduct market research for input suppliers, in terms of size and spatial distribution of input demand, and for agribusinesses (including retailers) to identify areas and farmers for product sourcing, with related risk scoring, production potential and harvest estimates.

Start-ups are quite diverse in terms of technologies and services offered and in terms of their business models. A number of start-ups provide services based on satellite imagery such as crop identification, crop growth monitoring, detection of problem spots in fields, along with hyper-local weather forecasting, early warning and advisory services (weather, pests, diseases, irrigation, etc.). Another growing area for start-ups is providing drone services for spraying and, to a lesser degree, for crop monitoring and analytics. A number of start-ups are specialized in developing IoT devices such as sensors, field climate stations and other hard- and software solutions. Use cases include greenhouse and irrigation automation as well as remote control and automation for precision agriculture and livestock farming. Many start-ups in this segment focus on developing lower-cost technologies that are more affordable than established brands (mainly from foreign providers) and can be retro-fitted onto existing machinery and equipment (new and already in use).

Table 3
Start-ups by main theme and type of service

Satellite-based services	Agrovisio, AgCurate, Bitkim, Doktar, Tarla I.O., ImeceMobil, Agrotics
Drone imagery analytics	Amanos Drones, Hummingdrone, Provea
Drone spraying	AirAgro, Baibars Mechatronics, Depar
Field sensors and stations	Doktar, Görsentam, Suyabakan; Topraq*
Precision agriculture	Farmlabs, Farmingo, TeknoKurgu
Precision livestock	BenimSürüm, Aktimoo*
Autonomous driving and remote control	MoveOn, Farmingo, Covisart
Smart irrigation	Esular, Doktar, Tarla I.O, Suyabakan, Topraq*
Greenhouse automation	EN/IO, Seracel
App and content development	Doktar, Tarla I.O., Agrovisio
Market research	Agrovisio, Doktar, DepoDone
B2B sourcing, traceability, blockchain	Farmer Expert, Tubu Arge, DepoDone
Integrated platforms	ImeceMobil, Farmer Expert
AgriFinance	TARFIN, AGRIO

*Start-ups established as subsidiaries of established companies

SOURCE: Authors' own elaboration.

2.1.3. Business models

Start-ups are pursuing different business models and growth strategies. Many of the pioneers started by developing specific content, systems or apps for corporates in agribusiness and finance. For example, Doktar started by developing an SMS-based extension service for Deniz Bank, and Tarla I.O. initially developed a contract farmer management system for Konya Seker as a specific proprietary solution. In the next stage, core services and content are offered through an adaptable programme interface (API) to a broader range of paying customers, which generates cash flow and supports further product design (Box 5). These business models are applied by AgTechs providing services based on satellite data such as hyper-local climate data (historic, now-casting and forecasting) and related services such as early warning, field monitoring, crop detection, harvest estimation, etc. Sometimes, services include a hotline function for agronomic advice.

Given the difficulty of selling such services to individual farmers, start-ups providing remote sensing-based solutions are targeting corporates in agribusinesses and finance as potential paying customers. These include suppliers of fertilizers and pesticides, banks, machinery suppliers, and large processors (Annex 7). Some of the more tech-savvy farmer organizations have also purchased satellite-based services on behalf of their members (e.g. Önder Ciftci Cooperative) (Annex 7). Overall, very few individual farmers have subscribed to such services so far. Some AgTechs have also been contracted by the Ministry of Agriculture and Forestry. For example, Agrovisio is providing services to monitor subsidies via satellite data.

With these services, AgTechs are able to generate data on an increasing number of farms that register their plots and use interactive functions of the apps. This growing pool of data allows data mining to improve the accuracy of algorithms, develop new products and services including for corporate clients, such as market research and product advertisements. Banks and insurance companies use hyper-local climate data for risk assessment and pricing models, monitoring and verification of crop insurance claims.

Some start-ups offer a broader menu of services striving to establish themselves as platforms, whereas others specialize in core services and products. Doktar in an example of a start-up offering a broad range of analytics and other services based on satellite and crowdsourced data analytics as well as field-level IoT devices. ImeceMobil and Farmer Expert are aiming to become platforms offering their own services along with services from other start-ups. Others provide specific content and data feeds to end clients such as agribusiness companies or to other AgTech service providers (e.g. Tarla I.O., Agrovisio). Most start-ups producing hardware-based solutions and IoT devices are more specialized in certain use cases such as drone spraying (e.g. Baibars Mechatronics) or analytics (e.g. Provea); sensor manufacturing (e.g. Aktimoo), or low-cost precision agriculture enhancements (e.g. Farm Labs).

Start-ups producing IoT devices target a broader range of customers including individual farmers, farmer organizations, agribusiness and public sector. Examples of such technologies include sensors, smart equipment, field climate stations, and related services (automation, remote control, precision farming, early warning and advice. The main approach of domestic AgTech providers is to develop less sophisticated and lower-cost solutions that can successfully compete with established brands (mainly foreign) which are too expensive for most farmers. Examples are manual assisted steering systems for tractors, retrofitting of conventional fertilizer spreaders or sprayers to introduce variable rate technologies, cow monitoring systems for oestrus detection, digital soil moisture sensors, digital insect traps, or greenhouse automation. While some companies focus on online marketing and remote support for their products, others have started embarking on intense marketing on the ground, using tech-savvy farmers and their organizations as entry points.

Economic fundamentals and government policies favouring import substitution through domestic technology creation are providing economic headspace for such strategies. Moreover, the Turkish market is not an easy target for foreign AgTech providers due to structural constraints related to geographic size and diversity, the demographic and farm size structure, language barriers and a policy environment favoring domestic technology development and import substitution. Hence, only a few foreign AgTech providers have entered the Turkish market so far. However, the major challenges facing these start-ups are threefold:

1. Building solutions that can compete technologically with established international players in terms of accuracy, quality and longevity can be challenging. For example, developing highly accurate algorithms for remote sensing-based farm management services requires not only a large volume of data to test, train and refine them, but also a large amount of ground truthing under many different farming conditions which is expensive and time consuming.
2. Even if a product is technically sound, start-ups and other domestic market entrants need to build a reputation among farmers and agribusinesses who may prefer established brands.
3. There is a need for developing on-site support services to train users and provide technical back-up. Rolling out products and building a technical distribution and support network takes time and requires resources.

Only a small minority of AgTech start-up founders have a background in agronomy or livestock production. Most come from electrical engineering or IT backgrounds. Intimate familiarity with this highly diverse sector and the mindset of farmers and agronomists of agribusiness companies are important ingredients. This leads to successful product design addressing real problems on the ground, developing user interfaces that are easily understood by farmers and other users, as well as designing and implementing strategies for marketing, initial training, and technical support. Some start-ups have hired agronomists to build that capacity. Still, interviews with farmers have alluded to the perception that representatives of AgTech firms often do not “speak their language” and do not have sufficient agronomic knowledge to provide specific advice and help farmers interpret the information produced by the smart technology.

BOX 5

DOKTAR: ONE OF THE AGTECH PIONEERS IN TÜRKİYE

Doktar Inc. was established in 2012 in the technopark of Ege University in İzmir as an AgTech company striving to develop data-driven solutions for the entire agrifood system. It started with an SMS-based information and advisory service for crop producers called "Agricultural Doctor," developed in collaboration with Turkcell. In 2015, the service was substituted by a field scouting and crop monitoring app called Orbit, which was complemented by an agricultural hotline staffed with 10 agronomists. Based on satellite data, the app allows farmers and agricultural technicians to monitor plant growth and health, identify problem spots, understand the yield potential of a field based on five-year averages, and create yield maps. The app generates maps that are based on 117 crop models developed by Doktar in collaboration with agricultural researchers and agronomists. If the app identifies a problem spot in a field, the farmer can make a visual inspection and send a picture through the app in order to receive advice through the hotline. The service is offered mainly through corporate clients such as banks, agricultural processors and input suppliers and reaches more than 120 000 farmers.

Since 2019, Doktar has been complementing its remote sensing-based services through low-cost IoT devices, including a portable soil scanner for soil nutrition analysis, a field weather station and insect traps. While these devices were initially marketed primarily to corporate clients, Doktar is now stepping up its efforts to market the devices directly to farmers. So far, more than 1 000 IoT devices have been sold. Through its various services, Doktar has built a database of 500 000 farmers and 450 000 ha of land are being tracked by satellite. Based on this database as well as its remote sensing capabilities and AI-based algorithms, Doktar offers market research and intelligence services to corporate customers. The recently launched Crop Map service offers field boundary detection, crop detection, and harvest monitoring for more than 20 crops.

Doktar's main clients are domestic and foreign corporates including Turkcell, Bayer, Türk Traktör, Deniz Bank, Tat, Toros, Eurodrip, and Cargill. Its turnover has increased by 30 percent year on year and the company currently employs 70 staff. An early-stage angel investor was paid off after five years and Doktar has financed its growth from its own revenues generated. Doktar is pursuing a regional expansion strategy and has customers in 15 countries.

SOURCE: Authors' own elaboration.

In view of the challenges to finding paying customers in Türkiye, several start-ups are pursuing regional expansion strategies. This approach is facilitated by international accelerator programmes, which provide funding and networking opportunities. Some start-ups have also relocated to countries in the European Union or built offices abroad, often in connection with Turkish diaspora entrepreneurs, or in partnership with other start-ups in these countries, or corporate mentors. There are also cases of Turkish serial entrepreneurs who have founded several start-ups in Türkiye and abroad, and on different themes. This approach helps diversify risks and generates spillovers in terms of cash flow, technologies and networks.

2.2. DOMESTIC IT COMPANIES DIVERSIFYING INTO AGRICULTURE

Established IT companies venture into AgTech as well. This includes companies providing remote sensing services through satellite and drone imagery, IoT devices, or blockchain technologies. In several cases, after initial research and proof of concept, the AgTech operations were spun off into subsidiary companies, which – at first sight (and judging from their web presence) – appear to be conventional start-ups. The advantage of these new ventures is their ability to draw on existing technologies and know-how of their parent companies and adapt them for use cases in the agriculture sector. They can also build on their parent companies' cash flow, access to finance, commercial networks, and – in some cases – clients. These AgTechs therefore tend to grow much faster than most start-ups that were established from scratch.

Table 4
AgTech subsidiaries of domestic IT companies.

AgTech subsidiary	Established	Ag solution/subsidiary	Parent company	Sector parent company
Topraq	2019	Soil moisture sensors, field weather stations, insect traps	Odine	ERP system for telecoms (global)
Aktimoo	2020	Cow monitoring system	Ankaref&Algan	IoT, Traceability, etc.
Benim Sürüm	2016	Herd management software	Algan Group	
ImeceMobil	2019	Multiservice digital platform	Softtech, İşbank	Software Dev Banking
Farmlabs	2021	GIS, precision agriculture	Geosys	GIS

Examples of domestic IT companies venturing into AgTech are listed in Table 4 and some key features are highlighted below. A more detailed description of these companies including their development trajectories, use of public and private support programmes and product offerings can be found in Annex 5.

SOURCE: Authors' own elaboration.

Ankaref is a leading Turkish IT company working on IoT and big data solutions in various sectors, including traceability and tracking of vaccines. Building on its vaccine tracking technology, the company started developing a cold chain tracking system for fresh produce (meat, fish, vegetables, and fruits) for the delivery service company Getir. In addition, it developed and launched a low-cost cow monitoring system for oestrus detection (Actimoo), in collaboration with another Turkish company (Algan Group).

Geosys is a specialized service provider developing geographic information system (GIS)- based solutions for various sectors. In 2008, Geosys began developing low-cost variable rate fertilizer application technologies that could be retrofitted on local farm machinery and equipment brands. After a long period of R&D in collaboration with universities, Geosys outsourced its smart farming operations into a subsidiary company called Farmlabs.

Topraq Tarim is an İstanbul-based spin-off of an established IT company offering ERP services to telecommunications companies in Dubai and London. In 2019, it introduced digital soil moisture sensors, weather stations, and digital pheromone traps through lease-based contracts to tech-savvy orchard producers in various parts of Türkiye.

İmeceMobil, a joint venture founded by İşbank and Softtech Ventures, has developed an all-in-one app for digital agricultural technologies, including by third-party developers. Following an initial drive of cross-selling İşbank products, the app introduced a growing number of more sophisticated services complementing its fee-service offerings.

2.3. INTERNATIONAL AGRICULTURAL TECHNOLOGY PROVIDERS

The number of international AgTech providers with direct presence in Türkiye is limited. A leading example is Metos (Pessl Instruments), which has been present in the country for more than 20 years and has become the market leader in digital field climate stations, digital insect traps and related services such as diseases in early warning and irrigation management. Recent partnerships with Vodafone and İşbank have created additional channels for distribution and financing. A second example is Allflex (Merck), which has had direct country presence for eight years and is the market leader in precision livestock farming and milking automation.

BOX 6

METOS – A LEADING INTERNATIONAL BRAND WITH PRESENCE IN TÜRKİYE

Metos is a digital field climate station brand produced by Pessl Instruments. Headquartered in Austria, the company has offices in 12 countries including Türkiye, which it entered in 2000. Metos field weather stations are powered by solar energy. The stations measure soil moisture, wind speed, solar radiation, soil temperature, air temperature, precipitation, relative humidity and leaf wetness. In addition to a data logging function, cloud-based software calculates agronomic parameters such as evapotranspiration and degree days and indicates suitable timing for agronomic practices such as irrigation, sowing or spraying. Hyper-local weather forecasts, irrigation management and disease early warning can be added as additional services.

Metos developed models for 80 diseases and pests in 35 crops over 30 years, in collaboration with universities. These models are constantly being improved based on user data from different countries. Based on the models and data from field sensors and satellites, the software provides crop and location-specific early warning alerts regarding critical risk threshold for specific diseases, which can be displayed on a smartphone or a computer. So far, more than 2 000 stations were sold to 900 clients in Türkiye – approximately 60 percent to public clients and 40 percent to private agroprocessors, input companies, farmer organizations and large farmers. Due to multifarm use, especially by public clients and cooperatives, a total of 250 000 users benefit from the stations.

More recently, “virtual weather stations” were introduced as a lower cost entry solution. Based on remotely sensed data, it uses the same algorithms for early warning messages. According to Metos, virtual stations work reasonably well in flat terrain with no water bodies, with an error margin between 3 to 10 percent. Another product recently introduced in Türkiye are digital insect traps allowing for remote pest monitoring and early warning. Metos also offers other sensors (e.g. for soil moisture), object trackers (e.g. for tractors and implements), and satellite-based solutions for irrigation management, crop growth monitoring and yield estimation. The Farm View software allows integrating all sensors, devices and services from Metos and several other suppliers. For the latter, Pessl Instruments has global partnerships with several hard- and software suppliers such as John Deere, Farm Facts, Manna, Syngenta, Corteva, as well as with distributions partners such as Vodafone.

SOURCE: Authors’ own elaboration.

There are also international manufacturers of agricultural machinery and equipment (including irrigation and greenhouses) that have developed smart enhancements to their equipment or even entire complementary digital solutions. One prominent example is TürkTraktör, a joint venture between Koc Holding and CNH Industrial Austria, which accounts for approximately 50 percent of the domestic tractor production, with its CASE and New Holland Brands. The company offers driver assistance systems for tractors (manual and automated), a yield mapping system for combine harvesters, and section control for chemical and fertilizer application via ready-to-go factory installation.

> ***TürkTraktör's app (Tarlam Cepte)*** *provides early warning and field monitoring functions to warn users about threats such as precipitation, lightning, hail, and storm. It includes an "Ask an Expert" service, through which farmers can ask questions about tractors and plant production. The app had 35 000 subscribers in 2021 and 115 000 subscribers in 2022. Among these, 30 000 subscribers are "premium" with access to the full range of services. However, only 350 of these users paid the annual premium of TRY 365, whereas the rest have received access through a loyalty programme linked to the purchase of a brand tractor. The total field area being monitored exceeds 40 000 ha. The apps were developed with domestic AgTech providers Tarla I.O. and Doktar.*

Rivulis (former Eurodrip) and Netafim are two global market leaders in pressurized irrigation systems (drip, sprinkler, centre pivot, etc.) with strong presence in Türkiye. Both companies established their smart farming subsidiaries for precision irrigation as well.

> ***Manna*** *was launched in 2016 by Eurodrip based on the acquisition of a United States-based start-up with 10 years of experience in crop monitoring via satellite imagery. Eurodrip merged with Rivulis in 2017, taking over Manna as a smart farming subsidiary. Manna provides irrigation scheduling advice based on high-resolution, frequently-refreshed satellite data and hyper-local weather information provided via a mobile app. Manna can work with any type of pressurized irrigation system. Manna also has a global partnership with Metos to combine its irrigation scheduling with Metos' pest and disease models and other agronomic advisory services.*
>
> ***Netbeat****, developed by Netafim, is a digital solution combining irrigation and fertigation management with automation. Netbeat was managed under Netafim's crop department until 2019, when a Digital Farming Unit was established. Netbeat consists of several software and hardware elements including dynamic crop models; field weather stations and soil moisture sensors; a control unit to automate the irrigation pump; and a remote terminal unit to connect the sensors. Field monitoring, analysis, automation and control are combined in one closed-loop platform. So far, dynamic crop models have been developed for 25 crops. Netbeat has been introduced to Türkiye in 2019 and access to the cloud platform was initially granted free of charge to promote the product. It is planned to establish the digital platform as a separate product which can be hooked onto different hardware solutions and brands. Initial market penetration has been slow with approximately 62 customers, including tech-savvy farmers and corporates in walnut, citrus, greenhouse banana, and olive oil production.*

Other international brands in the field of precision agriculture are only available through local distributors. Examples include Topcom (precision farming), Trimble (precision farming), Sentec (soil moisture sensors), Augmenta (N-sensors), and GEA (milking parlours and precision livestock farming). The distributors have varying levels of specialization in agriculture and differ in their ability to provide on-the-ground support services. Two examples of specialized distributors are presented below:

> ***Smartsoil*** *has focused on making leading global products and brands available to Turkish producers including: i) soil moisture sensors from Sentec (Australia); ii) field climate stations from Meteobot (Romania); iii) multispectral sensors and cameras for drones from MicaSense (United States); drone analytics for citrus producers from Aerobotics (South Africa); irrigation automation from WiseConn (United States); and LED lighting systems for greenhouse production from Tungsram (now Food Autonomy, Finland). Founded by an electrical engineer, Smartsoil has invested in field presence and direct follow-up with growers. Initial efforts were focused on Sentec soil moisture sensors which were marketed to citrus farmers in the Cukurova region, and almond farmers in the Aegean region, using farmer associations as entry points. It also localized some products by developing apps in the Turkish language and providing technical backstopping and after-sales support. In 2022, it had eight staff and over 150 customers.*
>
> ***Teknokurgu,*** *established in 1997, offers digital solutions for agriculture and other sectors, including drone services, development of websites and mobile apps, techno graphics, and sensors. Teknokurgu is the authorized distributor of the Augmenta N-sensors, which can be mounted on tractors to generate prescription maps for variable rate fertilizer applications. The sensor has been tested on several large farms in the Thrace region in collaboration with Önder Ciftci (Box 11) and was granted the Loan Eligibility Document [Kredi Uygunluk Belgesi] in 2022, which makes it eligible to be financed by Ziraat Bank loans. In addition, Teknokurgu is developing technical solutions for retrofitting variable rate fertilizer applications on conventional fertilizer spreaders and sprayers, as well as a low-cost manual aided steering system for tractors. Hence, the company's strategy is a mix between distributing foreign technologies and customizing them for the domestic market, including through local technology development and adaptation.*

There are also other providers in the livestock sector, providing milking robots which offer cow monitoring and related precision livestock services (e.g. GEA, Afimilk).

2.4. INPUT AND SCIENCE COMPANIES

Manufacturers of agricultural inputs and manufacturers of farm machinery and equipment are both users and providers of digital technologies and related services. These services include simple smartphone apps providing basic product and market information, as well as more specialized services such as location-specific advice or IoT devices.

> *For example,* ***Toros Tarim*** *– a leading fertilizer manufacturer with approximately 30 percent market share – has developed its* ***Toros Çiftçi*** *app in collaboration with Cukorova University and Tarla I.O. The app provides fertilizer recommendations based on farm location, crop type and planting date to be entered by farmers. The service is provided free of charge and is not linked to the purchase of Toros fertilizers. The app currently has approximately 13 000 subscribers, including 1 200 accredited dealers. Fertilizer recommendations cover an area of 1.8 million ha, 40 percent of which is covered by wheat, followed by corn, barley, sunflower, cotton, watermelon, potatoes, and melons. Toros Çiftçi is available through ImeceMobil and received 8 900 inquiries so far.*

Some input providers such as Adama, Bayer, and Syngenta are promoting digital insect traps and provide them on a courtesy basis to some large customers.

Following a global trend, other agri-input and science companies have invested in developing sophisticated digital solutions. In a market environment characterized by overuse of inputs, high input prices, and important negative environmental externalities, input companies are gradually moving from solely maximizing input sales towards smart input use with related analytical and advisory services. Especially in a saturated market like Türkiye, with high input costs and issues of residues, companies are seeking to position themselves providing smart advice, to achieve customer loyalty and gain market shares. Hence, while some companies use digital services and apps largely for sales promotion and customer loyalty, others are already transitioning towards developing digital services as future lines of business. This follows global trends of leading agri-input and science companies such as Corteva, Bayer, Syngenta and others. Similar development by leading manufacturers of pressurized and precision irrigation systems have already been mentioned in the previous section.

> *For example, before its takeover by Bayer in 2016, Monsanto had purchased Climate Corporation which developed Climate FieldView to enable farmers to generate precision seeding protocols based on satellite data and do field scouting to identify problem spots. While initially intended to boost sales of its own seeds, the system is compatible with any seed and services are sold as an independent business line in the United States and other markets.*

Most international input and equipment manufacturers have only recently introduced their digital solutions for the Turkish market and have limited uptake so far. Some are still being introduced as sales promotions of conventional products at no or reduced costs, rather than as stand-alone products. For example, Bayer has introduced a basic version of its Climate FieldView application, which offers features such as crop health monitoring, water consumption maps, and local weather forecast. The free version available to its customers is used by 2 000 farmers but only one large farmer has purchased the full version so far. The uptake of Netafim's and Rivulis' digital solutions Netbeat and Manna has also been slow, partially due to the high prices and adverse economic conditions. This provides opportunities for domestic companies such as Hektas to move ahead and gain a competitive advantage in the market.

BOX 7

HEKTAŞ'S SMART ASSISTANT APP

Established in 1956 in Adana, HEKTAŞ is a publicly traded company whose majority share is owned by OYAK – one of Türkiye's largest conglomerates. HEKTAŞ is a leading supplier of plant protection products in Türkiye and also active in plant nutrition, seed, and animal health products. A recent addition to HEKTAŞ's business lines is digital agricultural technologies developed in-house.

The Smart Assistant app offers free-of-charge disease diagnosis through AI-assisted image recognition. Based on an image library with 500 000 images, the app is able to identify 450 diseases with an accuracy level of at least 85 percent. Additional features include hyperlocal weather forecasting and early warning based on IBM's crowdsourced meteorological data. The app sends early warning messages for meteorological and disease risks and provides agronomic advice based on the farm location and other info entered by the user. Users can also validate the originality of Hektaş plant protection products. As of June 2022, the app has attracted 20 000 users (90 percent of whom are active users) who completed 50 000 disease queries. The company seeks to increase the number of users through marketing activities and improve the app by adding new features to recognize nutrient deficiency, pest and weeds.

Hektaş has also initiated the ***Traceable Safe Food Platform,*** with leading modern retailer CarrefourSA, by developing fully automated greenhouse technologies equipped with sensors and blockchain-based traceability. These examples follow trends of international input and agriscience companies that are developing smart farming solutions ranging from decision support tools to precision agriculture support and traceability systems.

The company's goal is to deliver a fully integrated service to farmers inclusive of digital technologies. To this end, it has also invested in developing drone services in house (TURNA) including both analytical functions (such as yield estimation, plant health monitoring, crop mapping, yield performance monitoring, nitrogen availability measurement, water stress measurement, weed measurement, canopy temperature measurement) and spraying.

SOURCE: Authors' own elaboration.

Chapter 3
Use of digital technologies in practice

Key highlights

- Despite a number of promising use cases of digital technologies across a range of actors including farmers, agribusiness and public entities, overall adoption levels are still low.
- Most farmers use the internet and social media to access information on prices, weather and e-government services, but use of specific technologies at farm level remains quite limited.
- Digital technologies at farm level are currently mainly used by tech-savvy large farmers with high education levels and good access to information and finance. Small and medium-sized farmers rarely purchase digital technologies or pay for related services.
- There is an increase in multifarm use of digital technologies, e.g. through early warning systems against pests, diseases and extreme weather events, and remote advisory services, benefitting greater numbers of small and medium-sized farmers.
- Most private agribusiness companies have started digitizing their field operations, sourcing, quality management and traceability systems but are still at an early stage of digitization.
- Agribusiness companies adopt a gradual approach by testing different technologies and providers on a small scale to assess their viability. As such, they play an important role as technology brokers eventually expanding services to contracted farmers.
- Agribusiness companies often start with technologies that allow large area coverage at low costs, such as digital weather stations and remote sensing. Eventually, the number of IoT devices is increased to enhance coverage and precision.
- Some companies have successfully integrated IoT devices and other field technologies into their ERP systems, allowing integrated monitoring of production and product quality and setting the basis for stronger traceability systems.
- There has been a strong growth of grocery e-commerce during the last five years, especially B2C last-mile food delivery from retailers to consumers, fueled by the pandemic.
- While there is also some progress regarding B2B platforms and agrifintech solutions, most of these are still in an early stage and no major platform has yet emerged.

- Digitization has been strongest in higher value crops such as orchards, greenhouse production and field crops with high input costs where the cost-benefit ratio is strongest.
- IoT devices such as digital field climate stations, digital insect traps and soil moisture sensors have seen rapid increases among public and private users due to a range of use cases and proven benefits in reducing input use and improved production management.
- Remote sensing based on satellite images has been underutilized and some quality issues were reported at field level. There is significant potential for expansion and additional use cases beyond farming for agribusiness, banks, insurance companies and government.
- Precision agricultural technologies are largely confined to assisted steering systems among large field crop farmers, whereas the use of variable rate applications is incipient. Some lower cost technology innovations and new delivery models may show some promise.
- Precision livestock farming is largely confined to medium and large dairy producers, but the recent entry of new providers and lower-cost solutions may lead to some expansion.
- Automation is mainly limited to modern greenhouses, tractor steering and large-scale poultry and dairy farming, plus some potential in irrigation.
- Despite rising interest in drone use, especially spraying, the potential for expansion is moderate and largely confined to certain crops. Progress with precision spraying may expand their use.

3.1. OVERALL ADOPTION LEVELS

Use of the internet and digitized services of the Ministry of Agriculture and Forestry has become widespread among farmers as described in Chapter 1. According to the 2020 MoAF survey, more than half of responding farmers used e-government services, followed by meteorological information (42 percent), Land Registry and Cadaster Parcel Inquiry (29 percent), and the Ear Tag Information System (17 percent). However, only 7 percent of interviewed farmers used smartphone apps with information on plant protection products licensed by MoAF, and 6 percent make claims to the agriculture insurance pool (TARSIM) via an app. The annual survey conducted by the Credit Bureau of Türkiye (KKB) in 2022 found that 71 percent of respondents used digital services to access meteorological information, 52 percent for agricultural news, and 30 percent for product and input prices. The survey also marks a consistent increase in these uses since 2020. Between 20 percent and 30 percent of the respondents used digital technologies to access information on government support, production techniques, pests and diseases, and agricultural machinery. Approximately one-quarter of respondents did not use any digital technology or service.

However, the use of digital technologies at farm and field level is much lower. According to the 2020 MoAF survey, less than 3 percent of farmers used smart farming technologies such as remote sensing, sensors and IoT devices, farm or herd management software, precision agriculture or livestock technologies, or robotic applications. A similarly low percentage used mobile apps from private service providers. A recent study also confirms very limited uptake of digital technologies, especially among small farmers and older farmers that need additional advisory and support services (MoAF and Standing Committee for Economic and Commercial Cooperation of the Organization of the Islamic Cooperation COMCEC, 2021).

Despite the limited uptake, survey results indicate that a higher percentage of farmers are interested in using digital technologies, even though they may lack specific information on the technological options available and suitable for them. The 2022 KKB survey of 596 farmers revealed that one-third were interested in using digital services to monitor input/product prices and commodity exchange information; 24 percent in monitoring their parcels through satellite-based remote sensing, and 21 percent in asking questions via their mobile phones for agricultural advice (KKB, 2022).

The low uptake of digital technologies is linked to several structural features of Turkish agriculture, as outlined in Chapter 1. These include: i) the large size of the farming population combined with a small average farm size and fragmentation into several plots; ii) the age profile of the farming population combined with low functional and digital literacy levels; and iii) the country's topography with its diversity of agroecologic zones, microclimatic and soil conditions. In addition, most farmers are not aware of or have limited knowledge about technical options available, or may not fully trust their usefulness, reliability and profitability in practice. There is little independent validation of technologies under field conditions, e.g. by research institutions, hence farmers must rely on information from the internet, technology providers, or (in a few cases) other farmers. Lack of knowledge and trust in new technologies limits farmers' willingness to invest in them. Limited and highly volatile earnings of most farmers pose further constraints to investing in new technologies.

This chapter summarizes the use of digital technologies by key food system actors such as agribusiness, farmers, farmer organizations, lower level public sector entities, and food retail. A more detailed review of the main digital technologies, users, and use cases, benefits and challenges reported, as well as potential for expansion is provided in Annex 7.

3.2. USE OF DIGITAL TECHNOLOGIES BY KEY FOOD SYSTEM ACTORS

To gain deeper insights into the drivers for the adoption of digital technologies, the most commonly used technologies and use cases were identified through interviews with different food system actors, along with the main benefits and challenges experienced in practice. More detailed and focused reviews of specific technologies, value chains and user groups are available in Annex 7.

Interviews were held remotely and during field visits to assess the use of digital technologies by key food system actors. In total, more than 120 stakeholders were met, including: 20 agribusiness companies; 15 farmers and farmer organizations; seven retailers and trade institutions; six financial and telecommunication service providers; five equipment manufacturers; four input manufacturers; seven international AgTech providers; 19 domestic AgTech providers; and 17 ecosystem stakeholders including MoAF, municipalities, and agricultural chambers. Given EBRD's interest, particular emphasis was placed on the use of digital technologies by agribusiness companies, especially those working with contracted farmers.

The interviewees were identified through a snowballing method starting from different sources of information including digital technology providers and EBRD agribusiness clients. After a series of remote interviews, several agribusiness companies, farmers, and public sector technology users were visited during two field trips to Central Anatolia (Kayseri), Mediterranean (Cukurova region), and in the Aegean and Marmara regions (İzmir, Aydin, Manisa, Balıkesir, and Bursa provinces) in late 2021. The main subsectors and value chains covered include orchards, industrial crops (tomato, potato, cotton, and sugar beet), and greenhouse vegetables. Interviews were conducted during the 2020–2022 period in several phases as new stakeholders were identified. Several of the stakeholders were interviewed multiple times for clarifications and recent developments.

3.2.1. Technology use by agribusiness companies

Approximately 20 large agribusiness companies were interviewed remotely or on their premises. Of these, 15 companies reported using specific digital technologies beyond their core ERP system in areas related to production, managing of suppliers, traceability, and other aspects of their operations. Most of the agribusiness companies are engaged in agricultural processing. Some also have primary production, such as Kavaklidere and Doluca (wine), TAT (tomato paste), Anadolu Etap (fresh fruits); Tekfen Agri (seeds) and Mapeks (organic fruits) and source some of their raw material from contracted and non-contracted farmers. Others purchase their raw material entirely from farmers. The latter include large-scale cooperatives with over 10,000 farmer members, such as Taris (olive oil); Marmarabirlik (table olives), Konya Seker and Kayseri Seker (sugar), but also private companies such as Barilla and Fritolay.

During the meetings, companies were asked about their use of digital technologies in their own operations as well as for primary production, sourcing, and supply chain management, as well as marketing and traceability. A particular emphasis was placed on the use of digital technologies in support of contracted farmers. Interviewed persons were mainly from IT, agronomy and field departments, and – in a few cases – from research or marketing departments. The use of digital technologies and automation in processing operations is therefore likely to be underreported in this study.

Table 5 provides an overview of the companies and main digital technologies used, use cases of these technologies, and plans for future investments in digital technologies, as disclosed during the meetings.

Table 5

A selection of agribusinesses interviewed

Company	Digital Technologies	Use cases
TAT (tomato paste)	GIS, farmer app, drones, field weather stations, digital soil scanner, digital insect traps, automated steering	Crop growth monitoring, plant health and water management, disease early warning, soil fertility management, applied on TAT's own fields and for contract farmers
Assan (tomato paste)	Field weather stations, remote sensing	Early warning (weather, disease), husbandry and water management, SMS and agronomist support to contract farmers
Anadolu Etap (orchards)	Field weather stations, digital insect traps, soil sensors, irrigation automation, drones, ERP integration of field operation	Early warning (pests, diseases, frosts), irrigation management, improved husbandry management, workforce management
Fritolay (potato, corn)	Supply chain management software (CropTrak), satellite imagery, weather stations	Managing contract farmer operations, disease early warning, irrigation management
Doluca (wine)	Digital weather stations	Improving husbandry and water management, disease early warning
Kavaklidere (wine)	New ERP system (Netsis), weather stations, soil moisture sensors	Improving husbandry management and wine quality, traceability (barcode)
Kayseri Seker (sugar)	Contact farmer management system (GPS), truck management system, robotics	Supply chain management, advance payments, managing sugar beet truck during peak season, disease management
Konya Seker (sugar)	Contract farmer management system (TARKOP)	Field registration, managing advance payments, agronomic support
Tekfen Agri (seeds)	GIS, field weather stations, automated steering, sensors in storage facilities	Agronomic support for contract farmers, product quality management
Barilla (wheat)	GIS, chat groups on WhatsApp	Production monitoring, agronomic advice and yield forecasting
Migros (fresh fruits and meat)	Traceability, image recognition, field weather stations	Shelf management (pilot), traceability from farm gate to store, food waste reduction, CSR
Mapeks (organic strawberry)	Weather station and soil moisture sensors	Irrigation management and disease risk early warning
Taris (olive oil)	Barcode based lot tracking system	Traceability for geographical origin labels
Marmarabirlik (olives)	Field weather stations, insect traps	Pest and disease early warning, crop management support
Agrobay (tomato)	Greenhouse automation	Irrigation, fertilization, ventilation, and heating (geothermal energy)
Kurt Grup (tomato)	Greenhouse automation, soilless production	Irrigation, fertilization, ventilation, and heating (geothermal energy)
Beypilic (broiler production and processing)	Fully automated slaughterhouse, precision livestock farming with contracted farmers	Automation of feeding, climatization of barns, some support to contracted farmers for technology upgrading

SOURCE: Authors' own elaboration.

Many of these companies are adopting these technologies for their own production but also to support their suppliers. These includes IT solutions to manage contract farming operations including registration and mapping of farmers and production areas, pre-financing of inputs and services, detailed recording of agronomic practices, purchasing of products and marketing of byproducts. It also includes technologies to support farmers through early warning of pest and disease risks, weather information and agronomic advice to improve quality and reliability of production.

Agribusiness companies visited are using a range of technologies for various use cases: to improve production and save water, energy, and other inputs, manage and monitor suppliers and contract farmers, improve overall management of the production process and traceability to enhance their brand value. Annex 7 provides a more detailed discussion on the main technologies and use cases of the agribusiness companies interviewed as well as their future technology development plans.

Agribusiness companies play an important role as technology brokers. Compared to farmers, they have superior capacity to identify and understand digital technologies, select relevant solutions and adapt them to specific local conditions, and negotiate with service providers. Most domestic agribusiness companies are scouting for and introducing solutions from AgTech suppliers present in Türkiye (both domestic and international). This includes off-the-shelf products, especially in case of IoT devices, remote sensing, and precision agriculture technologies, as well as the development of customized solutions, sometimes in collaboration with companies' IT, field, and research departments. Large agribusiness companies are frequently approached by start-ups eager to showcase and roll out their solutions.

Some international companies have introduced digital solutions from their head offices that have already been used in other countries (e.g. Fritolay/PepsiCo; Barilla). For example, Fritolay is using CropTrak as supply chain management software for agricultural enterprises, which works in conjunction with the systems applications and products (SAP) system. The company provides close support to contracted potato farmers through its agronomists to ensure quality. Barilla used Normalized Difference Vegetation Index (NDVI) satellite data from an Italian service provider for production monitoring and harvest estimation, in addition to field weather stations for activity scheduling.

FAO/Franz Pöllinger

BOX 8

USING DIGITAL TECHNOLOGIES TO MANAGE CONTRACT FARMERS IN SUGAR BEET PRODUCTION

Konya Seker is one of Türkiye's largest sugar manufacturers. It sources sugar beet from approximately 17 000 farmer members and a total production area around 46 000 ha. With the help of a domestic IT start-up (Tarla I.O.) and co-funding from TÜBİTAK, Konya Seker developed a system to manage its contracting operations. The system, called TARKOP, comprises several modules allowing farmers to monitor advance payments in cash and kind (in the form of inputs and services), the estimated value of their crops, and the final payment net of deductions. In addition, TARKOP offers an online market for by-products, which can be used for animal feeding. Because sugar beet is produced under crop rotation, fields change every season and rotation schedules are being digitized through mobile GPS devices. This allows the company to monitor its production base along with farmers' adherence to crop rotation. Based on soil testing results, soil maps of registered fields are being established, allowing company agronomists to provide location-specific fertilization recommendations. Growers can use TARKOP to receive hyperlocal weather forecasts. Konya Seker plans to integrate satellite data to better monitor plant growth and prioritize field visits of its agronomists, along with yield estimation, improved irrigation management and early detection of diseases.

Source: Authors' own elaboration.

Systems for managing contract farmers and supply chain operations are often customized and co-developed by IT departments and domestic software companies. For example, Konya Seker has developed a system to register farmers and plots producing sugar beet at the beginning of each season and manage pre-financing and payment operations in collaboration with a domestic service provider, whereas Kayseri Seker has developed a similar system in-house by its IT Department. Konya Seker's research department has developed a field robot for plant health monitoring and treatment, and a system to manage the arrival of trucks carrying sugar beet at factory gate and automate the weighing and clearance process, leading to a huge reduction of queuing time during the harvest season.

BOX 9

IN-HOUSE TECHNOLOGY DEVELOPMENT – THE CASE OF KAYSERI SEKER

Kayseri Seker is a large sugar manufacturing cooperative based in Kayseri sourcing on average 55 000 tonnes of sugar beet from approximately 15 000 farmers. The company developed a management system in-house for its growers, which allows tracking of fields including information such as plot maps, planting date, type of seed used, and farmer identification. The use of satellite data for plot registration is not feasible as 75 percent of the farmers are planting sugar beet on rented land. So, data is collected by 130 field staff and entered via smart-phones and tablets.

Kayseri Seker is also testing several other technologies to address key challenges for sugar production in the region, namely over-irrigation by farmers amidst declining water tables and disease pressure, as well as over-fertilization. Solutions being tested include satellite-based irrigation management (Manna) as well as field climate stations and disease models with pilot farmers. A major challenge is changing farmers' mindsets and cultivation practices, which requires extensive persuasion and follow-up by field staff who themselves need to be familiarized with digital technologies. The company is also encouraging its members to switch to drip irrigation (including subsoil drip irrigation) which would result in up to 40 percent energy cost savings from pumping, as well as substantial yield increases according to the company's research department. The introduction of auto-steering tractors and variable rate technologies to save fertilizer applications is also envisaged.

SOURCE: Authors' own elaboration.

Most agribusiness companies adopt a gradual approach to technology introduction, often starting with small pilots. Similar technologies and services from different providers are tested before decisions are taken to continue or upscale their use. For example:

> ***TAT*** *has been testing a range of technologies on some lands rented specifically for that purpose. These include field climate stations, remote sensing solutions for weather forecasting, crop monitoring and disease early warning. The idea is to identify the most suitable solutions for tomato production in the area and eventually pass them on to contract farmers. Early attempts to test technologies directly on contract farmers' land did not yield the expected results.*
>
> ***Anadolu Etap*** *has been testing different soil moisture sensors, drone service providers and digital insect traps. These trials are usually started on one of Anadolu Etap's eight farms and, if successful, technologies are rolled out to the other farms.*

Once some specific technologies have been established after successful trials, the next step is to gradually integrate them into the ERP system. This is a launchpad towards better traceability, including through blockchain technologies.

Companies often start with relatively inexpensive technologies covering a large area of land such as remote sensing based on satellite or drone images, or field weather stations with embedded early warning functions. Initial technologies often include field climate stations and remote sensing technologies for crop monitoring and early warning functions. Feedback has been mixed on remote sensing applications, which were sometimes considered as insufficiently accurate, but generally positive on field climate stations and sensors. Field climate stations require relatively modest investment and maintenance costs and cover broad area of approximately 5 km radius (depending on topographic and microclimatic conditions).[10] There are clear use cases in terms of hyper-local weather forecasts, monitoring and recording of site-specific weather and climate data, such as early warning of disease and pest risk levels, recommendations of suitable timing for spraying and other field operations, irrigation management, or supporting damage claims to the agricultural insurance pool TARSIM. In addition, the recording of weather and climate parameters allows a retrospective analysis of production results in relation to weather events and management practices. Such data-driven analysis helps to adjust and improve management practices as well as crop variety selection in the context of climate change. From an economic point of view, the use case is clearer for orchards and high-value field crops such as potatoes.

Remote sensing using satellite images and drones offers a range of potential use cases, but field experiences have been mixed so far. One prominent use case for agribusiness companies and large farms is crop growth monitoring and identification of problem spots, which then need to be further investigated on the spot. Such services are comparatively inexpensive and can help companies' extension workers better manage their field visits. This applies especially to companies with large numbers of contract farmers, such as TAT and Tekfen Agri. However, several respondents voiced concerns around prices and quality of services currently on the market. On the one hand, cheaper solutions based on freely available Sentinel satellite imagery data, with 10*10 m pixel size resolution, are often considered insufficiently accurate and instances of misrepresentation have been reported. On the other hand, most expensive products with higher levels of accuracy are often deemed too expensive. For example, several companies used Eurodrip's *Manna* service for irrigation management and were quite satisfied with its quality, but few were willing to continue using it at current price levels.

10 Investment costs range from EUR 1 500–5 000, depending on brand, size, number of sensors and range of complementary services such as weather forecasting, irrigation, and disease models.

Overall, solutions based on satellite data reportedly work better for field crops than for orchards, and some companies prefer satellite data over field stations or sensors. Tomato processors such as Assan have switched from physical to virtual stations for providing agronomic advice and early warning messages to their contract farmers. According to Assan, while the quality of service is comparable to physical stations, virtual stations require no maintenance and cannot be stolen, unlike physical stations, especially those installed on fields of contract farmers. Overall, the performance of such virtual stations depends on crop- and site-specific conditions: they work best in open, flat terrain with no water bodies.

Several companies used drone services with multispectral cameras on a trial basis for purposes such as plant health monitoring, disease detection, tree counting and identification of lower performing field areas and crops. The main usage has been in orchards. However, according to those companies interviewed, the services have not fully met expectations and the cost-benefit analysis is not yet considered.

> *For example, **Anadolu Etap** has been using drones with normal cameras for monitoring purposes and has been able to monitor workers and threats such as fires. TAT has used drones in its own demonstration tomato field to monitor crop health, and to validate field observation findings. Both companies have tried several drone service providers offering flight and analytical services using multispectral cameras but decided that the value added was not sufficient to invest in purchasing cameras and software. This might change in the near future, as the capability and performance of solutions and service providers increase and prices drop. Overall, several of the companies met have expressed interest in using drone services.*

There is also growing interest in using drones for pesticide application even though questions remain around technical and cost efficiencies, as well as environmental and health externalities, compared to conventional spraying. Drones are most clearly justified for crops where tractors cannot enter easily (such as paddy) or without causing crop damage (such as maize and sunflower). According to industry estimates, there are about 500 agricultural drones currently in use in the country. However, the use of drones, especially for spraying purposes, grapples with a complicated regulatory environment (see Annex 7 for a broader discussion) and most operators operate in a legal grey area.

More recently, digital insect traps and digital soil scanners have been introduced by several companies. Digital traps help monitor critical insect populations through image recognition technologies and determine critical infestation levels that may warrant spraying or other actions. Analytics and images are transferred to a user interface (e.g. a smartphone app). Some of the devices have shown great accuracy. However, given their costs and limited coverage level, only a small number of units are used. Typically, digital insect traps are complemented by conventional insect traps and serve as an early warning tool. Digital soil scanners allow a quick soil analysis on many points in the field and results are available after only a few minutes. Interviewees have different views as to whether the level of accuracy is acceptable or not. Such scanners might serve as an interim or complementary solution, given the costs and processing times of laboratory tests, which limit their use.

Digital soil moisture sensors are used by some companies to better manage irrigation and reduce water and energy consumption. These sensors measure soil moisture levels at different depths (up to 1.20 metres) in real time and indicate boundaries for under- and over-irrigation. The latter is a current practice in Türkiye and poses a threat for orchards as it increases the incidence of fungal disease and compromises the long-term health of trees, in addition to the implications for energy costs and groundwater depletion. In larger areas, several sensors are required to address differences in soil structure, increasing investment costs.[11] The sensors are mainly used in field orchards and greenhouses, in combination with drip irrigation systems. Precision irrigation requires the ability to regulate irrigation levels at different parts of the field in response heterogeneity in soil structure. Soil moisture sensors are one step closer to irrigation automation. While the latter is not yet very common outside of greenhouse production, some large producers are planning to automate their irrigation systems to save labour costs (e.g. Anadolu Etap).

Overall, field sensors, stations and IoT devices are used as decision support tools, still complemented by field observation and expert decision-making. Given the investment costs and ongoing fees for software licences and analytical services, digital devices are complemented by analog insect traps, moisture metres, etc., serving as additional measurement points and back-up and control devices. For all IoT devices currently used (including field climate stations), the software provides recommendations on risk levels, critical parameters and needs for corrective actions. This data must still be interpreted, in some cases validated, and converted into action or advice. Some providers are working on further automation of advisory functions based on big data analytics and machine learning (e.g. Topraq). They charge relatively low fees for devices and service – often offered on a rental basis – to maximize the number of measurement points under different field conditions and generate data for their algorithms.

Most companies with field operations use automated steering systems for tractors and machinery tracking. However, the use of variable rate technologies is still in its infancy.

Companies have achieved different levels of progress in integrating specific AgTech devices and solutions into their ERP systems. Some companies are still grappling with the integration of multiple specific solutions into one integrated decision support and management system (e.g. Tekfen Agri) and are planning to develop in-house solutions (e.g. TAT). Other companies found solutions to integrate various specific tools and applications into their ERP system. For example:

> ***Anadolu Etap*** *is using Qlik Sense to integrate data from different applications and field devices and general graphs and analytics. In addition, it uses BIMSER to create customized data entry models for field staff on mobile devices in field operations, data from soil moisture sensors, etc. Qlik Sense is integrated with SAP Fiori and linked to the company's ERP system.*

11 Depending on the model, investment cost is EUR 400–2 000 per probe.

***Fritolay** is using CropTrak, a special supply chain management SaaS for agribusiness companies and farmers connecting contracts, crops, carbon, compliance, sustainability, and data silos in different departments. CropTrak serves as a dashboard of information entered manually by FritoLay's field agronomists regarding on-farm operations as well as weather and disease early warning records provided automatically by Metos weather stations.*

Companies producing higher-value products or targeting export markets are especially using digital technologies to improve traceability. Several companies have developed traceability systems based on bar codes or QR codes. For example:

***Kavaklidere,** a leading wine producer and exporter, has integrated viticulture apps such as GBM Kav, a wine cellar monitoring and management extension, and GBM Argon, a mobile merchandising software that measures storage conditions and product handling during transport, into its ERP system Netsis. However, data entry for field operations remains largely manual, which is very time - and labour-intensive and susceptible to human error. Increased automation using sensors and IoT devices can ease this burden and improve reliability of data.*

Some companies use traceability systems primarily for internal use, e.g. to track and improve processes and performance and to identify causes of product quality problems (e.g. Anadolu Etap).

***Migros** has introduced a traceability system in its red meat supply chain to guarantee quality. It owns a large slaughterhouse, has contracts with two other slaughterhouse and conducts 15 000 microbiological and chemical analyses tests per year. Issues can be traced back to producers, who are then informed and assisted. Based on big data analysis supported under a European Union traceability project, Migros managed to reduce food waste as well as recall and withdrawal costs, and increased productivity. Other companies are improving their traceability systems to position themselves as leaders in specific market segments and cater to customer requirements in export markets (e.g. TAT and Kavaklidere).*

***In this context, several companies and some large farms are interested in developing blockchain systems for traceability.** This is partially driven by domestic retailers. For example:*

***Migros** already has a QR code-based traceability system for fruits and vegetables, allowing consumers to trace a product's origin and harvesting date based on data from the Wholesale Food Registry System (HKS) (Horuz, 2020). Migros has also considered upgrading into a blockchain-based solution, together with a domestic IT company, OBASE, by using Microsoft Azure infrastructure.*

***CarrefourSA** has started working on a blockchain-based traceability system with Hektas for some vegetables in selected high-end stores in İstanbul (Hektaş, 2021). To this end, Hektas has equipped greenhouses of 40 farmers with sensors and IoT infrastructure to fully automate greenhouse operations and direct data flow to a blockchain-based traceability system – minimizing human-intervention in the system.*

***Feyz Süt** is a large family-owned dairy and beef producer with an integrated feed production targeting high-end restaurants and consumers in İstanbul and Bursa with raw milk and sausages. The farm uses a large range of IoT devices and automation both in feed, dairy and meat production, which constitute an important building block for a blockchain system that includes the entire production process. One critical issue*

identified by Feyz is the need for independent auditing of the blockchain to ensure full trust and transparency to customers, preferably through an international service provider.

While several companies are looking into blockchain solutions for traceability, costs are high and benefits in terms of increased market shares and consumer willingness to pay higher prices are not clear. Issues around data reliability and validation, especially for field operations such as spraying and fertilization, remain a challenge for the credibility of the blockchain. Hybrid systems relying on third-party monitoring through agronomists are being developed by some start-ups as an intermediate solution (e.g. Farmer Expert).

Some companies use digital technologies to provide services to their suppliers, especially contracted farmers. This applies most notably to those companies that do not have their own production sites (Konya Seker, Kayseri Seker, Assan Foods, Barilla, Fritolay, Marmarabirlik, and Tekfen Agri). The main technologies used are interactive platforms to register farmers and plots and manage pre-financing, delivery of inputs, advance payments, product delivery and final settlements (see Box 8 on Konya Seker and Box 9 on Kayseri Seker), as well as early warning, crop monitoring and advisory services. For example:

__Marmarabirlik,__ in collaboration with the provincial directorate of the Ministry of Agriculture and Forestry, provides early warning messages about weather and disease risks to thousands of small olive producers delivering to the factory. Improvements in timing of advice and considerable reduction of pesticide applications have been reported.

Similarly, __Assan Foods__ uses virtual field climate stations to generate early warning messages and agronomic advice to its tomato farmers (including non-contracted farmers). TAT offers similar services.

Investment volumes for digital technologies are in most cases modest compared to the size of the companies, mainly below USD 100 000. This is partially owed to the relatively low unit costs of field climate stations, field sensors, and other devices, but also to the gradual approach taken by most companies. Only where more complex solutions are developed are the costs are higher (e.g. blockchain development, integrated decision support systems, supply chain management systems, new ERP systems, irrigation automation and greenhouse automation). Overall, in most cases, the scale of technology use remains limited even though most companies have plans for expansion. Some companies have technology development plans with slightly higher budgets (e.g. TAT, Assan, Tekfen Agri), but details were not disclosed. The challenging economic situation has caused companies to downscale some technology development plans or put them on hold temporarily.

Several companies have digitization plans or technology development plans. For example, ***TEKFEN's*** plan included the integration of several specific digital solutions into its ERP system to allow better monitoring in real time. ***TAT*** plans develop: i) a decision support system integrating all aspects of field operations including fertilization, spraying and irrigation; and ii) a traceability system from the field to the final consumer, which would be gradually introduced in three phases, including blockchain technology. ***Kavaklidere's*** five-year digitization plan "from vineyard to glass" – currently in the last year of implementation – is aimed at enhancing traceability, and improving and monitoring quality along the chain.

3.2.2. Technology use by farmers and farmer organizations

Fifteen interviews with farmer organizations and individual farmers using various types of digital technologies were held, mostly on their premises during field visits to Aegean, Southern Marmara, Mediterranean and Central Anatolia regions. Most of these farmers were large scale and represent a diversity of crops and regions. Table 6 provides a brief overview of the key features of the farmers and farmer organizations visited.[12] The key findings of these meetings are summarized below.

Currently, the use of digital technologies is mainly confined to medium and large farmers with high education levels and good access to information and finance. The farmers interviewed were highly educated, some of them with degrees in electrical engineering, and very prone to technology development and testing. Some have been living abroad in the European Union or in the United States and are following international developments in agricultural technologies. Similar to large agribusiness companies, these farmers have been testing various technologies and have also been collaborating with some start-ups to test product prototypes and provide feedback. These farmers are considered to be at the forefront of technology adoption. Smaller farmers are accessing digital technologies and related services mainly indirectly through multifarm use of such technologies by local offices of the MoAF, cooperatives and chambers of agriculture. Examples will be described in the following section.

The largest uptake of digital technologies is currently in orchards, greenhouses, and dairy farming. These subsectors require high investments per area but also generate high value added, so digital technologies amortize more easily. In addition, there are clear use cases for digital technologies. In orchard production, these include early warning systems for frost and other extreme weather events, pest and disease monitoring and early warning, and irrigation management. In greenhouse production, digital technologies are used to automate ventilation and heating systems, irrigation, and fertilization, as well as for pest and disease detection. Use cases in dairy production include the use of robotics in milking, feeding, and cleaning as well as precision livestock farming systems monitoring cow movements to detect health and feeding issues and predict oestrus.

One complaint frequently voiced by farmers is the lack of integration and interoperability. Farmers have several apps or software on their smartphones or computer that do not "talk to each other," which limits their use for farm management.

12 In some cases, farmers were met in groups, e.g. orchard producers in Kemalpaşa, İzmir and citrus producers in Adana.

Table 6

A selection of farmers and farmer organizations interviewed

Farmer/organization	Digital technologies	Use cases	Plans
Citrus farmers (Cukorova) **(ADATUB members)** Citrus and field crops above 100 ha	Weather stations, soil moisture sensors, insect traps	Early warning, improved husbandry management	Increase number of IoT devices
A large farmer in Tarsus (Tarsus) 100 ha (70% orchards, 30% field crops)	Digital weather stations	Early warning, Disease models, climate data recording	Digital cameras in trees to monitor growth
Feyz Süt (Bursa) Dairy and sausages, 2 000 cows plus feed production	Feed ration planning, GEA cow management software linked to milking parlour	Precision livestock farming, precision agriculture for feed production	Blockchain-based traceability and carbon footprint calculation
A large farmer in Aydin (Aydın) Cotton	Remote sensing, variable rate fertilization	Precision fertilization, irrigation automation	Improve retrofitting variable rate application (VRA) devices, continue testing irrigation automation for drought-sensitive cotton crop
A large farmer in Killis (Kilis) Wheat, barley, cotton, almond, olive, pistachio 400 ha	Weather station, soil moisture sensor, disease models, variable rate application, satellite imagery	Early warning, irrigation automation, precision spraying and fertilization	Develop and commercialize a VRA product with Hulusi **Özbaşatak;** procure drone services for spraying and irrigation scheduling
Contracted sugar beet farmers of Kayseri Seker >100 ha	Metos Field Climate station	Disease early warning, weather forecast and information, scheduling agronomic practices	Part of pilot project by Kayseri Seker's Research Department
Orchard producers (Kemalpaşa) 10 ha and smaller	Weather station, disease modules, soil moisture sensors	Weather forecast (predicting frost and hail), disease and pest early warning	Additional weather stations to cover microclimate, digital insect traps
A medium-size farmer in Aydin (Aydin) Cotton, 43 ha	Insect traps, weather station	Pest and disease management	Improve soil quality to increase crop resilience against insects; explore biological pest control
Önder **Ciftci Coop** 40 000 ha by 400 member farmers	Satellite imagery remote-sensing, digital soil scanner, weather station, variable rate fertilization and spraying, drone spraying	Land use estimation, crop growth and health monitoring, digital soil analysis, weather forecast, precision fertilization, drone spraying in sunflower	Improve the uptake of satellite crop growth and health monitoring tech, improve harvest estimation, offer drone spraying as a permanent service to members

SOURCE: Authors' own elaboration.

BOX 10

DIGITAL TECHNOLOGY USE BY CITRUS FARMERS IN THE CUKOROVA REGION, MEMBERS OF ADATÜB

Several of the more tech-savvy large farmers growing citrus and other crops close to Adana, members of its producer's union,[13] started using field weather stations, soil moisture sensors, and insect traps. Some farmers are transitioning towards irrigation automation. Overall, frost detection and disease early warning models are particularly important in the region. Despite some complaints about user interfaces not being user-friendly, farmers consider the technology, including disease models, as reliable. Given their educational background, interviewed farmers have no difficulties interpreting agronomic data recorded by the climate field stations, such as degree days. Farmers particularly valued the climate data recording functions, which help them improve their management practices. At the time of the field visits, there was great interest in digital soil moisture sensors to respond to rising irrigation costs related to electricity requirements for pumping stations. Farmers reported up to 25 percent savings in water consumption and energy costs as a result of irrigation scheduling based on recommendations generated by the sensors. Several service providers are actively marketing their products in the region, using different brands and marketing strategies.

SOURCE: Authors' own elaboration.

Some digital technologies with potential for multifarm use have been adopted by farmers' organizations, agribusiness companies and public sector entities benefiting large numbers of small farmers. This especially applies to field climate stations and related analytics, which can cover larger areas of land, especially in plain areas, as well as to remote sensing services. Several provincial directorates of MoAF (e.g. Manisa, Bursa) but also municipalities (İzmir) and local chambers of agriculture (e.g. Kemalpaşa in İzmir) have invested in digital field climate stations to provide disease and weather early warnings along with other agronomic recommendations to tens of thousands of small producers via SMS messaging. A specialized team of agronomists interprets the data from the climate stations, conducts field validation, and composes advisory messages to farmers. In some cases, such efforts are conducted in collaboration with large producer cooperatives, such as Marmarabirlik (Boxes 11 and 12).

13 Adana Citrus Producers' Union (Adatüb) is a provincial farmer organization with 180 members, 80 percent of whom have global certification of their use of good agricultural practices and export to the European Union, United States, Canada, Japan, and the Russian Federation.

BOX 11

ÖNDER ÇİFTÇİ – DIGITAL TECHNOLOGY ADOPTION BY A TECH-SAVVY FARMER ORGANIZATION

The Önder Çiftçi Cooperative was founded in Tekirdağ as a pilot project between the Turkish and German Agricultural Society (DLG) in 1987. Currently, the cooperative has 400 members (on average 55+ years of age), mainly medium to large farms with 100 ha of land on average, covering a total area of 40 000 ha with sunflower, grain and barley. The cooperative has subsidiaries including an insurance and an agri-inputs company.

In 2019, Önder Çiftçi introduced several digital technologies starting with a satellite-based crop monitoring service combined with hyper-local weather forecasting and disease early warning. In addition, a digital soil scanner was purchased (Doktar) to provide soil testing services to members. Most recently, a portable nitrogen scanner (Augmenta) that can be mounted on tractors in order to support variable rate fertilizer application has been tested by several member farmers, in collaboration with the Teknokurgu and Tekirdag University.

Still, technology uptake by farmers has remained low so far. While approximately one-third of the members (140 farmers) are registered for the satellite service, only 10 percent (40 farmers) are actively using the app, checking NDVI indexes and, in some cases, using accumulated rainfall data. The service has been funded internally from the surplus from the cooperative's trading activities, along with advisory services provided by four agronomists. Farmers are also reluctant to pay for digital soil analysis services, but the cooperative continues to charge farmers directly rather than embedding the cost of digital services in the price of inputs. At the same time, Önder Çiftçi continues promoting these digital technologies and has become a regional distributor of Doktar digital soil scanners and of Augmenta Scanners in partnership with Teknokurgu.

SOURCE: Authors' own elaboration.

Among field crop farmers, there is great interest in automated steering systems and machinery tracking to monitor speed, location and fuel consumption. Automated steering systems are simple to use and provide immediate and tangible benefits in terms of input savings, yield increases, reduction of driver fatigue, etc. However, the high costs limit its use to larger farm sizes. Manual assisted steering systems are also available at considerably lower cost and slightly reduced accuracy. The latter can be considered entry systems for precision agriculture, as they can be linked to section control, controlled traffic farming and other technologies. While very few tractors in Türkiye comply with the ISOBUS standard, which ensures interoperability with precision farming equipment of various international brands, several domestic farm machinery and equipment manufacturers are offering lower cost automated steering systems that can be retrofitted on existing tractors, including in the lower horsepower range.

The use of variable rate applications (VRA) for fertilization, spraying and seeding is still incipient. Türkiye follows a global pattern, whereby adoption of guided steering systems and recording technologies (remote sensing, sensors) precedes the VRA. The latter are more complex as they require the generation of digital field maps or on-the-go sensors that informs the electronic control units about the application levels in different parts of

the field. Different technologies are available to generate prescription maps, including sensors mounted on combine harvesters creating yield maps, satellite data in connection with soil tests, and nitrogen sensors mounted on tractors. Industry estimates suggest that less than 10 percent of the combine harvesters are equipped with yield measurement sensors. N-sensors have only recently been introduced and are still in the testing phase. As mentioned in Chapter 2, several domestic AgTech companies are collaborating with domestic equipment manufacturers to develop lower-cost solutions for VRAs that can be retrofitted on existing fertilizer spreaders, including used ones. Costs are much lower compared with international, ISOBUS compatible brands. There are also efforts to develop VRA through adjustments in driver speed in response to field conditions that would not require technical modifications on spreaders or sprayers. But reliability of these alternative technologies under field conditions is still to be proven, along with business models for service provision.

Precision livestock farming (PLF) is limited to large dairy producers. According to industry estimates, approximately 1 000 dairy farmers are using PLF technologies to monitor the status and trends regarding health, welfare, and fertility of each individual cow on a real-time basis. Integrated software enables farmers to aggregate, analyse and compare key performance indicators and trends at the level of certain groups of animals (e.g. dry or fresh cows), or for the entire herd. In most cases, these systems are combined with automated milking parlours or robots. PLF can help improve several areas of dairy farm management including fertility, health, welfare, and nutrition resulting in increased productivity and a reduction in input use and of unintended by-products such as manure, emissions, antibiotic effluents. On the aggregate, with improved management, fewer animals are needed to achieve the same production level. In terms of carbon efficiency, high productivity per animal is important to reduce GHG emissions per litre of milk.

The further expansion of PLF technologies in Türkiye will require product innovations to make them accessible and useful for smaller farmers. Overall, there are approximately 2 000 large dairy farms in Türkiye, with more than 100 milking cows accounting for about 20 percent of total milk production entering the formal market. The potential for market growth in this segment is limited. Several PLF providers are therefore developing simpler, lower-cost PLF solutions for select use cases, such as oestrus detection for improved fertility management. These systems can be used by smaller dairy farms of 50 cows and fewer. While such technologies show promise, broader adoption will require awareness creation, training and capacity building efforts for farmers, zoo technicians and veterinarians.

Modern greenhouses have a high level of automation of heating, irrigation, fertilization, fogging, and lighting systems. Türkiye is among the top four countries in the world in terms of greenhouse production area and the second largest in Europe, after Spain. Türkiye's greenhouse production area of 48 300 ha of which 75 percent is owned by small family businesses with a size of 0.3 ha and below. The modern greenhouse area[14] is only 1 400 ha with an average size of 2.7 ha. The government has provided support for greenhouse modernization in the form of grants and loans. As a result, the average greenhouse size has increased from 0.2 ha to 0.4 ha during the last 10 years.

14 Fully automated and using hydroponic production.

Türkiye boasts a large potential for using geothermal energy for heating purposes. While the main centres of greenhouse production are in the Mediterranean around Antalya and Mersin, modern greenhouse investments are also taking place in other (cooler) zones where geothermal resources are available (e.g. Afyonkarahisar, Isparta). Geothermal heating extends the growing period, while the summer season requires less cooling. Currently, 434 ha of greenhouse area is heated with geothermal energy. This potential has attracted several private and corporate investors into the sector. In addition, there are government-led initiatives to promote modern greenhouse cluster development through specialized agricultural aones, often in combination with the use of geothermal energy, using a public–private partnership model.[15] These modern greenhouses tend to be fully automated. In the current situation of rising energy prices, the use of geothermal energy presents a comparative advantage against other major produces using natural gas for heating greenhouses (e.g. Kingdom of the Netherlands). It can also make an important contribution in the transformation of the sector towards a post-carbon economy.

In view of the aforementioned trends, there is growing demand for greenhouse automation. As automation typically carried out in conjunction with investments in new superstructures and irrigation systems, investment costs cannot be separated easily. According to industry sources, the automation cost per square metre is about USD 65 for plastic greenhouses and about USD 90 for the greenhouses. While there are several Turkish suppliers of greenhouse automation solutions, Dutch technologies remain the benchmark and are used by most tech-savvy producers.[16]

There is also a large potential for modernization of small and medium-sized greenhouses. Such modernization includes gradual adoption of technologies such as climate and soil moisture sensors for better irrigation management, irrigation automation, as well as early warning systems for pests and diseases (e.g. in banana production[17]).

15 The public sector is setting up the greenhouse infrastructure including zones for storage and loading, as well as geothermal exploration wells and pipelines. Parcels of various sizes (depending on the scheme, between 0.5 and 7.5 ha) are being offered to private investors under long-term lease arrangements. Private investors need to finance the superstructure including roofing, ventilation and heating system, fertigation, etc.). Average investment cost per hectare is around USD 1 million.

16 Interviews with pioneers in the sector such as Agrobay, which manages 32 ha geothermal greenhouses in Dikili, and Kurt Group, which manages a 12 ha geothermally heated greenhouse in Afyonkarahisar.

17 A number of banana producers around Mersin, which were visited, are investing in such technologies.

3.2.3. Technology use and promotion by the public sector and public–private partnerships

Twelve public institutions were interviewed remotely or on their premises during the field visits including MoAF departments, universities and regional development agencies (Table 6). The institutions were selected based on their existing engagement with the digital technologies. Public sector representatives were selected based on referrals during the field visits and through recommendations during meetings held with MoAF bodies.

Table 6
A selection of public institutions interviewed

Institution	Technology	Use case	Plans
Kemalpaşa Chamber of Agriculture (İzmir) in collaboration with **İzmir Municipality Agricultural Services Department**	Weather stations, insect traps	Frost and hail early warning for cherry growers (main export crop), pest management for orchards	Increase the number of stations to cover microclimate areas, increase digital insect traps, offer other AgTech services e.g. drones, improve İZTAM demonstration farm
MoAF Provincial Directorate (Manisa)	Weather stations, insect traps	Meteorological and disease early warning for grape, olive, cherry, tobacco, sesame, tomato, corn, and melon growers	Explore other digital technologies such as drone imagery and spraying
MoAF Provincial Directorate (Bursa)	Weather stations, insect traps	Meteorological and disease early warning for olive growers in collaboration with Marmarabirlik Cooperative Union	Increase the number of stations to cover micro-climate areas
Dikili Agricultural Organized Industrial Zone (TDİOSB) (İzmir)	Geothermal-powered greenhouses	Geothermal-powered hydroponic greenhouse investment underway	Complete the construction through attracting private investors
İzmir Agricultural Technology Center (ITTM)	Various digital agricultural technologies in practice in demonstration campus	To bring together tech-developers and tech-users in a demonstration lab and farm	Complete the project in TAGEM premises, attract companies, investors and tech-developers to join the campus

SOURCE: Authors' own elaboration.

Digital agricultural technologies are primarily used and promoted by the ***provincial directorates of the Ministry of Agriculture and Forestry, municipalities, chambers of agriculture, chambers of commerce and stock exchanges.*** Public institutions integrate digital technologies in their service provision to farmers and agribusinesses in line with their mandate. Public bodies adopt technologies first with a few units and then expand their portfolio of devices and services. Nevertheless, limited funding remains a major impediment for technology adoption and expansion.

Weather stations with disease early warning modules and insect traps monitoring are the most common digital technologies that public institutions have adopted. While the use of weather stations and disease models is widespread and has a track record of several years, digital insect traps monitoring is more recent. In-house agronomists in public bodies often interpret the data and disseminate information among agribusinesses, farmers, and farmer organizations. To do so, public bodies, such as MoAF provincial directorates in Bursa and Manisa, directly disseminate SMS messages to farmers. In other instances, for example in İzmir, the municipality collaborates with local chambers of agriculture to disseminate the information among local farmers. The study team learned that approximately half of the 81 provincial directorates of MoAF are using automated weather stations and related disease early warning systems to support their early warning and advisory services for specific crops.

BOX 12

USING DIGITAL WEATHER STATIONS IN MOAF PUBLIC EARLY WARNING SYSTEMS

Manisa province is a major producer of table grapes, olives and tomatoes. Since 2016, MoAF's provincial directorate has been progressively incorporating digital field weather stations into its climate and disease early warning and extension system. The directorate currently operates 49 stations covering the total area of 80 000 ha in all districts of Manisa. In total, approximately 60 000 farmers are receiving SMS notifications including 40 000 table grape producers. Agronomists at the provincial and district levels have been trained by the solution provider (Metos) to manage and maintain the stations and analyse the information provided. For some critical diseases such as mildew and grapevine moth, MoAF has centrally approved thresholds triggering early warning messages. For other diseases, the directorate relies on the crop models of Metos. The main objective of the early warning system is to identify diseases at an early stage while avoiding unnecessary pesticide applications by farmers based on routines or pesticide prospectus. In addition to reduced input costs and environmental damage, evidence-based spraying also helps to reduce pesticide residues. Early warnings triggered by the stations are validated by MoAF field staff, which also visits farmers and provides advice on integrated pest management. More recently, the directorate has added 22 digital insect traps to monitor fruit flies.

In ***Bursa,*** a similar early warning and advisory system was established by the provincial directorate in collaboration with Marmarabirlik, a large corporative and market leader in table olives. The cooperative has 35 000 members, producing 72 000 tonnes of olives on 25 000 ha in Bursa, Balikesir and Tekirdag. Fourteen digital weather stations are used to provide early warning messages. While the stations are owned by different institutions (provincial directorates, Marmarabirlik and Bursa municipalities), the system is managed by a small group of experts in the provincial directorate. Agronomists report an accuracy level of 95 percent for these stations. Due to the microclimatic conditions in the mountainous production area, a larger number of stations would be desirable. Anecdotal evidence by MoAF staff suggests a considerable reduction of spraying against the fruit flies and a compliance rate of around 75 percent among farmers receiving the SMS messages. MoAF staff is also introducing digital insect traps. As a next step, Ministry staff plans to transition from SMS messages to an interactive communication channel with farmers. A further benefit of the stations relates to their recording function, which makes it easier to access compensation from the TARSIM insurance fund (e.g. in case of frost damage).

3.2.4. Digital technology use by retailers

Business-to-customer food retail e-commerce

The COVID-19 pandemic boosted e-commerce retail expansion in Türkiye. In 2020, the e-commerce volume increased by 66 percent compared to 2019, food and groceries showing the highest increase (283 percent) among all other product categories (Ministry of Trade, 2021). The share of food and grocery in total e-commerce sales volume reached 8 percent in 2021, up from 6 percent in 2020 and 3 percent in 2019 (ETBİS, 2022). Currently, in modern food retailers' annual turnover, the share of e-commerce ranges from 7 to 15 percent (Çokal, 2022). All modern food marketing channels have contributed to the rapid increase in e-commerce, including modern retail chains (such as Migros and CarrefourSA), discounters (ŞOK and A101), online marketplaces (Hepsiburada and Trendyol), and instant delivery companies (such as Getir and İstegelsin).

All retail formats heavily invested in grocery e-commerce, which is also reflected by the venture capital investments being made in start-ups such as Trendyol (almost USD 1.5 billion) and Getir (almost USD 2 billion). Discounters account for almost 80 percent of modern grocery retail. However, the expansion of the e-commerce channel is led by national retail chains, online marketplaces, and instant delivery companies.[18] In fact, Migros was the first grocery retailer introducing online shopping in 1997.

BOX 13

LEADING THE FOOD E-COMMERCE: THE CASE OF MIGROS

Migros Ticaret Joint Stock Company is a modern retail chain delivering a broad product range to meet the different needs of its customers through its Migros stores (MigrosJet, Migros, MM, MMM, 5M, Migros Wholesale), Macrocentre stores and e-commerce channels (Migros Sanal Market, Migros Hemen, Macroonline and Tazedirekt) in Türkiye's 81 provinces. Migros operates a super app which includes Migros Sanal Market, offering bulk delivery in 45 minutes, and Migros Hemen (smaller assortments delivered in 30 minutes). The interviews with the company reveal that the share of e-commerce in Migros sales stands at 15 percent on average. The company developed an audio simulation technology with BlindLook and launched Türkiye's first online market platform for visually impaired users. Migros also introduced robot-assisted product collection assistant TARO in order to accelerate the preparation of product orders for online operations during the pandemic.

SOURCE: Authors' own elaboration.

18 HepsiExpress and Trendyol Hızlı Market partnered with national and local retail chains to offer food e-commerce and last mile delivery services. Quick commerce companies, such as Getir and İstegelsin, introduced bulk grocery delivery options. Through their apps, GetirÇarşı and Yemeksepeti Mahalle connected local traditional retailers (e.g. grocers and butchers) with end consumers.

In food e-commerce retail, consumers have valued marketplace reliability (52 percent), price (52 percent), quick delivery (39 percent), product range (38 percent), free delivery (34 percent), and safe payment options (30 percent) (Competition Authority, 2021). E-commerce channels and formats have diversified in terms of their delivery models (quick delivery, scheduled bulk delivery, pick-and-collect) and product portfolios[19] (organic, farm gate sales, private label).

BOX 14

A NICHE PLAYER IN PREMIUM FOOD E-COMMERCE: TAZEDIREKT

Tazedirekt was founded by Turkish serial investor Hasan Aslanoba in 2013 in İstanbul as a premium fresh produce e-commerce company. Tazedirekt exclusively sourced organic products or GAP-certified fresh produce, and imposed audits and quality control for food safety. It grew quickly with a monthly growth rate of 30 percent in sales in 2015. Due to operational constraints, the company ceased its operations in 2016 and was acquired by Migros. Today a subsidiary of Migros, Tazedirekt is an online-only retailer, and it offers traceable and organic or GAP-certified fresh produce through its refrigerated delivery fleet in İstanbul, Ankara, Bursa, Kocaeli, and İzmir. The interview revealed difficulties in identifying qualified producers to maintain a resilient and diverse supply chain.

SOURCE: Authors' own elaboration.

Food retailers embraced omnichannel marketing strategies to offer a seamless customer journey across the marketing channels. For instance, a customer can place an online order from a food retailer's app, pick up the prepared order from the selected store or point of collection at a selected time slot. Omnichannel requires a high level of coordination across marketing channels. Using advanced user data analytics, it offers avenues for optimizing supply chain operations, reducing marketing costs, and increasing repeat sales as well as customer loyalty. To scale up omnichannel marketing, food retailers monitor the orders and inventory levels in real time and automate procurement processes when inventories deplete. This requires adapting the existing enterprise resource planning (ERP) systems to omnichannel marketing operations, e.g. integrating a store's inventories with the e-commerce app to make sure that all products marketed in the app can be picked up by the courier from the store. ERP software solutions manage accounting, procurement, project management, risk management and compliance, as well as supply chain operations in multiple marketing channels for food retailers.

19 E-commerce companies, such as TazeDirekt (a sister company of Migros) and local farm gate retailers, such as PortakalBahcem.com, have offered premium, local and/or organic fruits and vegetables.

BOX 15

ASSISTING LOCAL RETAILERS' OMNICHANNEL ADOPTION: THE CASE OF MARKETYO

Marketyo is an omnichannel marketing software and integration service provider which establishes its clients' branded online branch and offers online marketing software solutions such as order tracking, delivery tracking, loyalty and campaign management. Founded in Ankara in 2016, Marketyo lends its platform as a service for local retailers that cannot develop their online marketing channel in-house. Marketyo has digitalized numerous local retail chains in 60+ cities in Türkiye and it was acquired by Yemeksepeti in 2021 (Ulukan, 2021). With this acquisition, Yemeksepeti introduced its Yemeksepeti Mahalle channel which is a marketplace for local food retailers and grocers.

SOURCE: Authors' own elaboration.

As the market saturation is high, there are limited prospects for new entries and the competition is stiff for smaller e-commerce players. The erosion of urban purchasing power including of middle classes during the pandemic and due to high inflation in its aftermath is another factor that tones down the e-commerce growth prospects.

Business-to-business agrifood e-commerce

Business-to-business (B2B) e-commerce solutions facilitate agri-inputs and wholesale food trade. Türkiye's mainstream online marketplaces, such as ***Sahibinden.com*** and agri-focused ***Tarimgaraj.com*** enable online wholesale and retail trade of agri-inputs. The government had previously introduced the ***B2B Digital Agriculture Platform (DITAP)*** to enable food retailers to directly source from producers bypassing wholesale intermediaries. The platform was designed to integrate financial service providers. Upon development, the DITAP was to be handed over to the Union of Chambers and Commodity Exchanges of Türkiye (TOBB). Yet, the progress has slowed down, and the future of the platform is uncertain. The platform is inaccessible as of November 2023.

BOX 16

ONLINE MARKETPLACE FOR AGRI-INPUTS: THE CASE OF IMECEMOBIL BAZAR

ImeceMobil is a joint venture that was founded by Softtech Ventures and İşbank in 2019 in İstanbul. In ImeceMobil Bazar, users can request agri-input quotes from suppliers and decrease their input costs by comparing the offers from approved suppliers. Farmers can pay with credit cards or "buy now pay at harvest" with Imece Card. Suppliers can also request an İşbank online pos terminal through the app to receive payments. Currently, there are more than 175 000 users and 602 verified suppliers on the Bazar platform.

SOURCE: Authors' own elaboration.

There are some specific online agri-trade platforms that bring together wholesale food buyers, food producers (farmers/cooperatives), agri-input suppliers and enable competitive bidding and secure payment transactions. Some are also integrating options to purchase inputs on credit. One such example is ImeceMobil Bazar and another is Tarfin, a start-up that developed an innovative approach enabling it to mobilize funds on the capital market and channel these to farmers through a network of accredited input suppliers at competitive prices

BOX 17

TARFIN

TARFIN is an İstanbul-based fintech start-up founded in 2016 that provides farmers with access to high-quality farm inputs – fertilizers, seeds, chemicals, equipment or feed – with competitive credit terms. Registered as an input dealer, TARFIN has a network of 1 100+ local agri-input retailer agents in 78 provinces of Türkiye. Through these dealers, TARFIN provides inputs to farmers based on promissory notes payable at harvest. Its proprietary algorithm develops a credit score for farmer applicants based on data on farming operations and the applicant's track record with the local vendor. Inputs sales by small shops to farmers on credit is common, often at very high interest rates (up to 5 percent per month). TARFIN's value proposition is to make additional finance available at competitive rates at the lower end of the spectrum but without collateral requirements. It has approximately 53 100 clients so far. TARFIN mobilized some of its funding by bundling the receivables into securities that it sells to a range of banks and financial investors. There have been 17 issuances of asset-backed securities, starting with a volume of TRY 1 million in June 2018. The latest issuance of TRY 100 million was in October 2022. Cumulative volume of issuances is TRY 842 million. In addition, TARFIN has so far issued TRY 140 million in Sukuk to diversify their financial instruments, the latest round in January 2023 in partnership with the Development and Investment Bank of Türkiye and through Ziraat Investment and Securities.

SOURCE: Authors' own elaboration.

In terms of B2B wholesale food trade, modern food retailers in Türkiye use their own vertically integrated supply chains. Sourcing from wholesale food markets remains complementary. Diversification of suppliers remains key for retailers' supply security and to respond to customers' demand for niche products (i.e. organic, traceable products, products with geographical origin labels). Box 18 features Farmer Expert, a start-up offering traceable fruits and vegetables for modern food retailers, processors and hotel, restaurant and café/catering (HoReCa). Overall, there are several smaller B2B platforms in the country but no dominant large actors.

BOX 18

GOING ONLINE IN AGRI-TRADE: THE CASE OF FARMER EXPERT

Farmer Expert is a B2B e-commerce start-up founded in 2018 in Kocaeli. Through Farmer Expert, modern retailers' purchase units can place fruit and vegetable orders based on their product, packaging and delivery specifications. Farmer Expert matches the order with suppliers based on the farmer profiles in the platform. In parallel, the platform regularly assigns an agronomist for a site visit to collect test samples, agronomic and other relevant data based on the specifications of current and potential buyers. The farmers can request harvest, packaging and logistics services through the system. Farmers do not pay for these services and costs are added on top of the selling unit prices. Farmer Expert delivers the product to the modern retailer, issues the invoice and retailers pay through the platform. The company has so far worked with 15 large-scale buyers including modern food retailers such as İstegelsin and Getir, and food processors such as Komagene. The company plans to improve the platform through: (i) tracing all transactions with blockchain, (ii) engaging a commercial bank to handle all payment transactions, and (iii) collaborating with service providers such as Agrovisio to provide platform members with satellite-based crop supply and yield intelligence.

SOURCE: Authors' own elaboration.

Banks are also active users of digital technologies. For example, nine private commercial banks are using the Turkish Agricultural Loan Analysis system (TARDES) run by the Credit Bureau (KKB) to automate loans pre-appraisal. Ziraat Bank and Deniz Bank have developed similar in-house solutions. Banks are also partnering with AgTech providers to offer digitally-enabled services to farmers. For example, in 2016, DenizBank introduced a mobile app (From Deniz to Soil), developed by Doktar (see Chapter 2) which was downloaded by 280 000 farmers. Similarly, İşbank provides digitally enabled services through the Imece app, developed by its IT subsidiary company Softtech Ventures (see Chapter 2).

Chapter 4
Main findings, outlook and recommendations

4.1. CURRENT USES OF DIGITAL TECHNOLOGY

This review has shown that digital technologies can and do play an increasing role in Türkiye's agriculture and related value chains, in response to key challenges including: i) rising food, input, and energy prices; ii) climate change; iii) declining land and water resources; and iv) a worsening environmental footprint of crop and livestock production. Digital technologies can speed up the transition towards more sustainable and resilient production systems, with improved traceability along food value chains. They also enable better management and monitoring at farm, firm and policy levels.

Several promising digital technologies are already being used by farmers, agribusinesses, input suppliers, financial institutions, and public entities in Türkiye. For example, IoT devices such as digital field climate stations, soil moisture sensors, and insect monitoring traps play a growing role in high-value crops like orchards, greenhouse production, and field vegetables, as well as in industrial field crops such as cotton. Remote sensing is used for managing and monitoring field crops, along with GPS-assisted steering systems and pesticide applications by drones. Precision livestock farming is used on approximately half of the large dairy farms (those with more than 100 cows), often combined with robotics in milking, feeding and manure management. Automation is becoming standard in modern greenhouses.

Use cases and benefits of these technologies are manifold. Real-time monitoring of crop and livestock production and critical environmental parameters enables better planning and implementation of agronomic tasks and a more timely and accurate response to water or nutrient stress through decision support systems and automation. For example, digitalized early warning systems for pest and disease risks allow farmers to act before major damage materializes while avoiding the widespread practice of blanket preventive spraying. More adequate pesticide use based on predictive analytics reduces costs for farmers along with environmental pollution and health risks linked to pesticide application (for workers) and residues (for consumers). Precision irrigation technologies help reduce water and energy consumption and related costs whereas guided steering systems reduce fuel consumptions and input use. Real time monitoring of cows facilitates early detection of health- and feeding-related issues along with better herd management, thereby increasing productivity and reducing input use. The integration of data from various sources (sensors and IoT devices, drones and satellites) in combination with growing analytical capabilities creates powerful decision support systems for farmers, agronomists and veterinarians. Use cases of such technologies for upstream and downstream actors and financial institutions include market research, risk management, as well as price and production forecasts.

Despite these promising use cases, the adoption of digital and smart technologies is still limited, especially at farm level. In the absence of reliable survey data, available evidence and interviews with AgTech providers and other stakeholders indicate very low adoption levels. The aforementioned technologies are mainly used by tech-savvy large farmers with high education levels and good access to information and finance. However, a growing number of small and medium-sized farmers are benefiting indirectly from digital technologies through services provided by local public entities or agribusiness companies, either via mobile phones or field staff.[20] Examples for such multi-farm uses of digital technologies include improved early warning systems for pests, diseases and extreme weather events, and enhanced advisory services relying on data and analytics from remote sensing and IoT devices such as field climate stations and insect traps. While relatively few farmers use smartphone apps from input and machinery suppliers, many use the internet and social media for accessing information on prices, weather and e-government services.

20 Local public entities include provincial directorates of MoAF, municipalities and local chambers of agriculture whereas private entities include cooperatives, farmer associations and private agribusinesses.

Most private agribusiness companies have started digitalizing their field operations, as well as their sourcing, quality management and traceability systems. The main motivations for digital technology adoption include improving production (either on their own fields or by contracted farmers); managing contact farming operations and related accounts; managing and monitoring input use; improving product quality and traceability; and implementing corporate ESG targets, e.g. regenerative farming and related progress monitoring. Most companies are still at early stages of digitalization and integration of specific applications into the ERP systems. Typical entry points are cost-effective solutions utilizing satellite data and climate stations. Various solutions from different providers are tested on a small scale to understand their suitability and cost-benefit ratio. Agribusinesses thereby play an important role as technology brokers by validating and eventually adopting viable technologies for farmers. Once successful technologies have been identified, their use is scaled up. The integration of IoT and handheld devices for data entry into ERP systems helps companies to better manage and monitor the use of inputs and labour in relation to yields and product quality.

Most agribusiness companies met (including some food retailers) are interested in improving their traceability systems. However, traceability is still mainly based on manual data entry and insufficiently covers farm level operations. Despite broad interest in blockchain technology, no blockchain-based traceability system has yet been put in place in the agrifood sector. The integration of IoT and handheld devices into the ERP system enhances product traceability and provides the basis for the adoption of blockchain technology.

The last five years saw a strong growth of grocery e-commerce, especially B2C last mile food delivery from retailers to consumers, fueled by the pandemic. In addition, several start-ups emerged linking producers of higher quality products to urban niche markets, but their growth is constrained by spiraling food prices and an overall challenging economic situation. While there has also been some progress regarding B2B platforms and agrifintech solutions, most of these are still in an early stage and no major platform has emerged yet. Government plans to create such a platform through DITAP were stalled.

Several banks are using credit scoring and automated loan appraisal systems as decision support tools. While Ziraat Bank and Deniz Bank have developed their own systems, six private banks are using the Turkish Agricultural Loan Evaluation System (TARDES) managed by the KKB and developed with technical support from EBRD about 10 years ago. However, neither TARDES nor any of the banks are currently using satellite data for climate risk scoring, market research or monitoring of agricultural borrowers.

The MoAF has digitized many of its operations and offers various e-government services. Plans for a nationwide digitized information system (TARBIL) faced challenges but many provincial and district branches utilize digital technologies for early warning systems and farmer advisory services. Although MoAF manages numerous databases, interoperability is limited, hindering data sharing with technology developers. MoAF aims to enhance database quality and interoperability to improve planning, monitoring, implementation, and farmer support.

Overall, the enabling environment for rural digital transformation is sufficiently developed in Türkiye. The country boasts a strong and growing ICT sector especially in the area of software development. In international indices reviewing digital transformation capabilities, Türkiye ranks relatively high among upper middle-income countries but less so in comparison with European Union countries. In terms of mobile connectivity, physical infrastructure and satellite coverage, Türkiye is on par with regional averages. While rural areas are lagging behind, smartphone use is still high and the percentage of farmers with satisfactory internet access provides a solid basis for widespread access to digital technologies.

Türkiye's start-up support ecosystem has been expanding in the last decade with a multitude of public and private incubator and accelerator programmes, technoparks, and innovation platforms. However, very few of these programmes are agrispecific. There has also been a strong growth in venture capital investments in recent years, especially since 2019, both in number and volume of deals. There is also a range of support programmes for established companies to develop new technologies by TÜBİTAK, KOSGEB, and TAGEM, as well as some private organizations.

There has been a growing number of technology providers in Türkiye during the past five years, mainly start-ups. However, very few have managed to grow their customer base and attract external funding from angel investors or venture capital. Some domestic IT companies have also ventured into AgTech. While these companies are in a better position to enter the market by relying on existing cash flows, technologies and networks, most of them also faced challenges in expanding their customer base.

Overall, most AgTechs are struggling to find business models that are quickly scalable and profitable. For this reason, few of them have been able to attract private venture capital. Despite the huge increase in venture capital into Türkiye since 2019, AgTech is among the least invested categories. The main recipients of VC investments were e-commerce, gaming and fintech.

There is limited entry of international AgTech companies in Türkiye, especially with direct in-country presence. Most companies operate through local distributors offering a range of other products as well, with limited specialization in AgTech. Some international providers of irrigation equipment and inputs present in Türkiye have recently introduced their digital product offerings such as smart irrigation and field scouting technologies. However, product uptake has been slow so far.

Corporates in agribusiness and finance serve as clients, providers and developers of AgTech solutions. Major input providers, machinery manufacturers, and banks offer smartphone apps developed by AgTechs to farmers, delivering various services like crop monitoring, fertilizer recommendations, and plant disease analysis. These apps complement conventional product sales, boost customer loyalty, and gather data. Some banks and input providers introduce field climate stations, digital insect traps, and drone services to larger clients. There is a growing recognition among input companies that future market success hinges on offering value-added services to aid farmers in transitioning to smarter input use, reducing environmental impacts, and addressing pesticide residue concerns in response to consumer demand and export regulations.

4.2. CHALLENGES FOR EXPANDING THE USE OF DIGITAL TECHNOLOGIES

A number of factors act as constraints for the faster growth and adoption of digital technologies in agriculture, especially at farm level, affecting both demand and supply. These factors can be grouped into four categories:

1. scale-related constraints;
2. limited awareness, knowledge and skills;
3. heterogeneous quality of digital solutions;
4. cost of technologies.

Scale-related constraints

Türkiye's farm size structure is an important challenge for broad uptake of digital technologies at farm level. Despite substantial numbers of medium and large farms, the great majority of crop and livestock farms in Türkiye are small. Adoption levels need to be contextualized in terms of the overall size of the sector, with 2.2 million registered farmers (compared to 262 000 in Germany, 390 000 in France, and 915 000 in Spain) spread over a vast and diverse geography.

Many smallholdings lack profitability for investing in digital technologies and the value proposition of some of these technologies on small farms is not clear. For instance, satellite-based monitoring may not be necessary for small plots that can be easily inspected visually. Technologies like field scouting are more valuable for farmers with larger, scattered fields, where frequent visual monitoring by farmers becomes challenging. Variable rate applications are more beneficial for larger fields due to soil heterogeneity, making them less relevant for small farmers. Although shared IoT devices and analytics could benefit small farms, investment costs and licence fees require minimum operational sizes to be economically viable.

There are also technical path dependencies for certain digital technologies, which have to be hooked onto specific hardware. For example, soil moisture sensors or irrigation automation require sprinkler or drip irrigation systems where farmers have full control on the time and amount of water applied in different sections of a field or plantation. Most VRAs for field operations currently on the market require tractors with ISOBUS systems, which are expensive and rare in Türkiye. The use of blockchain technology for traceability purposes requires a high level of automated data capturing and entry through IoT devices, which cannot be altered, or significant third-party validation.

Limited awareness, knowledge and skills

Overall, there is limited awareness of available digital technology options and their benefits, not just among farmers but also among extension agents and other agricultural professionals. The rapidly evolving digital landscape poses challenges in keeping up with new technologies, suppliers and use cases. Even large farms and agribusiness companies lack comprehensive knowledge due to limited presence of international providers and insufficient field support. Conversely, limited demand hampers providers' field presence. Most AgTech providers are based in large cities, with product information accessible mainly online, further hindering accessibility for users in rural areas.

A further constraint is related to education and technical/digital literacy levels. Most digital technologies require specific skills to install, calibrate and operate software and equipment, analyse and interpret data generated by IoT devices or remote sensing images, and convert these into actions. While technology providers deliver some training and technical support during and after installation, the level of such support is heterogeneous and not always sufficient.

The willingness and ability to adopt new technologies tends to be correlated with age. The average age of Turkish farmers is above 55, with low technical literacy levels. The age profile of extension staff of private agribusiness companies is often in a similar range and some AgTech providers reported some reluctance to adopt new technologies and difficulties in understanding their use and how to best integrate them into the current operations.

Last, there are cultural factors shaping technology adoption, with some parts of the country being more open than others to technical innovations. Rural areas with denser linkages with other value chain actors such as food processors, modern retailers, and exporters are more receptive to technical innovations than other areas with limited downstream linkages in the value chain.

The combination of the aforementioned factors illustrates the risk of a digital divide in rural areas, along with a strong gender gap in technology adoption. The vast majority of AgTech providers and users are men. The gender divide has also been revealed by the 2020 MoAF survey: only 7 percent of the farmers using digital technologies were women.

Heterogeneous quality of digital solutions in the market

There are often gaps between the promise of technology providers and field realities. User feedback suggests that technologies do not always live up to their promises. Several reasons contribute to this gap.

- Technology providers have limited opportunities to field-test, calibrate and validate their technologies, which is particularly challenging due to the diversity of agroecological and farming conditions in the country.
- Many technology start-ups and IT solution providers lack agronomic expertise, which leads to underestimation of agriculture's complexities and farmers' realities. AgTech providers employing agronomists for sales and support are valued for their ability to troubleshoot specific agronomic issues. Complaints about complex user interfaces and language barriers further highlight this issue.
- There is a lack of quality assurance mechanisms for new technologies in agriculture, leading to risk and uncertainty for users. This burden may deter farmers, especially in challenging economic conditions, and poses challenges for agribusiness companies with limited resources. Concerns have been raised about new entrants launching immature products at lower costs, risking the loss of market development and consumer trust.

Cost of technologies

Some digital technologies, especially imported ones, can be costly due to investment and licence fees, which are compounded by limited market volumes. Additionally, the newness of these technologies and unclear benefits often result in limited willingness to pay, unless proven benefits are evident. Adoption is primarily driven by successful experiences from neighboring farmers. However, as technologies become more widespread and costs decrease, demand and willingness to pay are likely to increase. Economic constraints further limit investment in technologies, even among larger farmers who may appreciate their benefits. Moreover, the recent inclusion of digital technologies in the Rural Development Investment Support Programme (KKYDP) and preferential loans from Ziraat Bank has not yet been widely communicated.

4.3. OPPORTUNITIES FOR EXPANDING DIGITAL TECHNOLOGIES

Despite challenges, there is substantial potential to expand digital technology use in agriculture, especially as economic conditions stabilize. Climate change, input costs, environmental concerns, and consumer demand for quality and safety will continue driving technology adoption. Digital tools can help Türkiye meet its green targets under the Green Deal Action Plan and Paris Agreement. With a large pool of agribusiness companies and medium to large-scale producers, Türkiye can attract technology suppliers and develop local distribution and service capabilities. The country has the capacity to adapt technologies locally, generating cost-effective domestic solutions.

Among the technologies reviewed, IoT devices and remote sensing applications show the greatest potential for expansion in the short to medium term. Both technologies have a broad range of use cases both in the public and private sector and will rapidly benefit from increases in AI and data analytics. Likewise, an increased number of IoT devices and remotely sensed data will enhance the availability and granularity of real-time data feeding into big data analytics.

IoT devices have clear and proven use cases in supporting climate change adaptation, reducing input use, and improving management, monitoring and traceability at farm level and along value chains. The number of suppliers has been increasing and new distribution channels and partnerships are being established. While digital field climate stations are already widely used, digital soil sensors and insect traps monitoring are in increasing demand and can be integrated into early warning and decision support systems for single and multi-farm use at regional and national level. Beyond production, IoT devices are increasingly used in downstream operations, e.g. to monitor storage conditions and cold chains or to enhance energy efficiency along processing lines. As such, they strengthen the foundations for efficient and credible quality monitoring and traceability systems.

Satellite data is currently underutilized vis-à-vis its potential. With higher resolutions becoming available at lower costs, the range of use cases and quality of services will increase. Agribusiness companies can use remote sensing to monitor large catchment areas at low costs and prioritize areas to be visited by extension staff. Other use cases include managing irrigation and farm input use, monitoring farming practices such as crop rotation and conducting market research and agricultural intelligence. In the financial and insurance sector, satellite data can be used for climate risk scoring, crop monitoring and loss assessment. There are also additional use cases in the public sector, including subsidy compliance monitoring, yield and harvest estimation, and support to public extension workers, among others.

The market potential for drone-based analytics seems more limited given its high costs, limited area coverage and regulatory constraints. Beyond individual large farms and agribusinesses, there may be scope for drone use by public entities and by farmer organizations if farmers are clustered in specific geographic areas and costs can be shared. Drone spraying may have greater potential, especially for certain crops where tractors cannot enter easily, and in response to large-scale pest outbreaks. Progress with precision spraying applications may make drone spraying more attractive for a larger range of crops, including orchards.

The scope for precision agricultural technologies is also more limited due to high investment costs, scale requirements and, in the case of VRAs, technical complexity. Manually aided steering systems may have the largest potential for scaling, given their much lower investment costs compared to automated steering systems. The latter require larger operating areas to become profitable but may be used by machinery service providers and through machinery sharing arrangements. VRAs are costly and complex and their cost-benefit ratio is site-specific. Nevertheless, rising input costs may spur adoption through service provider models, especially in combination with combine harvesters that are equipped with yield sensors to create yield maps. In addition, several low-cost technologies are being piloted by AgTech providers based on retrofitting variable rate technologies on existing locally produced equipment, or in combination with driver assistance systems regulating tractor speed. Progress will depend on partnerships between AgTechs and local machinery and equipment suppliers with strong rural distribution networks and technical capacities to act a service provider, or through franchising.

The potential for precision livestock farming is mainly confined to medium and large dairy farms. While most PLF technologies currently in use are linked to milking robots, an increasing number of suppliers has introduced stand-alone cow monitoring systems, including low-cost solutions for specific use cases such as fertility and health management. Such systems can also be used by veterinarians for remote monitoring and advice. Improvements in AI to enhance precision levels and further automate advice to farmers will enhance demand, including from smaller farmers.

Automation is primarily seen in modern greenhouse production, particularly in areas utilizing geothermal and solar energy. Government initiatives promote geothermal greenhouse investments, attracting private sector involvement. There's potential for export growth to the European Union due to rising energy costs. Automation demand is also increasing in broiler production and large dairy farms to address labour scarcity. Similarly, irrigation automation is expanding in orchards, particularly in remote areas. However, overall demand is constrained by high investment costs and limited profitable opportunities for large-scale operators.

4.4. RECOMMENDATIONS FOR FASTER AND MORE INCLUSIVE DIGITIZATION

There are several ways for public and private stakeholders to enhance the pace, inclusiveness and impact of digital transformation of Türkiye's agriculture. A proactive approach is required to address the barriers to adoption and reduce the digital divide, including the gender-digital divide. Key public stakeholders include the MoAF with its many subsidiary institutions; TÜBİTAK and other public entities supporting research and technology development; public universities, and other research centres. Private stakeholders range from AgTech providers to corporates in agribusiness and finance, farmers and their organizations (e.g. cooperatives, associations and chambers), private foundations and universities.

The recommendations below are categorized as being led by public and private actors, although most recommendations require collaborative efforts from both public, private and non-governmental organizations to ensure inclusive and sustainable implementation. The main actors are listed under each recommendation.

Public-sector-led interventions

1 ***Strengthening domestic AgTech providers' ability to develop robust solutions meeting the needs of farmers,*** through:

a) ***Tailored support schemes for AgTech start-ups*** addressing the specific needs and challenges of agriculture beyond current sector-agnostic incubator and accelerator programmes. Smart agricultural technologies require extensive field validation and ground truthing, e.g. to train algorithms over several seasons to achieve high accuracy under a variety of local conditions. Co-development of new products and technologies with farmers and other users (e.g. local extension agents) should be encouraged. Schemes may include cost-sharing with AgTechs on a declining basis and may be extended over several seasons subject to agreed performance milestones and incorporation of user feedback. Specific programmes for women-led AgTech start-ups should also be developed.

Key actors include TÜBİTAK, MoAF, universities and Technoparks, as well as accelerator schemes sponsored by the private sector.

b) ***Blended finance instruments in the form of patient capital*** responding to the slower pace of product development and commercialization of smart agricultural technologies. Concessionary public funds could be blended with commercial angel and VC investors to allow smaller ticket sizes and longer divestment horizons, balancing differences in risk appetite and return expectations. Development and impact finance could be mobilized for AgTechs offering solutions that: i) target specific needs of smaller farms, women and MSMEs in agrifood chains; ii) can make important contributions to greening, climate change mitigation and adaptation. Such a programme could build on TÜBİTAK's Tech-InvesTR programme. It may be combined with sensitization of VC and angel investors to better understand the opportunities offered by specific smart farming technologies, along with the risks, returns and investment cycles in agriculture.

Key actors include TÜBİTAK, MoAF, impact investors, private angel and VC investors, as well as development finance institutions and impact investors.

2 ***Improving data governance frameworks and developing protocols and networks for data sharing and improved interoperability.***

a) ***In the public sector,*** interoperability of MoAF databases should be improved to reduce data silos and optimize the use of data for planning, policy monitoring and services to farmers.

b) ***Among private AgTech suppliers,*** an open interoperability network with common standards should be developed for agricultural applications, including smart agricultural machinery, sensor systems and data analysis tools and to build up a sustainable ecosystem for innovative data-driven agriculture (e.g. the European Union's ATLAS project).

c) ***In the public–private continuum,*** the broadest possible agricultural data repositories, integrating both public and private data, could provide a new boost to research and innovation for smart agricultural solutions. To this end, regulators should promote an open data approach and define standards for data quality, data ownership, data sharing, privacy protection, and fair sharing of benefits and revenues generated by big data among farmers, private technology providers, and the public sector.

Key actors include MoAF, the Digital Transformation Office, private AgTech developers, universities, and technoparks

3 ***Strengthening farmers' and other agricultural value chain actors' trust in digital solutions, through:***

a) ***Improved testing and quality assurance of smart technologies,*** by: i) developing robust testing protocols for various types of technologies (including sensors, decision support systems, etc.), in line with international best practices; and ii) accreditation of a broader range of qualified public and private institutions across Türkiye to carry out testing and certification.

b) ***Establishing a grievance mechanism*** allowing farmers and other users of digital technologies to report underperforming digital solutions in a drive towards increased consumer protection.

Key actors include the Agricultural Machinery and Equipment Test Center Directorate (TAMTEST) under the MoAF, specialized agricultural research centres under MoAF, universities (public and private), the Ministry of Trade.

c) ***Conduct independent research on use cases, costs and benefits of different technologies.*** This research should include cost-benefit analyses for different technologies in various settings to better understand their returns to investments and the underlying conditions for these returns. It should help to better understand the conditions for and barriers to adoption according to farm size characteristics, age, education level and gender. In addition to better informing the development of products, business and distribution models of smart agricultural technologies, research results would improve the design of public policies to support the digitalization of the sector.

Key actors include public and private universities and research centres (including those of agribusiness corporates), in collaboration with MoAF's research department (TAGEM).

d) ***Develop knowledge sharing platforms*** where farmers and other users can share their experiences with different technologies and providers, in addition to the results of independent research.

Key actors include MoAF, apex organizations of farmers, other VC actors, and NGOs.

Strengthening the ability of farmers and other agricultural value chain stakeholders including key staff of public entities to use and promote digital technologies, through:

4 a) ***Broad awareness creation and capacity development efforts at all levels including:***

i) ***Formal training and e-learning modules*** on the main types of digital technologies; key trends and use cases in agriculture and related value chains; costs and benefits; investment and knowledge requirements; main providers; and key lessons learned regarding potential challenges and pitfalls. Formats and content should be adapted to various target groups including public and private agronomists, livestock technicians, farmers, IT staff of agribusiness companies, cooperative leaders, ministry staff, etc.

ii) ***Technology demonstrations*** through technology fairs and field days, that allow direct communication between technology providers and potential users such as farmers and agriculture professionals in farmer organizations, agribusiness companies, and the public sector.

iii) ***Horizontal knowledge exchange*** – through virtual, in-person presentations and hybrid formats among current and potential users (farmers, agribusiness companies), within Türkiye as well as within neighboring countries.

Key actors: MoAF, chambers of agriculture, universities, industry associations, cooperatives, agribusiness companies with contract farmers, agriscience companies.

b) **Financial support for the adoption of energy-efficient and climate-smart digital technologies through matching grants and concessionary loans,** focusing on:

i) ***Sharing risks of early adopters of new technologies*** that are insufficiently proven under field conditions and have clear environmental or climate co-benefits (e.g. variable rate fertilizer and pesticide applications).

ii) ***Supporting multifarm use of technologies with proven environmental co-benefits by*** qualified rural organizations and service providers, such as cooperatives and farmer organizations, but also by agribusiness companies working with contracted farmers and specialized local service providers.

iii) ***Complementary technical assistance and advisory services,*** possibly on a cost-sharing basis, to help farmer organizations and agribusiness select the most adequate digital solution, support its integration in operational and business processes, and train relevant staff.

Key actors: MoAF, chambers of agriculture, municipalities, regional development agencies, industry associations, cooperatives, agribusiness companies with contract farmers, agriscience companies.

Overall, the above measures would support market development by strengthening demand and making it more viable for AgTech providers to invest in local distribution and support networks.

Private sector-led interventions

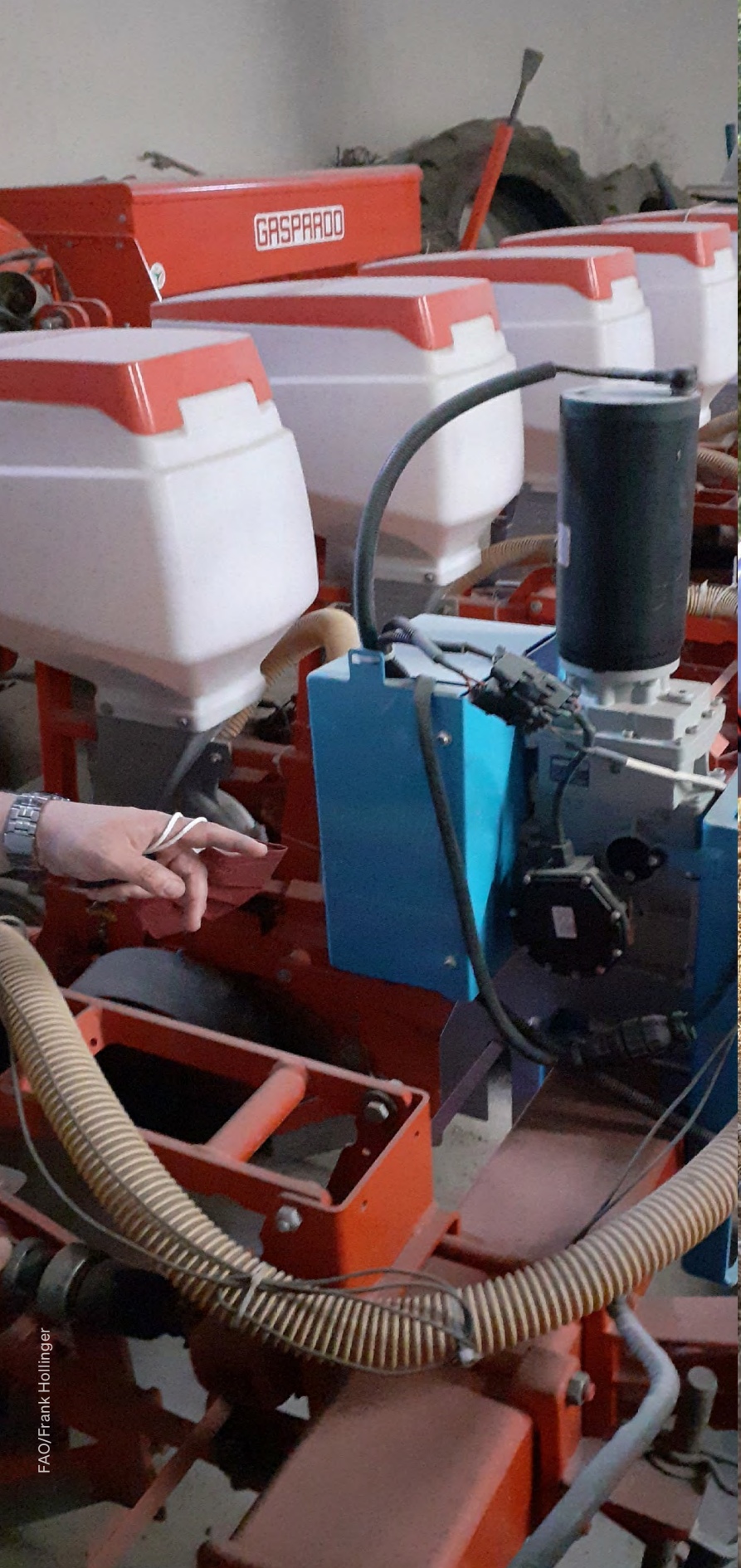
1 **Apply client-centric approaches for designing new digital products, services and delivery mechanism.** AgTech providers should devote more time to co-create new product ideas and co-design new solutions with the intended users, especially end-users, such as farmers, farmer organizations, agribusiness and local extension staff. This would help ensure that services better respond to the needs of users and that user interfaces are easy to understand and navigate. Decision support systems should be automated as much as possible to facilitate the interpretation of data and related decision-making by farmers and local technical staff.
Key actors: AgTech providers, in collaboration with farmers, chambers of agriculture, cooperatives, agribusiness companies with contract farmers.

2 **Ensure sufficient initial training and after-sales support services for users.** Relying fully on marketing via websites and remote technical support via hotlines or bots is insufficient, especially if main users are farmers. Most successful AgTech providers have invested in local support networks and local staff with agronomic or livestock background as "human touch points" interfacing with clients and conducting technology demonstrations, initial user training, and technical backstopping and support. This should be complemented by well-staffed hotlines with agronomists that have good practical understanding of agriculture and speak the language of farmers.
Key actors: AgTech Providers, in collaboration with lead farmers, agribusiness companies with contracted farmers, cooperative and farmer associations, local public extension agents.

3 **Invest in innovative partnerships and business models for service delivery to enhance rural outreach at scale. Partnerships with farmer organizations and** private firms operating in the rural space enable AgTech providers to expand their local presence at lower costs and rationalize investments in training, technical backstopping and support services. Joint ownership and service provider models can make technologies such as precision agriculture, drone services and decision support systems available to larger number of farms, including smaller farmers that would be unable to purchase and use such technologies directly. Examples include:

- Farmer organizations (cooperatives, associations) and local chambers of agriculture can not only serve as partners for co-developing, testing and improving products and services, but also as local service providers and as distribution partners.
- Established machinery and equipment suppliers with their local sales and after-sales service networks could become sales agents for start-ups.
- Local dealers and distributors of machinery and equipment and other farm inputs might also become service providers for precision agriculture and drone services, digital soil testing, etc.
- Uber-type systems for sharing of smart technologies such as drones or smart mechanization services could facilitate market development.

Key actors: AgTech providers, in collaboration with farmer organizations, chambers of agriculture, suppliers of farm machinery, equipment and other farm inputs, providers of mechanization services (e.g. combine harvesters).



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Annex I

Annex 1. Digital registries, databases and other systems of MoAF

Directorate	System
General Directorate of Agrarian Reform	• Integrated Administration and Control System • Farm Accounting Data Network (ÇMVA) • Agricultural Land Assessment, Permitting, and Plains Conservation Management Portal (TAD PORTAL) • Farmer Registration System (ÇKS)
General Directorate of Plant Production	• Seed Data Management System (TVYS) • Pasture Information System (MERBİS) • Organic Agriculture Information System (OTBİS)
General Directorate of Livestock Production	• Support Angora Goat Breeding and Angora Production (TKS) • Breeding Imported Animal Information System (DİHBİS) • Ministry Milk Registration System (BSKS) • Market Monitoring Tracking System • Red Meat Recoding System (KES) • E-Breeding System • Sheep and Goat Information System • Mobile Seeding System • Buffalo Breeding System (MIS) • Sheep and Goat Stud Book and Pre-stud Book Information System (SOYBİS) • Heifer Purchase Support • Herd Manager (Shepherd) Employment Support • Silkworm Registration System • Beekeeping Registration System
General Directorate of Food Control	• Veterinary Information System • Animal Registration System (TÜRKVET) • Poultry Information System • E-Prescription (electronic veterinary prescriptions) • Medicine Tracking System (ITS) • Vaccine Tracking System (ATS)
General Directorate of Fisheries	• Fisheries Geographical Information System (SUBİS) • Fishing Vessel Monitoring System (BAGİS) • Fisheries Geographical Information System (SubiSCBS)
Education and Publication Department	• Agricultural Publication and Consultancy Information System (TYDBİS) • Digital Agriculture Library • Agriculture Forestry Academy • Education and Extension Information System (EYBS)
General Directorate of Water Management	• National Water Information System
General Directorate of Combating Desertification and Erosion	• Monitoring and Assessment of Water Erosion
General Directorate of Strategy Development	• Statistics Information System • Digital Agricultural Bazaar (DİTAP)
General Directorate of Meteorology	• Agricultural Weather Forecast

SOURCE: Authors' own elaboration.

Annex II
AgTech and Foodtech start-ups receiving venture capital investment in 2020-2022 (KPMG, 2022)

Start-up	Business	Year	Investment (USD)	Investor(s)
AGTECH				
SeraCell	Smart greenhouses	2022	102 300	Fonbulucu.com
Cowealthy	Precision livestock farming	2021	400 000	Bilişim Vadisi GSYF
Ne Ekersen	Service sharing platform for combine harvesters	2021	55 000	Vestel Ventures
Hextech Green	Organic fertilizers	2021	100 000	Keiretsu Forum
Agrovisio	Sattelite-based agri digital technologies	2021	250 000 35 700	Start-up Wise Guys, Keiretsu Forum, Galata Business Angels (GBA), Egiad Melekleri Start-up Wise Guys
ForFarming	Vertical farming	2021	450 000	Korun Teknoloji, Bilişim Vadisi GSYF, TechOne, Yalın Karadoğan, Kerim Kotan (private investors)
Farmer Expert	B2B e-commerce	2022	1 000 000	Re-Pie
AGRIFINANCE				
Agrio	Agrifintech	2021	1 000 000	Innovate21st
Tarfin	Agrifintech	2021	8 000 000	Collective Spark (Fund II), Elevator Ventures, Syngenta Ventures, Wamda Capital, Quona Capital
FOODTECH				
Plant Factory	Vertical farming	2021	2 328 000	Swiftcom Gıda, Kerem Erçin, Mahmut Adnan Kefeli, Bahar Yıldız Kutman (Private Investors)
Fazla Gida	Food waste	2021	2 775 796	212, MAP, Atlantic Labs, 500 İstanbul
Nanomik Biotechnology	Nano packaging	2020	265 000 118 000	TR Angels Rockstart Accelerator Fund
Biftek.co	Lab meat	2021	725 000	Sankonline, TR Angels, Cult Food Science, Hüseyin Karayağız (Private Investors)
Reneva	Collagen drinks	2020	50 000	Sadık Ventures, Girişim Türk, Keiretsu Forum
Arkim	Food chemistry	2021	75 000	Hatcher+
Pacha	Natural protein and collagen products	2021	118 561	Levent Cem Eğritağ, Tahir Murat Tortopoğlu, Işılay İlgin Ceylanlı, Bedia Gökçe Erden, Undisclosed Investor, Umur Özal (private investors)
SBS Bilimsel Bio	Bee products	2021	Undisclosed	Ak PE Fund II
SAF Nutrition	Plant-based protein	2021	350 000	Private investors

SOURCE: Authors' own elaboration.

Annex III
Recent venture capital transactions in the agrifood sector and major investor profiles

Investor	Location	Founded	AgTech investment portfolio
Venture Capital			
Tarvenn Ventures	İstanbul	2017	Tarvenn Ventures is an İstanbul -based international investment and advisory firm investing in seed and early-stage start-ups. Its subsidiary TechOne Venture Capital (TechOne Fund I amounting to USD 29 million) and İstanbul Portföy previously invested in ForFarming (USD 422 000).
Letven Capital	İstanbul	2019	Letven Capital is a portfolio management company operating TARS, an agriculture and food technologies venture capital fund which invested in HST Tarım.
Collective Spark	İstanbul	2013	Collective Spark is a venture capital fund (USD 35 million) focusing on early-stage high-impact tech start-ups including Tarfin (USD 8 million with other financiers), under the fintech category.
Idacapital	İstanbul	2013	Idacapital is an investment management firm. Idacapital Innovation Fund is an SME Impact Fund investing across technology-enabled businesses in inter alia finance and agriculture. Idacapital invested in AgrioFinans in 2021 (USD 1 000 000).
Sankonline	İstanbul	2014	Part of the Sanko Holding, Sankonline is a venture capital company that invests in start-ups including in AgTech such as Biftek.co in 2021 (USD 725 000).
Re-Pie Asset Management	İstanbul	2014	RE-PIE is Türkiye's first alternative asset management company operating a venture capital fund (USD 70 million) and various private equity investment funds. Re-pie invested in Skysens (USD 500 000), HST Tarım (USD 700 000 together with Letven Capital), and Farmer Expert (USD 1 million).
Angel investors			
Kültepe Investment	Kayseri	2019	Kültepe Investment is an angel investment network supporting early-stage start-ups including in urban farming (e.g. Vahaa).
EGIAD Angels	İzmir	2015	Aegean Young Businesspeople Association (EGIAD) Angels is an angel investment network supporting early-stage start-ups including in food and AgTech value chains, e.g. ForFarming (undisclosed share as part of total USD 422 000 investment), Nebyan Doğal, and Fazla Gıda (USD 370 000).
Galata Business Angels	İstanbul	2011	Galata Business Angels is an angel investment network that has invested in inter alia AgTech start-ups such as Agrovisio (EUR 2 million) and Fazla Gıda.
Trangels	İstanbul	2015	Trangels is an angel investment network that has invested in inter alia AgTech start-ups such as Biftek, Türkiye's first lab-grown meat (USD 12.5 million).
BUMED Business Angels (BUBA) Ventures	İstanbul	2019	TreeT Agricultural Technologies Inc. is a subsidiary of BUBA Ventures focusing on AgTech investments, R&D and agricultural production with a demonstration field (20 ha) in Manisa. TreeT collaborates with Doktar, Boğaziçi University, Akdeniz University Technology Transfer Office, Sabancı University, and Intellectual Ventures.
Keiretsu Forum Türkiye	İstanbul	2012	Keiretsu Forum Türkiye is an angel investment network, that is part of the Keiretsu Forum global investment community. The Forum has invested in food value chain start-ups such as Pazardan (USD 210 000), For Farming, and Agrovisio.

Note: The list is non-exhaustive, and the cited investors have investments in other sectors in their portfolio. The cited VC companies invest in AgTech start-ups as per their respective investment strategies. Angel investors often follow a more flexible approach in terms of their investment focus.

SOURCE: Authors' own elaboration.

Annex IV
Start-ups in smart farming and supply chain management & traceability

Start-up	Lead Technology/Service	Established	Location	Stage
Actimoo*	**Precision livestock farming**	**2020**	**Ankara**	**Seed**
Afara	Robotics (cotton)	2015	İstanbul	Pre-seed/idea
Alpha Farm	Smart mushroom production	2020	İstanbul	Pre-seed/idea
AgCurate	Satellite imagery	2020	Ankara	Seed
AGRIO	Agrifintech	2020	İstanbul	Seed
Agrisens	Tractor performance tracking	2017	Adana	Pre-seed/idea
Agrotics	Satellite imagery	2019	Delaware	Pre-seed/idea
Agrovisio	GIS / market intelligence	2017	Ankara	Seed/early VC
Air Agro	Drone services	2019	Aydın	Pre-seed/idea
Baibars	Drone imagery and spraying	2015	Mersin	Seed
BenimSürüm*	**Precision livestock farming**	**2016**	**Ankara**	**Seed**
Bitkim	Crop health monitoring	2020	Ankara	Pre-seed/idea
Covisart	Machinery remote control	2015	Manisa	Pre-seed/idea
Depar	Drone imagery and spraying	2021	Hatay	Seed
DepoDone	Supply chain management	2021	İzmir	Seed
Doktar	GIS, IoT, call centre	2012	İzmir	Early VC stage
EN/IO	Greenhouse technologies	2018	İzmir	Pre-seed/idea
Esular	Irrigation automation	2019	Ankara	Pre-seed/idea
Farmingo	Autonomous/remote control	2020	Manisa	Pre-seed/idea
Farmlabs*	**Variable rate application, GIS**	**2021**	**Ankara**	**Pre-seed/idea**
Farmer-Expert	Traceability and B2B sourcing	2017	İstanbul	Seed
Görsentam	Field weather stations	2020	Bursa	Seed
Hummingdrone	Drone imagery services	2019	İstanbul	Seed
İmeceMobil*	**Smart farming platform**	**2019**	**İstanbul**	**Seed/early VC**
Maxwell Innov.	Drone imagery services	2014	İstanbul	Seed
Moveon AI	Tractor automation	2019	İstanbul	Pre-seed/idea
Provea	Drone and VTOL imagery	2012	Ankara	Pre-seed/idea
Seracel	Smart Greenhouses	2020	Muğla	Pre-seed/idea
Smart Soil**	**Field sensors and other IoT**	**2020**	**İstanbul**	**Seed**
Suyabakan	Soil moisture sensors	2016	Ankara	Pre-seed/idea
TARFIN	Agrifintech	2016	İstanbul	Late VC stage
Tarla I.O.	Data feed, satellite imagery	2014	Ankara	Seed/early VC
TARSENS	Yield estimation orchards (AI)	2015	Balıkesir	Pre-seed/idea
TeknoKurgu	Variable rate application	2017	Kocaeli	Seed
Tubu Arge	Traceability and blockchain	2015	İstanbul	Seed
WiCow	Precision livestock farming	2018	İstanbul	Seed

*Subsidiaries of existing IT companies. ** Specialized distributor of international digital agricultural technologies.

SOURCE: Authors' own elaboration.

Annex V
Examples of Turkish AgTech start-ups

a) Tarla.io – A source of weather intelligence and agronomic advisory

Tarla.io was established in Bilkent University technopark in Ankara in 2014. The company has developed a range of weather information and agronomic advisory services for various clients based on a combination of remote-sensing, weather data, crowdsourced data, and plant growth models. It has been benefitting from technological capabilities developed under another start-up founded by the owner's family – Iklim.co established in Estonia – offering early warning of severe weather events such as hail and lightning for different sectors.

Initially, Tarla worked for individual agribusiness clients on a project basis developing management systems for contract farmers, apps and specific content based on remotely sensed data (e.g. Konya Seker, Sumu Agri, Toros, and TEB Bank). In 2020, TARLA.IN was launched as a structured delivery channel to provide hyper-local agricultural information to farmers, insurers, banks, and food processors via APIs. TARLA.IN offers two types of products:

1) TARLA.IN Track offers field monitoring services using data from satellite images, weather information networks and a broad range of other sources. IoT devices such as field weather stations and soil moisture sensors can also be integrated. Services include plant growth monitoring, weather information, key agronomic variables (e.g. soil moisture, temperature, aggregate precipitation, evapotranspiration, and growing degree days), and related early warning messages (weather and disease). Other features include information on local product prices and land prices, and the possibility to offer farm produce or land for sale. The services can be accessed via custom web interface, smartphone apps, or through an API for integration into existing corporate systems. Customers can chose the type of data according to their needs. TARLA.IN Track offers a freemium model allowing individual farmers with up to 100 ha to access about 70 percent of the service offerings without a fee.

2) TARLA.IN Risk generates drought and climate risk reports for any specific field or location based on historic climate data and soil information databases. The service is primarily targeted to banks and insurance companies but can also be used by farmers or agribusinesses wanting to purchase or rent land.

Tarla has about 3 000 freemium subscribers and 450 individual clients. It reaches another 90 000 farmers indirectly through B2B contracts with ImeceMobil, Toros, Şekerbank and Önder Ciftci Cooperative. In total, 19 000 fields with a combined area of 150 000 ha are being monitored. Tarla IO has 10 full time employees including agronomists, software developers, and electrical engineers. Tarla.io plans to expand its services abroad into neighboring countries.

b) Geosys – developing low-cost precision agriculture solutions

Geosys is a specialized service provider developing geographic information system (GIS)-based solutions for various sectors. Geosys develops turnkey IT solutions and services primarily based on geographic information system and technologies. Established in 2002, Geosys has started research and development projects on precision agriculture in 2008. The main focus has

been on retrofitting low-cost smart enhancements on conventional fertilizer spreaders to upgrade them into smart devices for variable rate applications. These projects were first conducted in the Middle East Technical University technopark in collaboration with Ankara University with funding from TAGEM, and later in Adana with funding from Cukurova Development Agency. During these projects, Geosys managed to develop and fine-tune its algorithm for crop detection, crop growth monitoring, detection of water and nitrogen stress levels and crop diseases, as well as yield estimation based on satellite imagery. These capabilities are prerequisites for developing prescription maps for variable rate fertilizer applications. In addition, Geosys developed a hardware kit under the brand name of TARGIS VRA to be mounted on conventional fertilizer spreaders, including older ones prevalent among Turkish farmers. The price tag of around USD 4 000 makes the kit affordable for medium-sized grain farmers as well.

In 2021, Farmlabs was established as a spinoff company based on the know-how and aforementioned products developed by Geosys. Currently, Farmlabs has about 5 000 farmer subscribers for its satellite-based field monitoring services (Agro4 Web and Mobile application), mainly paid for by the South-east Anatolia Project (a.k.a. GAP) Regional Development Administration. For the AGRO4-KIT (old brand name is TARGIS VRA), there are eight users so far. To spur the uptake of this product, Farmlabs has partnered with machinery and equipment suppliers such as TürkTraktör to modernize conventional and old machinery, e.g. fertilizer spreaders for field crops. After joining the EIT Accelerator Programme in 2022, it has opened an office in John Deere's Innovation Center in Madrid to develop a VRA platform in collaboration with John Deere, especially for high-value crops such as those grown in orchards and vineyards. Farmlabs is planning to establish a franchise dealership network at various rural outreach points including gas stations, agricultural machinery dealers, fertilizer dealers and tech-savvy farmers to make AGRO4-KIT technology accessible for small and medium-sized farms under the business model of hardware-as-a-service. The franchisees would provide variable rate fertilization services to other farmers in their respective areas. A basic service provider unit would be equipped with four kits of TARGIS mounted on fertilizer spreaders, with a combined daily operating capacity of 100 ha.

c) Topraq Tarim – Making digital technologies affordable through sensor-as-a-service model

Topraq Tarim is an İstanbul-based spin-off of an established IT company offering ERP services to telecommunications companies in Dubai and London. Founded in 2019, Topraq introduced digital soil moisture sensors, weather stations, and digital pheromone traps through lease-based contracts, circumventing high investment costs for agribusinesses and farmers. The devices are handed over to the farmer against a deposit, for example USD 200 for soil moisture sensors, and an annual service fee. Topraq designs and manufactures its own agricultural sensors and develops its own algorithms that aid farmers' agronomic decisions. The system collects data from the sensors through SIM-card-based GSM. An AI based decision support is communicated to farmers through Telegram bot messages. Farmers can also receive automated advice through the Topraq app. Relying on its cash flow from its established IT operations, the company introduced 300 pilot devices free-of-charge for testing purposes in five pilot regions, Adana, Aydın, Antalya, Çanakkale, and Manisa. As of December 2021,

Topraq had 70–75 clients, mostly stone fruit growers, who were using 400 leased devices. The company plans to install 2 000 additional devices in 2022 and expand to Azerbaijan, Uzbekistan, Romania and Chile.

d) ImeceMobil – An all-in-one app for digital agricultural technologies

ImeceMobil is a joint venture that was founded by Softtech Ventures and İşbank in 2019 in İstanbul. Initially, ImeceMobil offered a range of free-of-charge services such as location- and crop-specific meteorological information, price information through integration with the Turkish Mercantile Exchange, combined with cross-selling of loans and insurance products from İşbank and Anadolu Sigorta. In 2020, new services were added, such as "Ask an Expert"– an interactive communication function via a hotline, and Bazar – a platform where producers can receive offers from input suppliers.

In 2020, the app reached 45 000 users and generated revenues through leads generations, advertisements and fees on inputs traded on the Bazar.

In 2021, ImeceMobil added a range of paid services, including: i) fertilization recommendation service based on 1 million soil samples from laboratories; ii) satellite-supported irrigation advice; iii) satellite-based field monitoring and plant health early warning service with expert support for nine field crops; iv) payment services for farmers and agrisuppliers through İşbank's ImeceCard or other agricultural credit cards; v) agricultural drone sales; vi) ImeceStory – a communication outlet where suppliers can market their products to farmers; and vii) ImeceKnows – an agricultural intelligence outlet where farmers can see cultivation areas, yield estimates and forecasted prices for given crops in a given location. ImeceMobil is a platform where data and hardware providers such as Tarla.io, Agrovisio, Tarsim, private soil laboratories, and Baibars Mechatronics (drones) offer services.

ImeceMobil has 180 000 subscribers, including 6 500 using paid services, mostly through B2B channels. ImeceMobil plans to introduce new services such as AI-based agri-loan scoring, drone spraying, and financing services. In collaboration with Softtech, it also offers a B2B platform as a digital interface for large-scale companies working with large numbers of farmers (e.g. Kayseri Şeker). International expansion into Italy, Spain, France and Romania is planned for 2023, subject to funding.

e) Ankaref – a domestic IOT solutions providers venturing into agrifood

Ankaref is a leading Turkish IT company working on IoT and big data solutions in various sectors, including traceability and tracking of vaccines. Prior to establishing Ankaref in 2007, the owner was involved in developing the Farmer Registry System at MoAF. In 2020, Ankaref used its technology for vaccine tracking to develop a cold chain tracking system for fresh produce (meat, fish, vegetables, and fruits) for the delivery service company Getir. The tracking system is to be rolled out in various phases over five years to be gradually expanded into Getir's 4 000 refrigerated trucks and warehouses in Türkiye. The project's last stage envisages a transition from QR-based to blockchain-based system.

In 2016, Ankaref started R&D for low-cost oestrus detection system for dairy cows, together with Ankara University and Algan Group. Based on its research, Ankaref launched a pedometer in 2020 under the brand name

Actimoo. The solution was a joint subsidiary of Ankaref and Algan Group. Actimoo is a low-cost solution based on a simple plug-and-play system connected to a cloud and with remote support through a hotline. The system predicts oestrus based on continuous monitoring of animal movement and temperature, and sends an SMS message to the famer and his veterinarian some hours ahead of predicted oestrus. In 2022, 7 500 cows were being monitored through the system. Though it is experiencing slow growth in the Turkish market, Actimoo has also been launched in other European Union countries and in the United States.

Annex VI
Interviews held with key stakeholders

Domestic AgTechs	
Doktar	Largest domestic AgTech, GIS, sensors, decision support, API services
Tarla I.O.	Established AgTech, GIS based services, API services, Apps
Tarsens	Small start-up, AI for image recognition, orchards
Geosys	Remote sensing and precision agriculture (VRA)
Provea	Remote sensing (GIS and drones), olives, vineyards, orchards
Ankaref	Ear tags for oestrus prediction in dairy
Agrovisio	GIS applications
Agcurate	GIS applications
TARNET	Technology subsidiary of Association of Agricultural Credit Coops (ACCSs)
Softtech	Software for large agribusinesses to manage contract farming operations
Imece Mobil	Mobile app providing different services via API (İşbank subsidiary)
TABIT	Smart Village
KoçSistem	Koç Group's corporate traceability solutions provider
Tubu Ar-Ge	Blockchain traceability solution provider, start-up
Topraq	Originally an ERP provider for telecommunications sector; offers soil moisture sensors as a service
Farmer Expert	A B2B marketplace for farmers, purchase units/companies, agronomists, logisticians, and labs offering traceability solutions
TeknoKurgu	An authorized reseller of Augmenta autonavigation systems, and precision farming service-provider
Agrisens	Prototype of tractor tracking system using LoRaWan
Farmlabs	Satellite-based field monitoring; variable rate application
International AgTechs and their distributors	
Metos (Pessl Instruments)	Field sensors and stations, disease detection, crop models, etc.
Rivulis/Eurodrip (Manna)	Smart precisions irrigation and crop models
Netafim	Manna (Digital subsidiary)
Smart Soil	Offers international solutions in-country: Sentek (Australia); Aerobotics (South Africa); WiseConn (USA); Meteobot; MicaSense; Tungsram
Graftek	Authorized reseller of Trimble auto-navigation devices (USA)
Merck (Allflex)	Precision livestock farming (market leader)
Paksoy	Distributor of Topcom Precision agriculture Equipment (Japan)
Input and technology providers	
Bayer	Field View App, entered Türkiye three years ago
Toros Tarim	Toros Ciftci App providing fertilizer recommendations
Syngenta	Protector, Spray Assist and myFIELD Apps
HEKTAŞ	Publicly traded company, sector leader in plant protection, active in plant nutrition, seed, and animal health products

Equipment manufacturers	
Türk Traktör	Market leader in agricultural machinery; app provides field monitoring and market information
Cansa	Domestic farm machinery manufacturer, retrofitting VRT (fertilizer)
Naras Makina	Precision farming machinery and retrofitting company, reseller of Trimble
Teta Teknik Tarım	Founded in 1983, develops digital milking parlours and barn equipment, offers end-to-end livestock farm establishment services
Nergistepe Tarım Makinalari	Machinery manufacturer providing retrofitting solutions related to autonavigation and VRA
Agribusiness companies	
Konya Seker	Sugar beet, maize, barley, livestock; cooperatives as shareholders; uses ICT for outgrower management and agronomic field support
Kayseri Seker	Sugarbeet and other crops, piloting various digital technologies
Barilla	150 contract farmers, uses some GIS monitoring and weather stations
TAT	Türkiye's leading tomato and pepper paste producer founded in 1967 in Bursa by Koç Holding; a major exporter
Beypilic	Large integrated chicken meat producer with 850 contract farmers
Danone	Produces mainly yogurts in Türkiye, 3 000 farmers
Tekfen Agri	Seed and sapling producer, uses various digital technologies
TARİŞ	TARİŞ Olive and Olive Oil Sales Cooperatives Union representing 30 unit cooperatives and 24 000 olive farmers in the Aegean region; exports small portion of production
Anadolu Etap	Türkiye's largest fruit orchard operator with 3 000 ha of land producing apple, peach, plum, nectarine, apricot, sweet cherry, sour cherry, persimmon, citrus, pomegranate, and olive
Assan	Recently bought by Kraft Heinz, produces tomato paste, ketchup, mayonnaise and various sauces in Balıkesir; exports to 30+ countries
Doluca Winery	Founded in 1926, this large-scale winery produces French varieties, owns 400 ha, and works with 4 000 contract farmers on another 3 000 ha
FritoLay	Subsidiary of PepsiCo Türkiye, produces food (potato, corn, and semolina) and beverage (fruit juice)
Kavaklıdere Winery	Founded in 1929, this large-scale winery owns 700 ha and works with 2 000 suppliers on another 3 000 ha; a major exporter
Agrobay	Subsidiary of Bayburt Group, the company operates Europe's largest greenhouse plantation for tomato (32 ha) in İzmir
Işık Tarım	Founded in 1974, based in Manisa, the company operates in 14 500 ha to produce organic fruits and vegetables; a major exporter
Mapeks	A major organic fruit and vegetable producer and exporter, based in İzmir
Marmarabirlik	Marmarabirlik Agricultural Sales Cooperative comprises eight unit cooperatives with 35 000 members in Marmara region; major exporter
Kurt Group	A large-scale producer of tomato using greenhouse automation and engaged in soilless production in Afyon
Beypiliç	Large-scale poultry producer headquartered in Bolu; operates a fully automated slaughter-house; precision livestock farming exercised by contracted farmers
Migros	Türkiye's largest supermarket retail chain also engaged in food processing
Farmers and farmer organizations	
Önder Çiftçi Cooperative	Based in Tekirdağ, production and marketing cooperative comprise 400 members with 40 000 ha producing sunflower, grain and barley
Feyz Süt	Large dairy farmer (3 000 cows) plus fodder production; uses a range of advanced digital technologies in dairy and fodder crops; President of TUSEDAD (Milk, Meat and Cattle Breeders Association)
A large farmer in Killis	The farm (400–500 ha) is located in Kilis; grows various wheat, barley, cotton, almond, olive, pistachio, other fruit orchards and vegetables

Adana Left Bank Irrigation Cooperative	Using digital weather station to provide weather advice and irrigation scheduling to orchard farmers
Adana Citrus Producers' Union (ADATUB)	Large citrus producers using digital weather stations, soil moisture sensors and insect traps
Adana farmers	Durdu Mehmet Danışoğlu, Niyazi Danışoğlu, Mustafa Teke, Yaşar Özekenci
Member of Kayseri Seker	Large farmer testing field weather stations provided by KS
Orchard producers (Kemalpaşa)	Farmers producing cherry and peaches, benefitting early warning and agronomic advice powered by weather stations and disease models
Organic farmer (Manisa)	Producing raisins for Rapunzel (German organic marketing chain); receives early warning messages
Marketing/trade	
Nuri Bey Ciftligi	E-commerce
İzmir Commodity Exchange	İzmir Technology Center, new public–private initiative to promote digital agriculture
TOBB	Umbrella for chambers of commerce, engaged in E-commerce platform DTAP
DITAP (MoAF)	Newly launched B2B e-commerce platform developed by MoAF
Agrobil	E-commerce
TazeDirekt (Migros)	Organic/high quality E-commerce subsidiary of Migros
Migros	Traceability in meat and horticulture, e-commerce
Financial services	
İşbank	Second largest private bank lending to agriculture, uses app for its customers (Imece), partnership with Vodafone and Metos
Deniz Bank	Main private bank lending to agriculture, uses app for its customers
KKB	TARDES automated credit appraisal system (developed with EBRD support), potential integration of GIS
TARFIN	Fintech providing finance for fertilizer dealers based on lending algorithm
Telecommunication companies	
Vodafone	Distribution partner of Metos; Smart Village (with TABIT)
Turkcell	Distribution partner of Doktar
Other ecosystem actors	
Kök Project	Accelerator programmes in food-agri sector
Tarmakbir	Association of Agricultural Machinery Manufacturers; created Smart Farming Platform together with Ministry
Poultry Association	Represents fully integrated broiler producers (21 members)
Frankfurt School of Finance and Management (Türkiye office)	TARDES system with KKB, potentially upgrading into TARDES 2.0
Scientific and Technological Research Council of Türkiye (TÜBİTAK)	Directorate of Technology and Innovation Support Programs (TEYDEB)
MoAF	Relevant departments using or interacting with data and AgTech: • Mechanization Department • Marketing Department • TAGEM • TRGM
Ankara Development Agency	TAGTech – Support to AgTech start-ups in Ankara Province
Bogazici University	Professor in agricultural economics, Prof. Gökhan Özertan
Ankara University	Professor in smart mechanization, precision agriculture, Prof. Ufuk Türker
Namık Kemal University	Professor in smart mechanization, precision agriculture; Department of Biosystems Engineering under the Faculty of Agriculture, Prof. Akdemir,
Çukurova University	Prof. Ali Bayat and Research Assistant Çağdaş Civelek
IPUD	Better Cotton Association is a part of BCI Global, works with cotton farmers in the Aegean and southeastern Türkiye

İzmir Metropolitan Municipality	Operates Agricultural Services Department and İZTAM as an agri-demonstration farm in İzmir province; collaborates with chambers of agriculture
Kemalpaşa Chamber of Agriculture	Collaborates with İzmir Metropolitan Municipality and serves the district's cherry, olive, and peach growers
Manisa Ministry of Agriculture and Forestry Provincial Directorate	The provincial directorate serves Manisa's grape (dried and fresh), olive, cherry, tobacco, sesame, tomato, corn, and melon growers; Manisa ranks eighth in the country in terms of plant production with 5.1 million decars of agricultural land
Dikili Agricultural Organized Industrial Zone (TDİOSB)	Geothermal-powered greenhouse plantation area under construction financed privately; greenhouse parcels are offered to private investors
İzmir Agricultural Technology Center (ITTM)	AgTech implementation/demonstration campus project coordinated by the İzmir Commodity Exchange

SOURCE: Authors' own elaboration.

Annex VII
Technologies in action: examples from the field

Annex 7 can be accessed through the following link:
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FAO/Frank Hölinger

Advances in digital technologies are transforming every sector of the economy including agriculture and the food system. Digital technologies offer great potential to enhance resilience, efficiency and greening of agrifood systems, from production, processing, logistics, retail and trade to support services and finance.

This study reviews the current state of digital technologies in agriculture in Türkiye. Following a brief review of key trends and challenges in the agriculture sector, the study describes the ecosystem for digital transformation and the current technology supplier landscape. It then identifies key digital technologies in agriculture and their most prominent use cases, main user groups and adoption levels, as well as practical challenges facing users and the potential for expansion in the short to medium term. The report targets a broad audience ranging from policymakers to investors, farmers and their organizations, agribusiness companies, and other practitioners in the sector. This publication is part of the Country Investment Highlights series under the FAO Investment Centre's Knowledge for Investment (K4I) programme.

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