Regional Survey and Study on Inclusive Digital Transformation of Agriculture in the NENA Region

Final Technical Report

Association of Agricultural Research Institutions in the Near East & North Africa

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Contents

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Executive Summary

This study explores the possibilities for strengthening agriculture, in particular small agriculture, often represented by family farming, with the use of digital technologies. Within the framework of the Collective Action on Inclusive Digital Agriculture, funded by the European Commission, the Global Forum on Agricultural Research and Innovation (GFAR) seed-funded a proposal from AARINENA to conduct a survey and a study on attitudes and challenges of small-scale famers towards digital agriculture in the NENA region, to support GFAR's work on participatory identification of good practices for an inclusive digital transformation of agriculture. This study will contribute to GFAR's mission of strengthening and transforming agri-food research and innovation systems and to the objectives of the EU DeSIRA project; under that- umbrella, the study will contribute to GFAR's Key Focus Area 1 (Empowering Farmers at the Center of Innovation) more in particular to the objectives of the GFAR Collective Action on Inclusive Digital Transformation of Agriculture.

The study built on existing documentation on the subject matter at hand, and on an effort to collect new information through a survey questionnaire to identify and assesses needs, gaps and challenges of adopting digital agriculture and smart farming. Furthermore, the survey will contribute to the monitoring and evaluation of the adoption of digital agriculture in Jordan, Egypt and Tunisia and taking into account the complex and dynamic nature of the scaling process in these countries. There was a total of 214 collected responses from farmers in Jordan, Egypt and Tunisia. An in-depth and comprehensive desk research review of the current scenario of digital agriculture from the perspectives of farmers in these three countries was presented in this study. The results of this study revealed that the adoption of digital technologies can lead to improved productivity, increased efficiency, and reduced costs. The use of digital agriculture such as drones and satellite imagery can help farmers to optimize their use of fertilizers, water, and other inputs, leading to higher yields and lower costs. Similarly, the use of digital innovation platforms such as mobile apps and online marketplaces can help farmers to access information, connect with buyers, and access credit and other financial services. However, there are also challenges associated with the adoption of digital technologies in the NENA region. These include limited access to digital infrastructure and services, low levels of digital literacy among farmers and other stakeholders, and concerns around data privacy and security. There is also a complex relationship between the uses of digital agriculture and the education levels of farmers. Finally, the adoption and effective use of digital agriculture technologies require certain levels of knowledge and skills. Farmers with higher

education levels may be more likely to have the necessary skills and knowledge to adopt and use these technologies effectively. Therefore, it is important to promote access to education and training programs that focus on digital agriculture for farmers of all education levels. This can help to bridge the digital divide and promote the effective use of digital agriculture technologies, leading to improved agricultural productivity, sustainability, and livelihoods for farmers.

The technical report is divided into four chapters. The first chapter explores the topic of digital agriculture, from secondary sources, with an emphasis on inclusion, it also lays out background of research, research objectives and research questions. The second chapter is a conceptual and analytical framework on digital agriculture including the methodology of the study which was a survey questionnaire. The third chapter presents the relevant literature review and an overview of the role, adoption and use of technology in agriculture in NENA region and more specifically, in Jordan, Egypt and Tunisia. In the last chapter, findings of the study and discussion and conclusion were presented.

CHAPTER 1

1.1 Introduction

Agricultural research organizations, governments and civil society are increasingly looking at how to successfully scale up agriculture and food security innovations to bring more benefits to more people, more importantly small-scale farmers and have lasting impact. Digital agriculture including the information and communication technologies (ICTs) can play an important role in greater uptake of innovations. Communication tools, methods and approaches can help create interaction between partners, share information about the innovation to potential beneficiaries and distribute materials, services and products related to the innovation. In the Near East and North Africa (NENA) region, agriculture is largely traditional and practiced by small-scale farmers. This type of agriculture is predominantly rain-fed, has low-yielding production and lacks access to critical information, market facilitation and financial services. International organizations such as the World Bank, FAO and GFAR recognize the important role of digital agriculture can play in addressing these challenges. However, small-scale farmers are not harnessing the benefits of the ongoing and accelerating digital transformation (mobile /web applications, innovation platforms, precision agriculture, using e-finance and e-commerce, use of IoT in irrigation etc.). The lack of inclusion of small-scale producers in the design and governance of digital agriculture processes often results in technologies that do not respond to their needs, thus discouraging them from fully embracing digital agriculture. Consequently, the benefits that digital agriculture could bring to farmers in terms of income and resilience, as well as to the efficiency, transparency and equity of agri-food value chains and to climate change mitigation and adaptation, are not being realized.

Digital food systems are probably the most general term used to refer to digitalization of all aspects of the food systems, from farming to supply and value chains to government policies to extension services to markets to consumption and health. Digital agriculture is a term sometimes used with a similar meaning, but normally used to refer to a slightly more limited subset of the digital food systems, closer to the farming activity: smart/precision farming, digital advisory and extension services, open data for agriculture, and value chain traceability. Smart or digital farming can contribute to exponential income growth, enhanced decision making, better services and products, as well as productivity and profitability. Smart and digital are used interchangeably, however while digital tools in general can automate operations and transmit orders remotely, the smart aspect of digital solutions, the one that automates decisions and optimizes efforts, depends on the underlying data: without data that was collected from the field or from external sources, digital solutions cannot be smart.

1.2 Background to the Research

Digital agriculture has been very effective in providing information to the farmers (most successfully, market prices information). However, there are challenges in adoption of digital agriculture, especially by small-scale producers, which need to be addressed and will require a better understanding of the attitudes and constraints of these farmers, consultations to devise best practices, and extensive capacity building. For instance, small-scale farmers in Jordan, Egypt and Tunisia are generally on the "receiving end", thus to maximize the use of interactive digital tools, this will require awareness and attitudes change from all actors in the digital solutions value chains; and the agribusiness community is not naturally open to change, and thus important technical information such as weather forecast and the related advice, provided via short messaging services (SMS), mobile and web, will require time until the farmers effectively use it and interact with it. As demonstrated by the Collective Action on Inclusive Digital Transformation of Agriculture facilitated by GFAR, there is a great recognition that the key driver towards the full realization of the benefits of the digital transformation of agriculture is the inclusion of farmers in the design and governance of digital solutions, and in the negotiation of related data practices and business models. This stems from the recognition of farmers as central actors of innovation and innovators themselves, generators of valuable agricultural knowledge and holders of intellectual property rights, not just recipients of others' solutions, knowledge, and data. Transformative change is all about power dynamics. There is a lot of opportunities for rural women and men that they are able to do and there is a lot of assumptions about what rural women and men can do. There is a need to rebalance power relations and representation of stakeholders voices within the discourse of food systems transformation and provision of solutions.

1.3 Problem Statement and Justification

Personal ICT devices (e.g. mobile phones, tablets) are becoming more widely available and mobile technology is increasingly being adopted for delivery of services and solutions. Despite this, there remain gaps in understanding the role and contribution of digital agriculture to the adoption and scaling-up of agricultural innovations, the factors for success and challenges to the application of digital agriculture in the NENA region and the specifics of the rural context of this region for scaling-up. Digital agriculture was proposed as one of the entry points for researchers and farmers to co-innovate and enable them benefiting from agri-food value chains and helping revive extension services in NENA region. The role of disruptive technologies in enhancing rural youth entrepreneurships and in transforming food systems was also proposed as a research area of relevance to NENA region. Digital agriculture facilitates and enables buyers and sellers to reach agreements, while securing their linkages and advising associations of farmers on their optimum marketing plans; it also addresses the lack of sustainability of most past donors' projects which secured capacity building of small-scale farmers, without considering the need for an external structure to manage the supply chain deals on a permanent basis. The supply of market and technical information play a major role in improving the livelihoods of small farmers, as it enables them to take both cultivation and selling decisions in a better manner. The cooperation with the state agencies is in fact mainly related to this component of the network. To date, for instance, prices information of crop markets does not reach the small-scale farmers, therefore, digital agriculture will enable small-scale farmers to better negotiate selling conditions with the traders, as these remain the main supply chain operators. As such, the digital network by putting the small-scale farmers directly in contact with the market buyer, is a major leverage to help them grow in the value chain. Digital agriculture provides small-scale farmers directly with information and knowledge which otherwise reached them distorted through the local traders. The daily national wholesale market prices of fruits and vegetables will be sent by short messaging services (SMS), enables the farmers to better negotiate their crop sales at local level. As well the technical data provided by SMS such as the weather forecast and related irrigation and pest control advice, supply them with weekly reminders of the main operations needed for each main crop in each area and season.

1.4 Research Objectives

The main objective of the GFAR Collective Action on “Inclusive Digital Transformation of Agriculture” conducted under GFAR’s Key Focus Area 1 “*Empowering Farmers at the Center of Innovation*”: enabling farmers as key actors and co-innovators in the design, governance and benefit sharing of digital Agriculture technologies, data and infrastructures, as well as the promotion and support of pertinent policies and best practices. The foreseen impact of this is that the use of equitable and sustainable digital agriculture technologies will help farmers increase productivity and income, reduce risk, use natural resources sustainably, mitigate and adapt to climate change, at the same time contributing equitably to the agri-food data value chain improving value chain transparency and efficiency as well as monitoring of the sustainable development goals (SDG) indicators.

The GFAR Collective Action foresees different phases, from surveys of small-scale farmers’ attitudes and challenges with respect to digital solutions, and in general needs assessment exercises, to multi-stakeholder consultations on good practices and business models that work for small-scale producers, to capacity development activities. For this initial work for the NENA region, the study covers phase 1, a survey accompanied by research on the current scenario of digital agriculture from the perspective of small-scale producers.

This preliminary bottom-up survey will contribute to understanding the strategic role of digital agriculture in some partnered countries in the NENA region (Jordan, Egypt and Tunisia) in catalyzing, enabling and supporting the scaling up of agriculture and food security solutions, including innovation, good practices for transitions from trials and pilot projects, organizational issues and restructuring, and policies. Therefore, the main objectives of this study are to identify gaps and challenges in adopting agricultural technologies and digital agriculture by the small-scale farmers and how they can be best addressed, explore factors influence adoption of digital agriculture why and how certain groups of farmers may decide to employ particular farming technologies or not.

1.5 Research Questions

Questions emerge with respect to identification of current uses, needs, and expectations in terms of digital solutions in countries such as Jordan, Egypt and Tunisia. The questionnaire (attached in pdf file) was used to facilitate responses from farmers with necessary adjustment as needed and to collect data for the research study. The use of digital tools for agriculture, usefulness of information on the internet for family farming, constraints to the use of digital technologies in agriculture, and addressing issues related to digital agriculture. To some extent, the following key-questions offer an example of questions that were used to solicit information: what would influence adoption and use of digital agriculture, and what would influence farmers' decision to adopt or not adopt technologies in agriculture. What are farmers' needs related to digital technologies and best practices. Are digital technologies sufficiently accessible for agricultural producers, particularly for family farmers and the most vulnerable groups? Are there relevant tools and appropriate contents for the context in which farmers work? Are there limitations to the use of these technologies?

CHAPTER 2

2.1 Conceptual and Analytical Framework

Digital agriculture, including precision agriculture or smart farming, is a rapidly growing field that involves the integration of technology and agricultural practices. It aims to use data-driven insights and technological advancements to improve efficiency, productivity, and sustainability in agriculture.

Although digital agriculture has the potential to reach large number of beneficiaries, there should be a consideration for the potential transformational role that they could play in catalyzing changes in the agriculture system required for the scaling process to be locally relevant. This field of study provides examples of the various pathways by which digital agriculture can address agricultural system challenges and how can support social and behavioral change, and communication strategies that can tackle the social-cultural norms and practices affecting how local populations perceived agricultural innovations. The conceptual framework of digital agriculture is based on three key components: data collection, analysis, and application.

Data Collection:

The first step in digital agriculture is to collect data from various sources such as sensors, satellites, drones, and farm machinery. This data can include information on soil moisture, temperature, humidity, and crop growth. Data can also be collected from external sources such as weather forecasts, soil maps, and market prices.

Analysis:

Once data is collected, it needs to be analyzed to extract valuable insights. This involves the use of algorithms and machine learning techniques to process large volumes of data quickly and accurately. The analysis can help farmers make data-driven decisions about when to plant, fertilize, and harvest crops. It can also help identify problems such as pests, diseases, or nutrient deficiencies, allowing farmers to take corrective action before significant damage occurs.

Application:

The final step in digital agriculture is to apply the insights gained from data analysis to improve farm management practices. This can include optimizing irrigation and fertilization, improving crop rotation, and reducing waste. Digital agriculture can also help farmers make informed decisions about marketing their crops and managing their finances.

The analytical framework of digital agriculture involves the use of various technologies and methods to collect and analyze data. For example, sensors are used to collect data on soil moisture, temperature, humidity, and other environmental factors. They can be placed throughout the field to provide a detailed picture of crop conditions. Satellites can be used to collect data on crop health and growth patterns. This information can be used to identify areas of the field that require additional attention and resources. Drones can be used to collect high-resolution images of the field, which can be used to create detailed maps of soil and crop conditions. They can also be used to apply pesticides and fertilizers precisely, reducing waste and improving crop health. Machine learning algorithms can be used to analyze large volumes of data quickly and accurately. They can identify patterns and trends that may be missed by human analysis, providing valuable insights into crop health and management. Blockchain technology can be used to create transparent and secure systems for tracking the supply chain of agricultural products. This can help farmers and consumers trace the origin of food products and ensure they are safe and of high quality.

In conclusion, digital agriculture has the potential to transform the way we grow and produce food. By collecting and analyzing data, farmers can make data-driven decisions that improve efficiency, productivity, and sustainability. The analytical framework of digital agriculture involves the use of various technologies and methods to collect and analyze data. As digital agriculture continues to evolve, it has the potential to improve food security and reduce the environmental impact of agriculture. Digital agriculture has the potential to revolutionize agriculture by improving productivity, reducing costs, and enhancing sustainability.
However, the adoption of these technologies is not without challenges and limitations, due partly to poor infrastructure and lack of capacities of farmers, and partly to the fact that most solutions do not cater for small-scale farmers, because they do not influence the design of these solutions since the beginning. Governments and stakeholders need to invest in infrastructure and provide adequate support to enable farmers to adopt digital technologies effectively. Additionally, besides the obvious need for farmers to be adequately trained and educated on the use of these technologies to enable them to benefit fully, there is a need to change the culture that sees farmers, especially small-scale farmers, as mere recipients, devising appropriate mechanisms for real co-innovation, involving small-scale farmers, perhaps through their associations, in design and governance. Ultimately, the successful adoption of digital agriculture will require collaboration among all stakeholders, including farmers, governments, and the private sector.

2.2 Methodology

The outputs of this study in the region are a) a better understanding of farmers' attitudes, challenges, concerns and drivers towards the use of digital agriculture solutions, in view of future consultations and capacity development activities, and b) strengthening and increased cohesion around common priorities of regional agricultural research and innovation organizations, which is one of the objectives of GFAR. The research methodology for this study is straightforward and appropriate. It starts with a survey of small-scale farmers which will be a baseline for further studies and measuring the impact. The research study identifies and assesses needs, gaps and challenges of adopting digital agriculture and smart farming. Furthermore, this survey will contribute to the monitoring and evaluation of the adoption of digital agriculture in Jordan, Egypt and Tunisia and to the taking into account the complex and dynamic nature of the scaling process in these countries. The survey will build more robust novel evidence on the adoption of digital agriculture in the NENA region.

Partners

The strength and quality of the partnership are grounded in the existing synergies among the partners under the umbrella of AARINENA. AARINENA has strong and close ties with the selected countries: Jordan, Egypt and Tunisia and their representatives of agricultural research and development. AARINENA has also a solid relationship and collaboration with representatives of small-scale farmers in Jordan through farmers' organizations, cooperatives and others. AARINENA has selected the Jordanian Farmers Union as a close partner in conducting the preliminary survey among farmers due to its influence and presence among farmers in different parts of the country especially rural areas. The partnership and network of AARINENA locally and regionally facilitated this research study and leveraged the required data collection through the survey. The partnership also generated large interest in data collection and a growing number of respondents to the survey. The selected partners all together have a potential reach of 150 farmers at least, the aim for this specific research study was to collect survey data from 50 farmers from each country. The partners agreed to work together committing their own resources, which is the agreed practice for Collective Actions, with the coordinating partner AARINENA.

Upon signing the Letter of Agreement between FAO and AARINENA on September 1, 2022, AARINENA started performing an in-depth and comprehensive desk research review of the current scenario of digital agriculture from the perspectives of farmers in these three countries to complement the collected data from the survey. Afterwards, the data collection activities through an in-depth survey questionnaire on attitudes and challenges of famers towards digital agriculture in the NENA region were conducted and disseminated by various methods, to support GFAR's work on participatory identification of good practices for an inclusive digital transformation of agriculture and to complete the required data for the systematic analysis. The sources of information were projects design documents, progress reports, fact sheets, technical reports, evaluation reports, published manuscripts, etc. The survey questionnaire was designed, developed, and adopted from the survey template that was administered by GFAR partners in Latin America and Caribbean and then the survey questionnaire was modified to adapt to the targeted countries in the NENA region and more specifically Jordan, Egypt and Tunisia. The survey was made available online via Google Format and face to face (hard copy) via communications, workshops, networking and field visits with farmers and stakeholders. The survey was translated from English language into Arabic language to accommodate farmers in the targeted countries. The main goal was to collect data and have perspectives, attitudes, perceived challenges and drivers related to use of digital solutions from farmers in different regions within each country. Therefore, AARINENA coordinated the regional survey and collaborated with farmers' associations and unions across Jordan and with its networks and members in Egypt and Tunisia.

The survey questionnaire (attached in pdf file) was targeting farmers who had adopted any form of digital agriculture and who had not adopted digital agriculture in Jordan, Egypt and Tunisia. Gender was taken into consideration with the aim to create a gender balance. A total of 214 responses was collected, 69 responses were from farmers in Jordan of which 8 responses were from women, 74 responses were from farmers in Egypt of which 2 responses were from women, 71 responses were from farmers in Tunisia of which 5 responses were from women. The collected data and responses from the survey questionnaire in the three countries were transferred into an Excel sheet for analysis purposes (attached the Excel sheet of collected data and responses), and then the data was analyzed using the software analysis SPSS. Preliminary analysis of the data took place parallel to the data collection process. The final analysis was made immediately after all required data was completed. The findings were only used in aggregate with the responses of all other participants due to the nature of this study in digital agriculture. After data analysis was completed, qualitative and quantitative descriptions and interpretations were carried out to draw discussion and conclusions.

CHAPTER 3

3.1 Literature Review Analysis

3.1.1 Overview of the Role, Adoption and Use of Technology in Agriculture in Jordan

The agricultural sector is one of the most important economic sectors in Jordan. Agriculture plays an important role in the development system, especially for rural communities, and contributes a large percentage to achieving food security. It is also a primary source of income for many families in Jordan despite the decline in agricultural land areas as a result of urban expansion; the fragmentation of agricultural property; low productivity; widening food gap (between production and actual needs); reluctance to pursue the profession of agriculture; poor agricultural labor efficiency; its reliance on immigrant workers; high costs of agricultural production; misuse of pasture lands; and attacks on forest and agricultural lands. Despite the low contribution of agricultural production to the gross domestic product, it represents, in its economic and social dimensions, one of the most important sectors of the national economy.

Jordan is small and relatively stable country that has become a refuge for large numbers of people fleeing conflict in Iraq and Syria. The inflows had raised Jordan's population to 10.2 million by 2020, placing heavy strains on its resources and economy. International organizations such as the World Bank and World Intellectual Property Organization rank Jordan as an upper-middle income country. The unemployment rate has reached 24.7% during the fourth quarter of 2020 (for males 22.6% and for females 32.8%). The national poverty rate has already reached about 16%. Rural population estimated at 1.5 million, 12% of which is made up of Syrian refugees and poverty is highest in rural areas as a result of rapid population growth, degradation of natural resources, and scarcity of water. Agriculture in Jordan plays a major role in sustaining the country's economic well-being. Although agriculture contributes 5.6% to the GDP in 2021, the value chain of agri-food accounts for 15-20% of GDP and employs more than 15% of Jordan's active population (Ministry of Agriculture, National Strategy for Agricultural Development, 2020-2025). Agriculture sector is one of the most labor-intensive sectors that generates large numbers of job opportunities at the level of food supply chain. It employs 76 thousand labors of about 5.5% of Jordan total labors and more than 50% of rural women. As a result, revitalizing the agrifood business sector in Jordan can double the number of jobs by 2025, as well as increasing the added value by an average of 15-20% annually (Ministry of Agriculture, National Strategy for Agricultural Development, 2020-2025). Additionally, Jordan is among the scarcest countries in water with a per capita of less than 100 cubic meters/year. Climate change has heavily impacted all components of food security and food systems in Jordan. Rainfall is reducing year after year; drought is increasing, and land degradation is becoming a major challenge in the country. This has led to a witnessed decline in production and overall productivity especially for small-scale farmers who often rely on rain fed agriculture and sheep husbandry.

Jordan is considered a food secure country with a score of 8.8 on the 2020 Global Hunger Index. Food security is challenged by a multitude of structural and political factors such as high poverty rates, unemployment, slow economic growth and increased cost of living, with marked disparities between regions and population groups (World Food Program, 2022). Jordan currently imports the vast majority of the basic food crops (corn, barley, wheat and soybean, rice, sugar), including almost 98 % of wheat, but Jordan makes up to 50-60% of the potential exports of fruits and vegetables and the available export potential is still not fully used (World Bank, 2018). Jordan has and continues to have competitive advantages as a supplier of fresh fruits and vegetables. However, there are some structural issues related to the absence of a national marketing strategy as a result of low priority by the government and a weak interaction between the public and private sector. The total exports of agricultural products count for 25 % of the grand total of Jordan's export. A considerable quantity of the Jordanian production of fruits and vegetables exports to high end markets such as Western and Eastern Europe. Jordan has and continues to have competitive advantages as a supplier of fresh fruits and vegetables. This is also due to the unique and diverse geographical climatic zones of agricultural areas in Jordan, more specifically the production of Jordan Valley especially in the winter time. In addition, Jordan produces vegetables for example throughout the year and other fruits in unique harvest times, along with good agricultural practices and latest growing technologies that would give it a special comparative advantage.

However, agricultural production is facing many challenges such as limited availability of surface water resources in Jordan Valley, the rapid depletion of ground water resources in highlands due to over exploitation; inefficient and misuse of irrigation water; degradation of soil and water quality, small size holdings, and weak extension services that link the results of agricultural research with farmers. Furthermore, the agriculture production is facing the challenge of marketing that is closely linked to high post-harvest losses; inefficient markets; food safety issues; and the difficulties to ensure production that meets quality standards. Jordan has lost some export markets as a result of the political and stability situation in the region and the pandemic of COVID-19 which had a significant impact on agriculture production. Household food processing activities are a major source of livelihood in Jordan particularly in rural households. Although many marketing outlets have recently evolved in Jordan such as the local supermarket retail chains. The rural informal food processors are not well connected to these market outlets due to inferior quality of products, poor hygienic standards and lack of proper packaging. In general, most of marketing functions such as quality control system, packaging, and collection related to micro and small scale food processing are substandard. The rural poor in Jordan makes a substantial amount of the total poor, rural people are often the first victims of natural resource degradation and are impacted by crisis more severely than any other segment of the population.

Beyond the economy, however, the agriculture sector is a critical enabler of employment, rural development and food security, as well as being a locus for addressing many of the environment and climate change related challenges facing the country. The government aims to improve the exportability of agricultural goods while at the same time coping with climate change and achieving sustainable development goals (Green Growth National Action Plan, 2021-2025). The agriculture sector has been growing and increasing its share with a variety of lucrative investment opportunities are present in Jordan's Agriculture sector. However, Jordan is still a substantial importer of food, a situation that is unlikely to reverse. Boosting the productivity of farmers can help them to leverage the food system, earn more money from what they grow and help meet the demand coming from cities for higher-value crops. This must be accompanied by public investment in agricultural research, innovation, and extension. There is a large scope for technology and inclusive sourcing to help connect rural people to better production techniques and more lucrative markets, bringing them into the value chain more effectively. Jordan needs to capitalize on new agricultural technologies and to digitize the input and output of agricultural decision-making that would be an opportunity for Jordan to enhance the efficiency of the agricultural sector and to build resilience in relations to importing food. Furthermore, agricultural productivity growth and higher investments in agricultural productivity would help contain future replacement needs and lower foods imports needs. Thus, increasing contribution of the agriculture sector in GDP, exports, and labor force participation. A strong agricultural investment plan would improve productivity although such measures will require access to improved water and energy (Jordan Economic Growth Plan, 2018-2022). Digital agriculture is an emerging field that utilizes digital technologies to improve agricultural productivity and efficiency. In Jordan, the government has been promoting the adoption of digital agriculture to enhance food security and address the challenges facing the agricultural sector.

Digital agriculture

With over 80% of the Jordanian farmers using smartphones, the information and communication technologies (ICTs) will change the way agriculture is doing business. The widespread adoption of ICTs reduces information gaps and transaction costs, improves service delivery, creates new jobs, generates new revenue streams, and helps conserve resources. ICTs also transforms the way people and governments work, interact, and communicate. These technologies are effective instruments for empowering rural populations, for increasing choices for rural men and women, especially youth, and for enhancing their abilities to increase incomes and participate in a more effective manner in the development of their communities. In Jordan, there are a few examples of digital agriculture that are being implemented to improve the country's agricultural sector. Here are some of them:

- Agri Jordan: This is a mobile app developed by the Ministry of Agriculture in Jordan that provides farmers with information and advice on farming practices, weather, market prices, and other agricultural-related topics.
- Farm Crowdy: A digital platform that allows people to invest in agriculture in Jordan. The platform connects investors with farmers and provides them with funding to grow crops and raise livestock.
- Agri coolture: A Jordanian startup that uses hydroponic technology to grow vegetables in urban areas. The company uses sensors and data analytics to optimize plant growth and reduce water usage.
- Smart irrigation systems: The use of sensors and automated irrigation systems is becoming increasingly popular in Jordan. These systems can monitor soil moisture levels and weather conditions to optimize water usage and reduce waste.
- Digital soil mapping: The Ministry of Agriculture is using digital soil mapping technology to create detailed maps of soil properties across the country. This information can help farmers make more informed decisions about crop selection, fertilization, and irrigation.
- Al-Masiah Smart Agriculture: Is an ambitious agricultural project that applies hydro biological farming. This kind of agriculture saves 80% of the water used in traditional farming, limits the use of insecticides and chemical fertilizers and increases harvest eightfold. Hydro biological farming is an integration between two farming systems, aquaculture and hydroponics. It requires controllable environments or conditions using machines and pumps to provide the right requirements of oxygen, moisture, temperature, etc. All these requirements can be administered via artificial intelligence and the internet of things. But so far, this system has not been adopted widely in Jordan.

These examples show that there is a growing interest in using technology to improve the efficiency and productivity of the country's agricultural sector.

Digital agriculture in Jordan is limited by many factors, including low awareness and understanding of digital technologies and their potential agriculture sector applications, limited interest among public and private sector agents, a general lack of appropriateness to small-scale farmers (for instance, a mismatch between the language used by technologies and those understood by farmers), and inadequate access to finance and data. Achieving successful results will require that users have a better awareness of digital applications, and digital applications provide timely, localized, and customized information addressing specific farming concerns in a comprehensible format and in Arabic or local languages. The public sector has an important role in identifying public goods, policies, and investments needed to maximize the societal benefits from digital agriculture in increasing efficiency, equity, and environmental sustainability in agri-food systems. To achieve the development goal of digital transformation, the public sector can facilitate and attract private investment resources by: promoting direct investment; adjusting the regulatory and incentive frameworks for private sector investments; and forming partnerships with the private sector, donors, and nongovernmental organizations. Public action to facilitate digital technologies adoption can contribute through three pathways: developing a vision, then developing the foundation, and providing catalytic investments and policies. The vision should include an aspirational statement and specific targets and actions to foster digital agriculture. The vision can be realized though a national agricultural strategy or a stand-alone e-strategy. Further, digital technologies are only a means to reach development objectives, and adopting these technologies should not be considered as the end goal. They must be accompanied by enabling policies and reforms, both in terms of services and infrastructure and in terms of socio-economic and cultural acceptance.

The catalytic investments and policies include establishing e-Government systems for all public services, facilitating the deployment of smart irrigation and fertilizer management systems along with appropriate policies to safeguard overexploitation of natural resources, and fostering digital ecosystem development. E-Government systems can include: gathering and disseminating statistics relevant to the agriculture sector, creating farmers' digital identification, providing extension services, regulating land tenure and markets, and ensuring delivery of public support payments. While promoting the deployment of smart irrigation and fertilizer management systems, it is important to apply diverse service delivery approaches to enable smallholders to adapt digital technologies. To promote innovation, it is important to invest in platforms for data collection and access from public and private sources. This investment may accelerate the development of appropriate products and services for smallholders and develop a foundation of data for evidence-based policy making.

Parallel investments are required in the enabling ecosystem at country, regional, and international levels for developing and supporting incubator and accelerator services targeting start-ups and private sector innovators in the agri-food sector.

Policies that facilitate socio-economic and cultural acceptance are for instance policies that rebalance the power dynamics, ensuring that farmers have negotiating power, are not damaged and share the benefits of the wide-spread use of digital technologies: for example, adopting policies on digital privacy, ownership, data reuse consent, commercial lock-in, data sovereignty in general, unfair monetization and benefit sharing is essential to safeguard against unintended consequences.

Production and precision agriculture

Agriculture occupies a minor share of the land area in Jordan, and the major agricultural products include vegetables, fruits, and roots and tubers. Agricultural land occupied only 12.0 % of all land area in Jordan in 2016. In absolute terms, agriculture occupied 10,660 km². The production volumes have at least doubled between the 1960s and 2010s, largely due to yield improvements. In contrast, the production of cereals and pulses has declined in volume over the same period, as the area devoted to the production of these crops has fallen (World Bank 2018). Vegetables are produced primarily in irrigated areas of the Jordan Valley and to a lesser extent in the eastern plains. Citrus and palm trees are grown under irrigation in the Jordan Valley. Stone fruits and grapes are mainly grown in the northeastern areas of the country under irrigation. Olive trees comprise a major share of all trees grown (72 %), though only a minor share of these are irrigated (38 %) (Department of Statistics 2017). Jordan is self-sufficient in the production of vegetables, citrus, olives and olive oil, goat meat, poultry, table eggs, and fresh milk (Jordan Investment Commission 2017).

Digital technologies can improve the quantity and quality of agricultural output while using less inputs (such as water, energy, fertilizers, and pesticides), increasing efficiency by performing farming practices remotely, and achieving positive environmental effects through lower input (fertilizer and pesticides) use (World Bank, 2019). Controlled-environment agriculture (greenhouses, indoor farms, and vertical and hydroponic farms) increasingly uses digital technologies including sensors, robots, and digital communication. More advanced digital agriculture approaches such as precision agriculture leverage digital, mobile, Internet of Things (IoT), and cognitive technologies by relying on tools including global positioning system (GPS) enabled guidance, control systems, sensors, robotics, drones, autonomous vehicles, variable-rate technologies; automated hardware, telematics (that is, an interdisciplinary field that encompasses telecommunications), electrical engineering, computer science, and vehicle technologies; and software. Precision agriculture practices for livestock farming include sensors, radio frequency identification (RFID), and automated or robotic milking and feeding systems. Digital technologies are particularly used for improved irrigation and hydroponic production in Jordan. In Jordan, the largest uptake of digital technologies on farm is the application of imported irrigation-related technologies such as sensors. The focus on irrigation is reasonable, given the scarcity and relatively high cost of water. Digital technologies that control irrigation, fertilization, temperature, and humidity are used in many initiatives to develop soilless agriculture, led by Jordan’s Ministry of Agriculture. Large, private farms are also pursuing initiatives to digitize agricultural operations to control irrigation, fertilization, temperature, and humidity. However, the use of digital images or drones in the agriculture sector is limited due to security concerns and the need for legal permissions. Several private sector vendors are currently offering digitally enhanced agriculture technologies to the market. Private companies import precision agriculture technologies for the high-value and export-oriented firms, but there is a lack of local firms providing mobile applications for operations management or blockchain solutions in local languages. Additional digital technologies are under development by start-up companies, with plans for commercial sale in the future. The domestic start-up space is largely focused on developing technologies that are appropriate to small- and medium-size farmers. Large-scale farmers tend to import technology directly from outside. For example, a Jordanian start-up company has developed devices that can provide early detection of red palm weevil larvae inside palm trees. A device attached to a palm tree can assess whether the tree is infected by either listening to the sound produced as weevils eat the insides of the tree or by capturing vibrations from inside the tree. Measurements are then analyzed using algorithms to distinguish noises and vibration caused by weevils compared to other sources. Remote sensing and digital modelling are increasingly used to assess agricultural water use efficiency and the impacts of climate change in Jordan. Remote sensing technologies are used to estimate evapotranspiration for monitoring agricultural water use.

Prices and marketing

Digital Technologies to deliver market information and e-commerce, several web-based applications have been introduced to support agri-food marketing by sharing information on prices. In Jordan, web-based applications on prices have proven very popular. For example, the wholesale and vegetable market of the Greater Amman Municipality maintains a website that displays the quantities of local and imported fruits and vegetables and the prices traded in the market (highest, lowest, and majority). The Jordanian Exporters and Producers Association for Vegetables and Fruits (JEPA) also operates a website containing price data, including the local prices in the country of origin and market prices in the countries importing fruits and vegetables. It also details information and standards required by exporters. Wider adoption of digital marketplaces can reduce price manipulation. For example, in Jordan, current practices within wholesale markets allow for manipulation, with traders buying the same goods multiple times to artificially raise the prices. Farmers paid the initial lowest price while the trader retains the margin between the lowest and highest prices obtained. For digital marketplaces to be widely adopted and to meet their potential for significant growth, policies and investments are needed to eliminate the main constraints. These constraints to faster adoption of e-marketplaces include a lack of knowledge and skills, low trust in online transactions, and limited logistics infrastructure, such as storage and transportation of fresh produce. Private and public sector initiatives have sought to establish web-based applications for the marketing of agri-food products, linking producers and consumers. For example, Ghoorcom (entrepreneurial firm) launched in Jordan in 2017 as an online marketplace connecting farmers with businesses (B2B) and with consumers (B2C). Jordan also has the Open Market website that focuses on popular food products but also sells electronics. Informal Facebook and WhatsApp groups are used sporadically for agri-food e-commerce. The government has launched an online platform called e-Agriculture, which provides farmers with information on crop prices, weather forecasts, and agricultural best practices. This platform also facilitates e-commerce transactions between farmers and buyers, which can help to increase farmers' incomes and reduce food waste. And ongoing EU projects are supporting the development of a digital agriculture platform, including access to finance and connection to input suppliers. The mixed performance of digital platforms serving agriculture suggests that policy makers and other relevant actors should consider their experiences as they work to develop and implement similar platforms in the region, since not all e-commerce attempts lead to successful outcomes.

Overall, digital agriculture in Jordan is still in its early stages, but it has the potential to transform the agricultural sector and address some of the challenges facing farmers, such as water scarcity, climate change, and market access.

3.1.2 Overview of the Role, Adoption and Use of Technology in Agriculture in Egypt

Agriculture is Egypt's third largest economic sector, accounting for 11.2 % of the country's gross domestic product (GDP) and 23.8 % of the total employment census (5.2 million workers), which considered the largest participation of those engaged in economic activities. Although only 3.8 % of land is cultivated (European Centre for Economic Studies, 2020). It is an essential sector for employment, growth, poverty alleviation, food security and export promotion. This sector employs a large number of women, representing 24.6 % of total employment and equaling to 45 % of total women in Egypt's labor force. The sector employs more than 55 % of all jobs in Upper Egypt, which demonstrates its ability to improve the social and economic conditions of farmers. Although the sector accounts for about 20 % of total exports and foreign exchange earnings, Egypt imports about 40 % of its food needs and incurs a total food import bill of US $2.5 billion annually (FAO, 2021). There has also been a significant expansion in land reclamation in recent years. Nearly 840,000 hectares will be added to the agricultural area during 2020-2023, most of which follows modern methods of cultivation, making the sector more important. Contribution of the agriculture sector to the GDP reached 14.8% in 2020 reaching 669.8 billion, public investment in agriculture greater 5 times at present, it reached 28.7 billion pounds in 2020 compared to 5.2 billion pounds in 2015.

Since the COVID-19 pandemic, due to its various repercussions on society, much has changed in the behaviour and attitude of many Egyptians towards the adoption, diffusion and adaptation of technology. Digital transformation provides great opportunities for Egypt. However, innovation in general and ICT in particular cannot solve all the problems or answer all the economic and social challenges that have evolved over many decades. While digital transformation can make a big difference to the economy and provide a more convenient business environment, it must be supported by the required global digital infrastructure and capital, appropriate legal, regulatory, investment, governance, education and security environments and other enabling and supportive environments. Previous studies showed that Egypt suffers from great challenges such as 1) increasing the scarcity of land and water resources, 2) challenges and risks of agricultural land per capita which is less than 0.1 acres, 3) Egypt imports more than 60% of its food needs, and 4) the problem will be worsen in the future with population growth, Ethiopian dams and climate changes (Gamal Cium, 2021). Thus, Egypt can only resort to technological advances as an effective means of increasing the overall productivity of production elements (land, water, labor, capital) and thus accelerating growth rates in agricultural and food production.

The updated 2030 Sustainable Agricultural Development Strategy indicates that the overall productivity of agricultural production components is growing at a rate of 1% per year, which is slow and productivity at the crop level is almost constant over the past decade. Thus, the use of digital transformation could be an effective tool in raising productivity growth rates. Egypt's agricultural systems were less efficient as a result of the sovereignty of small farms. Digital transformation could link these farms to the market, thus, the use of digital transformation could be an effective tool in raising productivity growth rates, which included the digital system of the agricultural sector and increased national incomes. The vast majority of Egyptian farms are small; hence

digital farming is very important to them. The acceleration of Egypt's digital transformation is an opportunity for the government to influence various economic sectors and industries including, but not limited to, financial services, retail, health care, agriculture, manufacturing, education, tourism, media, culture, in order to achieve inclusive, sustainable and impactful economic growth. Egypt needs to implement a comprehensive approach to building a dynamic and integrated ecosystem through digital transformation. The adoption of digital tools, including artificial intelligence, can help address some of these problems and transform the sector.
Over the last seven years, the Egyptian Government has had no other option to upgrade the agricultural sector and increase the productivity of crops. But the trend towards the world of agricultural digitization and the exploitation of the digital transformation that the world is witnessing in all sectors to develop Egypt's agricultural wealth, enhance the productivity of agricultural commodities and increase the invoice for exporting products abroad. After many countries in the world made a major breakthrough in their circulation to modernize and digitize agricultural services cultivation and climate change that changed the course of the agricultural map. The Ministry of Agriculture and Land Reclamation is currently making considerable efforts in the area of digital transformation, given the importance and value of transformation in the management of this vital sector. Digital transformation has been included as one of the programs of Egypt's updated agriculture strategy. Currently focusing on modernizing the agriculture sector and attention to smart farming applications. The enormous revolution that digital technology will bring in the world of agriculture and how agricultural processes will perform, pointing out that this enables farmers to have access to information and guidance on their crops and livestock health to make sound and effective decisions on how to optimize the use of their plant and animal resources.

There are efforts through cooperation between the Ministry of Agriculture and the Ministry of Communications and Information Technology, which include the work of inventorying the tenure of agricultural land, smart cards for farmers, and identification of crops through satellites and artificial intelligence and smart assistants for farmers, digitization of agricultural documents, and the creation of electronic archiving. This is in addition to the transition to more modern irrigation systems (MCIT 2021). In 2019, FAO and the Egyptian Government launched a program to enhance agricultural productivity through digital technology. The implementation of digital technology helps farmers to access information for improving crop and livestock management and thus helping them make better agricultural decisions. Digital technology also helps to enhance food security by reducing production and waste costs. It also increases crop productivity with accurate data to calculate production activities such as estimating daily irrigation and composting requirements. The application of ICT facilitates the flow of information and services to farmers and expands market access. With the help of several research institutions of the Agricultural Research Center, the program transformed technical content into digital content accessible via mobile applications. With the adoption of mobile applications, Egypt's agriculture will expand as a result of increased access to resources. It manages the group of agricultural operations by providing information on the dates of irrigation, the temperature required for the growth of the cultivated crop and the agricultural machine used in this process. It automatically implements the orders and this is done at all stages of agriculture, from the beginning of crop cultivation to the harvest.

The Ministry of Agriculture and Land Reclamation, in collaboration with the Ministry of Planning and Economic Development and the Finance Group, launched in 2021 Egypt's first online platform for the agricultural sector, within the Egyptian Digital Agricultural Network to provide support, finance, trade, research, extension, marketing, inventory, mechanization and supply services to the agricultural sector. The establishment of Egypt's first digital agricultural network took more than 5 years of continuous work, in cooperation with various relevant agencies, ministries and bodies, to develop the agricultural sector in various ways and modern technological methods, meeting the aspirations of the Egyptian economy for development and financial inclusion, integrating the informal sector, supporting small enterprises and developing Egypt's villages. Similarly, the Ministry of Agriculture and Land Reclamation, in collaboration with the Ministry of Planning and Economic Development and the Finance Group, began the first step of building the digital agricultural network in 2016, finalizing the digitization of the agricultural holdings database for about 9 million agricultural acres, issuing a farmer's card for more than 5.5 million farmers, including ownership information, space and cultivated crops, which has seen successive stages of development and the inclusion of more services. The Ministry of Agriculture and Land Reclamation, in collaboration with the Ministry of Planning and Economic Development and the Finance Group, worked on the second phase of construction of Digital Agricultural Network, automation of electronic services for more than 5,700 agricultural associations and also supplied with tablets and devices. In addition to training 8100 association workers in the use of modern technology to make the best possible use of the farmer's card. In 2019, the first and largest agricultural database was completed and started linking associations with Kart al-Falah in one network at the Information and Decision Support Centre of the Ministry of Agriculture.

In 2019, the Finance Group in partnership with the Ministry of Agriculture and Land Reclamation established “Markets Egypt” to achieve the first steps for Egyptian farms to benefit from the Digital Agricultural Network.

“Markets Egypt” developed a platform "Make Egypt" with state-of-the-art in e-commerce technologies and features to serve as the interface between farms and all parties in the sector from suppliers, agricultural associations, supporting bodies and finance institutions. “Markets Egypt” also provides packaging, shipping and delivery services, providing all electronic payment methods, and granting facilities through Cart Al-Falah, which has become a card of payments with advantages and banking services, thus using e-commerce technology to transform traditional supply chains into value chains. In 2021, in cooperation with Finance Group, “Markets Egypt” and the Agricultural Bank of Egypt, played a pivotal role in extending financial inclusion program for the agricultural sector through the establishment of the first integrated digital finance platform "Finance Egypt". The new system offers many forms of financing supported by the digital lending feature through the Agricultural Bank. Financing is calculated on the basis of the area of land and crops allocated to each tenure, after the approval of the applications submitted electronically and the finalization of the final signatures in one of the branches of the Agricultural Bank. The platform thus contributes to supporting the country’s policies of financial inclusion and support the economy through export opportunities as well as contributing to the application of professional quality control systems and contributing to application of the latest international standards associated with agricultural, animal and fishery production and manufacturing systems.

Agricultural digital platforms set the right policies for different agriculture sectors not only in crop cultivation, but also for livestock farms, poultry husbandry, fish farming farms, and state-owned private agricultural projects. For example, digitization played a significant role in monitoring the fall army worm through an early warning system to help farmers in the fields calculating, anticipating infection ratios and proposing remedial actions to address the threat of this rough bug as well as saving farmers and minimizing losses. The importance of expanding the use of space imagery and its use to feed artificial intelligence and technological development programs, making data available and expanding the exchange and circulation of information, as well as building up-to-date databases. Projects to automate the agricultural tenure system and issue of farmer's card, were completed by the Ministry of Agriculture. Implementation of these projects aimed at accelerating the digital transformation process of the Ministry of Agriculture and developing working methods based on modern technologies. The agreement also included the digitization of 130 services covering all sectors to be launched on Egypt's digital platform within four phases, with the first phase comprising 20 services most in demand.

Digitization of agricultural extension is a top priority for digital transformation. This is followed by the digitization of agricultural marketing, the digitization of soil and water management, and the digitization of livestock and livestock production.

The Ministry of Agriculture and Land Reclamation, in collaboration with the FAO, has launched a digital application entitled "Beneficial in Food and Agriculture" to support extension services for farmers and rural women. Information and guidance recommendations are presented in a variety of written, visual and audible images to meet the diverse needs of farmers, rural women and young people in rural areas. Zarie is the first agricultural platform in Egypt to rely on satellite technology and provide services to farmers and agricultural companies to help promoting agricultural production and overcome obstacles facing farmers, especially the impact of climate changes on agriculture. Agrogate Masr is a digital platform that serves the exploiters of agriculture, including small-scale farmers and agricultural investors. It provides agricultural guidance through read, audio and recorded content in the form of training courses, articles, etc. It provides a specialized agricultural consultancy service that focus on caring for livestock and strategic crops for food security, as well as some exported crops and linking them to the value chain global. Recently, the FAO launched a digital model of agricultural extension under the framework of enhancing national capacities in information exchange and technology transfer to enhance agricultural productivity within the country program framework signed between FAO and the Government of Egypt for the period 2018- 2022. Digital technology is a technique that can help to face the famine threat and to achieve food security in a world where challenges exist in the nutritional field due to the rapidly growing population growth with the shrinking arable lands, to the decline of workers especially young people from practicing agriculture. “MoALR” is working to activate the role of ICT in the agricultural sector. It is working to raise the personnel’s efficiency and the management of services provided, in order to facilitate citizens’ access to the services provided by the Ministry to support the agricultural system and raise awareness among farmers in Egypt. The Central Laboratory for Agricultural Climate (CALR) provides agricultural meteorological data in line with agricultural activities, including the use of mathematical models to estimate the daily needs of irrigation, fertilization. The provided data can also help in predicting future diseases and pests and calculating the cold degree needed for fruit trees. “MoALR” is currently establishing an advanced central information that includes a comprehensive database on animal, poultry and fish production within the National Information Technology Program. Moreover, an epidemiological map of animal diseases has been developed, which helps making a controlling plan. The remote sensing technique is used to monitor encroachment of lakes and agricultural land, and to help put an end to them. It can also help to develop an early warning system to predict transboundary diseases such as Rift Valley Fever.

The logical step of digitizing the sector is to build a comprehensive digital platform capable of providing comprehensive services to farmers - from crop selection, improved planting times, seeding and composting rates based on plants' actual needs and regulatory requirements. All data collected during a particular crop cycle can be compared with other farmers who grow the same crop in similar conditions. Lessons learned from the field can automatically be applied to another field to increase production, and this approach can help improve the productivity of major crops with 20 to 30% intensive farming. The Government of Egypt determined to implement and mainstream the digitization system and replace documents and papers with modern technology that ensures the continuity and vitality of life and removes the burden of waiting and red tape. The Ministry of Agriculture has therefore continued to digitize and automate its services. Digital transformation, automation of services, and modern technology are very important in the Egyptian agricultural field, especially there were a number of fields where modern technology was used and data became more accurate and accessible. The Ministry of Agriculture recently signed an agreement with the Ministry of Communications for digital transformation process with state-of-the-art technology. For example, satellites now are able to determine the size of rice crop cultivation and consequent determination of the quantities of consumed water in those areas, once the cultivated areas of rice exceeded the specified quantities, this will be immediately disclosed using satellites and taking the necessary steps and measures.

In conclusion, Egypt has shown some reasonable progress in the digitalization journey over the last decade. Such progress could be described to include: 1) some clear and relatively advanced adoption by segments of the society on an individual basis; 2) a growing and promising adoption by tech-enabled start-ups and through ICT-enabled services; 3) early-stage adoption of electronic government services; and 4) an insignificant ICT adoption level by private sector enterprises. Moving forward, with further universal dissemination of the ICT infrastructure and connectivity coupled with a growing level of ICT adoption, the potential impact of digital transformation on the economy in Egypt could be significant and a game-changer for the economy. However, as it stands, the associated evidence remains limited and requires further research to assess the repercussions of current and future disruptions on employment opportunities, micro, small and medium enterprises (MSMEs), productivity, and inequality, and to study the correlation between adoption of digitalization and implications on labor productivity and performance. However, most of these efforts and initiatives remain scattered and fragmented and lack coordination and integration within national agricultural systems. It is not clear how current digital transformation efforts will be reflected in the legal framework, however, digitization without addressing lack of a clear vision or long-term structural issues, will have limited impact. Some of these issues include failure to properly implement many agricultural laws due to lack of implementing regulations e.g. Contract Agriculture and Agricultural Insurance Act, insufficient incentives to invest in water conservation technology (Kassem et al., 2018), institutional conflicts of interest with Government's participation in professional associations, and allocating small budget for research and development (European Centre for Economic Studies, 2020). In addition, there is a lack of coordination among various stakeholders, especially those involved in agricultural policies, weak telecommunication, illiteracy, technology infrastructure, all this lead to low levels of agricultural productivity.

3.1.3 Overview of the Role, Adoption and Use of Technology in Agriculture in Tunisia

The digitization of the agricultural sector is lagging behind in Tunisia, despite the benefits that these technologies can provide and despite the incentives put in place by the State, for the benefit of investors in this sector. The Ministry of Agriculture is developing the appropriate strategy in this area, in consultation with all stakeholders, partners and donors. The State will also have to ensure the necessary infrastructure, adjust the regulatory framework to the requirements of digitization and provide the necessary incentives for young developers and startups interested in investing in agriculture. Experiments initiated in the use of new technologies in agriculture, including the use of drones in the monitoring of field crops and fire prevention, digital management of water resources, the use of satellite data to count the cultivated area and predict the harvest. In the same sense, the Tunisian Agency for the Promotion of Agricultural Investment supports the initiatives of young people in this field by intensifying the specialized support and training in the field of modern technologies, in cooperation with the Foundation Tunis Smart Poles, in order to reach advanced stages to benefit from this digital transformation. The constraints that hinder the digital transformation of Tunisian agriculture so far are lack of necessary digital infrastructure in some areas, weakness of digital payment options, and a regulatory framework unfavorable to access data (open data) (Omar Ksibi, 2019).

In Tunisia, although still in its early stages, precision agriculture has been developed and used by a small number of start-up companies such as Ifarming, Seabex, Ezzayra, and MooMe. This type of agriculture also relies on activities that use drones, managed by the Société Nationale de Protection des Végétaux. I-farming, a startup founded in 2015 that took part in an acceleration program in France in 2019, also known as Station F, is currently in talks to be awarded international venture capital funding. In Tunisia, financial services for the agricultural sector are limited. However, the microfinance organization Enda/Tamweel has established a major initiative to provide loans via a digital platform for the purpose of financing precision farming and livestock. Today, there is no technology used to screen lending and reduce the risks associated with agricultural lending in Tunisia (FAO, 2020). Plantix is a mobile application, on smartphones, was established by the German Agency for International Cooperation in Tunisia. This application for cell phones can diagnose plant pathologies and detect pests and nutrient deficiencies that affect crops. This digital solution for which allows farmers to identify, through photos, diseases and pests that attack their plants and quickly access information on methods of curative and preventive control necessary. It is a digital decision support tool that allows Tunisian farmers, especially those in disadvantaged areas that do not have access to expert services, to better protect their crops and reduce production losses due to diseases and pests of plants. Plantix Tunisia provides useful information on plant diseases and pests affecting the following agricultural products: olives, apricots, pistachios, potatoes, peppers, tomatoes, citrus (lemons and oranges), peaches, almonds, vine. PlantMed, a network of young plant specialists, was recently created (with a significant participation of women in the steering committee) and also includes the creation of an exchange forum in Arabic with over 8,000 downloads. It is already used by more than 15,000 people in Tunisia and has more than 70,000 images taken collected and validated locally during almost a year (FAO, 2020; Web Manager Center, 2018). Coconut, a name that three young Tunisians have given to a robot designed to be intelligent, autonomous, connected, economical, ecological and capable of solving concrete problems, including planting on specific plots. This robot can plant small plants in the fields without intervention. It can identify insects and weeds that harm the plant and diseases and adapts in height and width to different types of planting. The objective of their creation is to help farmers to do without some small repetitive tasks that lack manpower. The robot is, on the other hand, a mobile platform that looks like a tractor, but with an interchangeable and programmable part (Web Manager Center, 2019).

A study was made showing the potential offered by ICT for the development of agriculture, by proposing an innovative method of integrating drones in the technical management of orchards in Tunisia. Such feedback should contribute to the evolution of current regulations in Tunisia in order to make these technologies accessible to the greatest number of people and to increase their economic and environmental benefits. Thus, it is proposed to test a method of estimating the leaf area index or LAI (Leaf Area Index) of a peach orchard using low altitude images taken by a drone. It allows to manage the technical itinerary of the crop, because the leaf area depends in part on the water needs for irrigation and the necessary doses for phytosanitary protection. For step 1, low altitude aerial photos were taken from a self-piloting hexacopter drone, with a payload of 900 g for a flight autonomy of 12 min. In step 2, the aerial photos are processed with AgisoftPhotoscan, a software program that creates a 3D model of the plot from multiple images of the same area. In step 3, the 3D model is then used to simulate hemispheric photos via image synthesis based on the Raytracing technique. This approach allows to simulate hemispheric photos at any point. Thus, it is not only possible to simulate the same images as those taken in the field, but also to simulate other images, which allows a denser sampling of the plot. The simulated images are then processed by the "Hemisfer" software to calculate the LAI. However, the encouraging results obtained with the proposed method make it possible to consider an operational use of LAI in the technical management of the orchard (Mabrouk et al., 2018).

Among the successful experiences in the world of digital agriculture in Tunisia is the agritech start-up: Ezzayra. The technology of sensors installed in the irrigation pipes and in the soil, and a wireless box connected to Ezzayra's software, help managing the farm. In this case, the system allows to regulate the salinity of the soil and inject the necessary mineral salts or not in relation to the rainfall. The farm is connected to a station that automates the irrigation and fertilization processes. This system is connected to a citrus crop that consumes a lot of water. Instead of having workers spend their time opening and closing valves, everything is calculated and established by the computer. The program is also able to identify drip leaks that are difficult to identify with the naked eye. It reduces the costs associated with waste and lack of monitoring (Blaise, 2020). Similarly, another successful experience in the world of digital agriculture in Tunisia is the use of drones in the agricultural sector which will allow, in the near future, to significantly optimize the work of Tunisian farmers. This will allow farmers to make reliable and relevant decisions to better manage their land. A camera equipped with "RGB" technology, the drone takes note of the nitrogen levels emanating from the potato field and it flies over. The data collected will be analyzed and interpreted. Then, in consultation with the farmer, the decision will be made to give a boost to one or more sectors of the plot by spreading additional doses of nitrogen necessary for the photosynthesis of the crops and, therefore, their growth. A very precise mapping of the areas lacking in fertilizer will allow the additive to be spread with a precision of a few centimeters. As a result, the farmer will boost yield and save quantities of nitrogen by targeting only the deficit areas (Groupe de la banque africaine de développement, 2022). The application Kolfa, which means cost in Arabic, has just been officially launched by the National Observatory of Tunisian Agriculture to Tunisian farmers. This application aims to provide Tunisian farmers with useful information such as prices of agricultural inputs and services (seeds, seedlings, pesticides ...). It is a great step forward for farmers in the country, thus, each farmer will be able to compare the prices charged by different suppliers to avoid speculation and create price transparency (Tekiano, 2020). The first Tunisian digital platform "Farmer to Farmer", dedicated to learning and agricultural extension distance for the benefit of farmers and fishermen, was launched in 2021. This is a virtual space that will popularize good agricultural practices to increase the yield of the sector and preserve natural resources through new technologies and development of scientific research results (Web Manager Center, 2021).

3.2 Conclusion

Digital agriculture is an emerging field that utilizes digital technologies to improve agricultural productivity and efficiency. Governments in the NENA region has been promoting the adoption of digital agriculture to enhance food security and address the challenges facing the agricultural sector. Digital agriculture has the potential to transform the way we grow and produce food. By collecting and analyzing data, farmers can make data-driven decisions that improve efficiency, productivity, and sustainability. As digital agriculture continues to evolve, it has the potential to improve food security and reduce the environmental impact of agriculture. Likewise, digital agriculture has the potential to revolutionize agriculture by improving productivity, reducing costs, and enhancing sustainability. However, the adoption of these technologies is not without challenges and limitations. Governments and stakeholders need to invest in infrastructure and provide adequate support to enable farmers to adopt digital technologies effectively. Additionally, farmers need to be adequately trained and educated on the use of these technologies to enable them to benefit fully. Ultimately, the successful adoption of digital agriculture will require collaboration among all stakeholders, including farmers, governments, and the private sector. Therefore, it is necessary to make efforts in the development of research processes and the regulatory environment to contribute to achieving sustainable development by preserving natural resources through the introduction of modern technologies and raising the efficiency of agricultural production using artificial intelligence and the concept of agricultural digitization and mechanization of agricultural work, which would organize the progress of work related to the agricultural sector in accordance with a pace that ensures achieving scientific research priorities, and sustainable development goals, with a focus on spreading the concepts of growing deficit crops and crops with high added value.

Advances in science, technology and innovation are providing immense options in generating knowledge and providing solutions to increase productivity. New digital technologies are driving the agri-food transformation process at a faster pace that has never been experienced before, shifting how agricultural value chains are organized, providing new opportunities for more and better jobs, entrepreneurship, and innovations to address binding constraints in food systems. On the other hand, it is also argued that innovation and deployment of technology should be driven by a bottom-up inclusive process, with smallholder producers and SME agribusinesses at its center (farmer, rural communities and women). This argument highlights the imperatives for building support systems and capacities for small holder producers and SME agribusinesses. Strengthening the capacities of the smallholder producers and SMEs is a key element in all its aspects (information and knowledge, skills, behavioural, institutional, organizational, financial, etc.) to generate effective demand for science, technology and innovation. Harnessing science, technology and innovation, including digitalization therefore raise issues of growing concern about sustainable and equitable accessibility and affordability to significant actors, small producers in particular in the NENA region context such as Jordan, Egypt and Tunisia.

CHAPTER 4

4.1 Presentation of the Study Findings

A regional survey in Jordan, Egypt and Tunisia was undertaken to gather data from farmers and family farms in these countries to identify the current uses, needs and expectations of digital agricultural solutions. The goal was to collect data and have perspectives, attitudes, perceived challenges and drivers related to use of digital solutions from farmers in different regions within each country. The instrument and main method for data collection was a survey questionnaire that was disseminated online by various digital media through email, social platforms, and Google Form, and face to face through farmers' organizations, cooperatives, meetings and field visits. A total of 214 responses was collected, 69 responses were from farmers in Jordan of which 8 responses were from women, 74 responses were from farmers in Egypt of which 2 responses were from women, 71 responses were from farmers in Tunisia of which 5 responses were from women. Participants were selected purposively and representing diverse farmers (small to large farmers, men and women, family farming) from different agricultural regions within each country. Preliminary analysis of the data was done parallel to the data collection process to track emerging themes and patterns from the responses and to evaluate the sufficiency of the data. The findings were only used in aggregate with the responses of all other participants due to the nature of this study in digital agriculture. The final analysis was made immediately after all the required data were completed using SPSS software analysis.

4.2 General characteristics

The first question was asked to participants was about the method of irrigation on farm because irrigation is an essential element of modern agriculture, and the choice of irrigation method can have a significant impact on the efficiency, productivity, and sustainability of farming systems. The choice of irrigation method should be carefully considered, based on factors such as crop type, soil type, climate, and water availability. Most of respondents were using either surface irrigation or drip irrigation methods as shown below in Figure 1, these methods are essential in farming systems as they play a crucial role in water conservation, crop yield, soil health, and environmental sustainability.

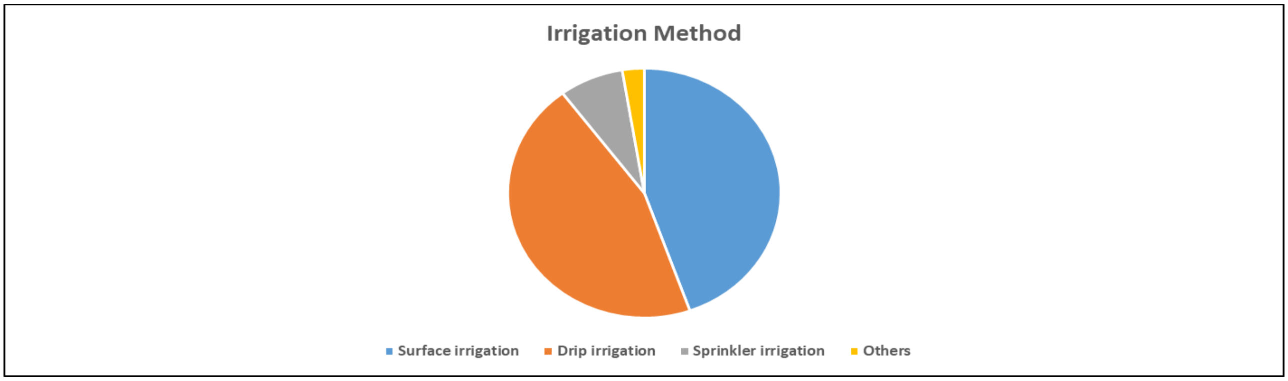

Figure 1: Methods of irrigation that were used by farmers.

The majority of respondents 83% identified themselves as family farmers, 15% as members of a family farming unit, 14% as member of farmers' organizations which indicate that the majority of respondents were engaged in family farming. There were only 1 to 8% of respondents who were leaders of trade organization or marketing organizations or farmers' organization or farmers' representative in dealing with other types of bodies. Nonetheless, those respondents were also producers and working in the farming system as shown below in Figure 2.

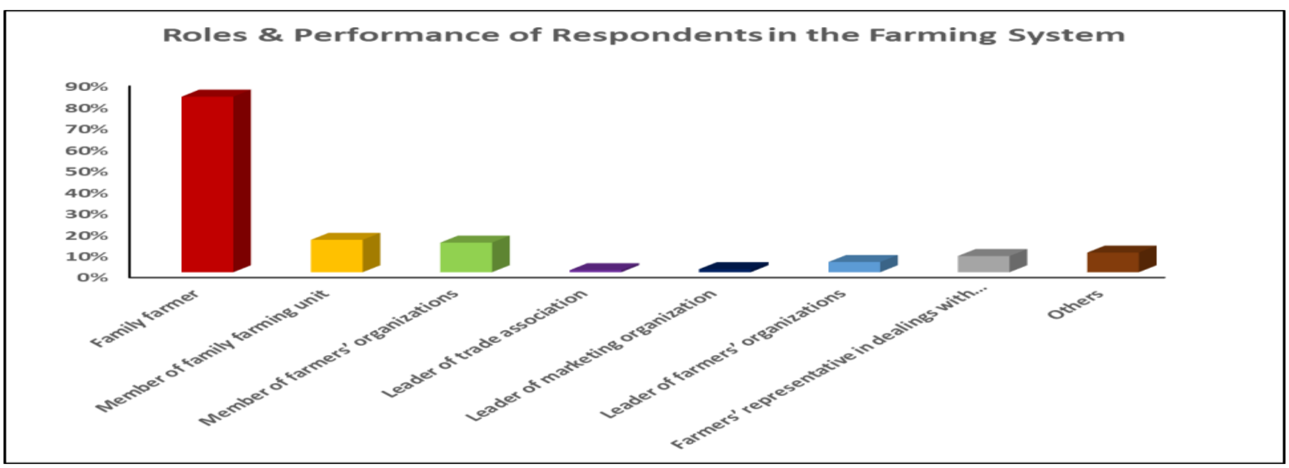

Figure 2: Roles and performance of respondents in the farming system.

The predominant range of age of respondents was 40 to 60 with 60% of respondents fell in this category. Only 20% and 18% of respondents corresponded to the age category of 20 to 40 and over 60, respectively, as shown below in Figure 3.

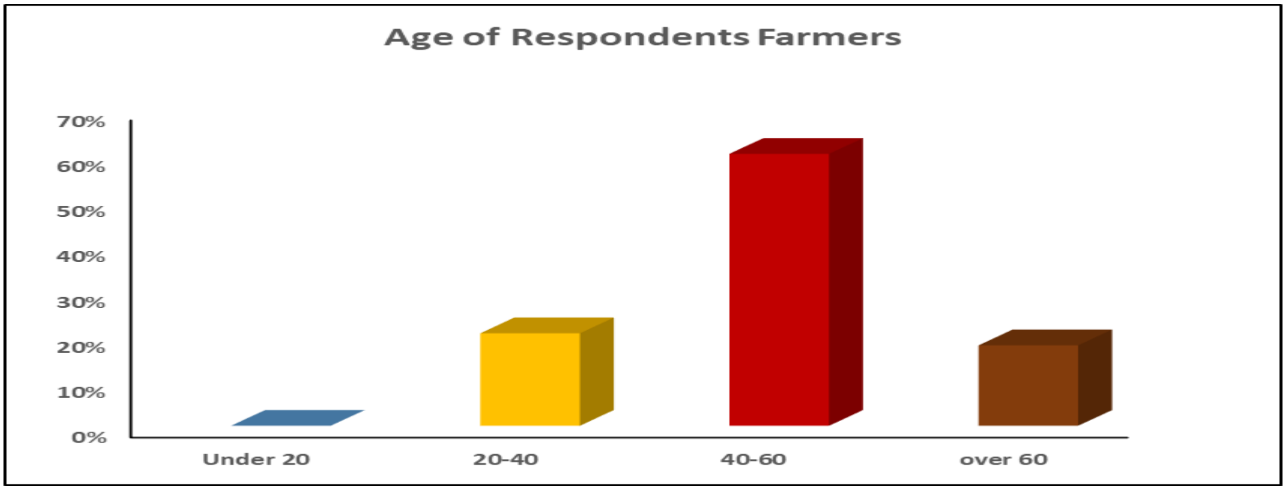

Figure 3: Age categories of respondents' farmers.

A very important aspect of using digital agriculture tools is the education level of farmers, therefore, participants were asked about their educational level where most of respondents indicated that they have a college or university degree, this followed by respondents who indicated that at least they have a high school diploma. A very low percentage 17% of respondents who indicated that they have a primary educational level as shown below in Figure 4.

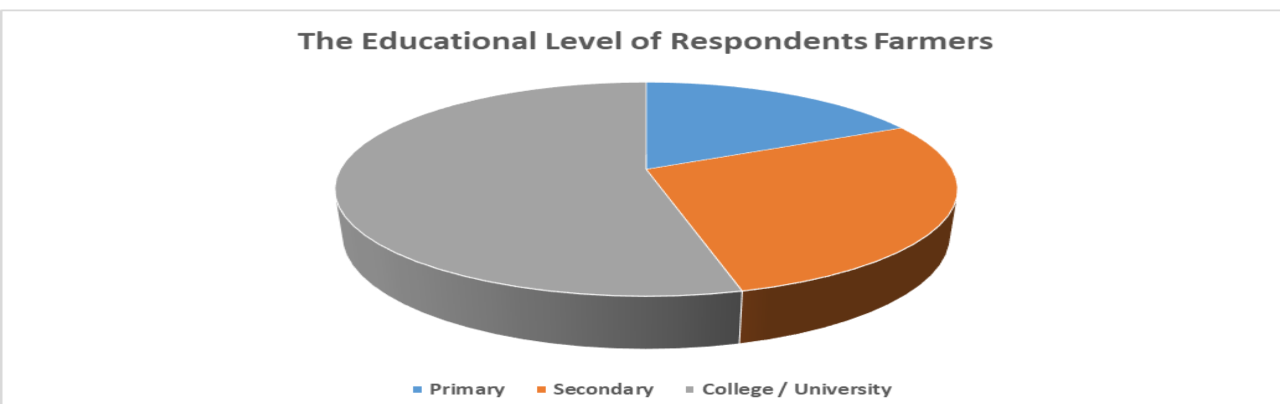

Figure 4: The educational level of respondents' farmers.

4.3 Use of digital tools for agriculture

In regards to technological devices and accessibility to these devices, there was 84% of respondents using smart phone device, while 35% and 33% used computer and basic cell phone, respectively. There was a low percentage 6% and 1% using other devices including drones, GPS, electronic sensors and other, respectively, as shown below in Figure 5.

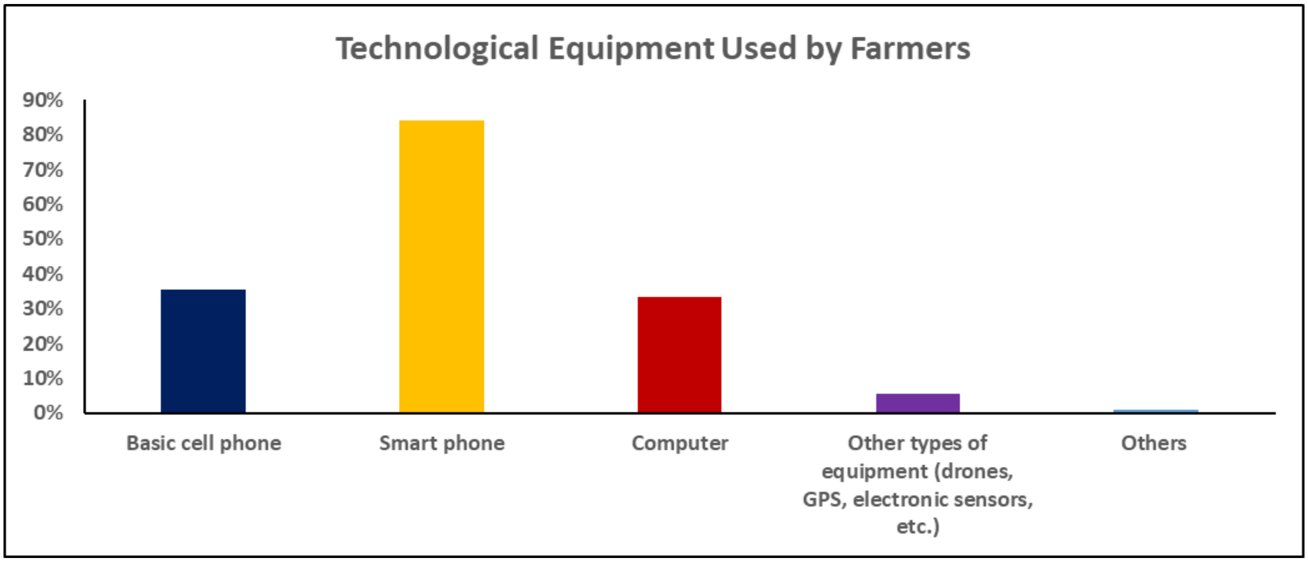

Figure 5: Technological equipment and devices that were used by farmers.

It is clear that farmers who responded to the survey were having access to the internet. However, there were 52% and 48% having a poor internet signal and internet signal goes down at their houses, respectively. There were also a low percentage of respondents 32% who indicated the cost of internet services, programs and applications are expensive. There were a low percentage 19% of respondents who do not know how to use programs, services and applications, and 6% of respondents indicated that they do not have a cellphone or modern computer devices as shown below in Figure 6. This means skills and knowledge are needed for taking better advantage of digital technologies. Network connection and bandwidth in networking where the maximum possible data transfer rate of a network or internet connection with appropriate devices, quality and permanent signal as well as accessing any information from a variety of places continue to be a central problem in rural areas. The quality of connectivity stands out as one of the main issues for farmers and rural people in the agriculture sector, especially for those who live in rural areas.

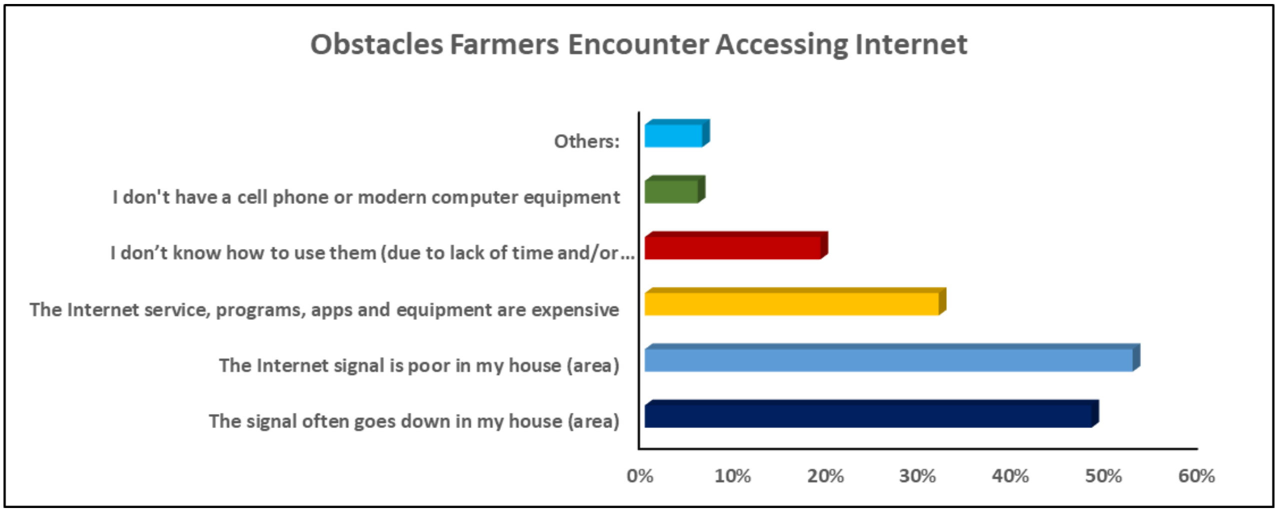

Figure 6: Difficulties that farmers encounter in accessing internet.

It is important to note that the majority of respondents 86% relies on the local service provider and the national local companies for network connection as shown below in Figure 7. While there was a very low percentage of respondents relies on other service providers such as international telecommunication companies, community network or other non-governmental organizations and cooperatives where these entities had the ability and capability to create connectivity projects that aim at achieving social, economic and environmental impacts in the areas where they operate.

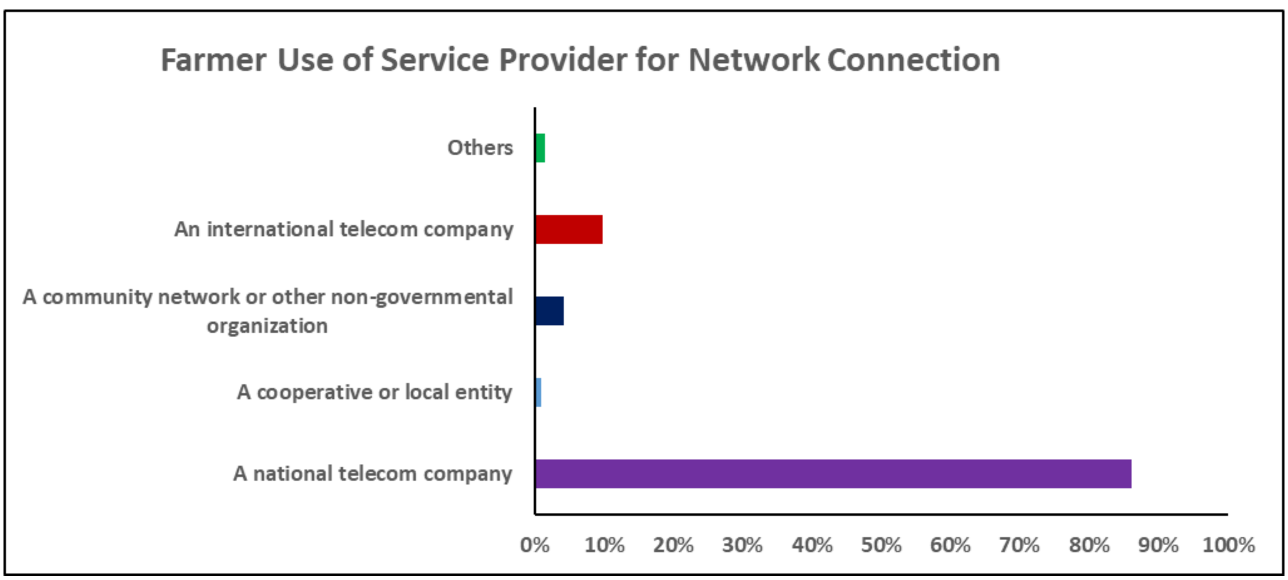

Figure 7: Most of service providers that are used by farmers for network connection.

There were digital tools and applications that respondents used the most. The majority of respondents 84% and 74% indicated that they were using social media such as Facebook, You Tube, Instagram, Tik Tok etc. and Whatsapp, respectively as shown below in Figure 8. There was 56% of respondents using internet search engine and browsers, this was followed by 40% for both email and phone messaging, 29% for applications related to agriculture, 20% for meeting and workshops platform such as Zoom, 17% for banking, municipal and government applications, and 16% for cloud storage.

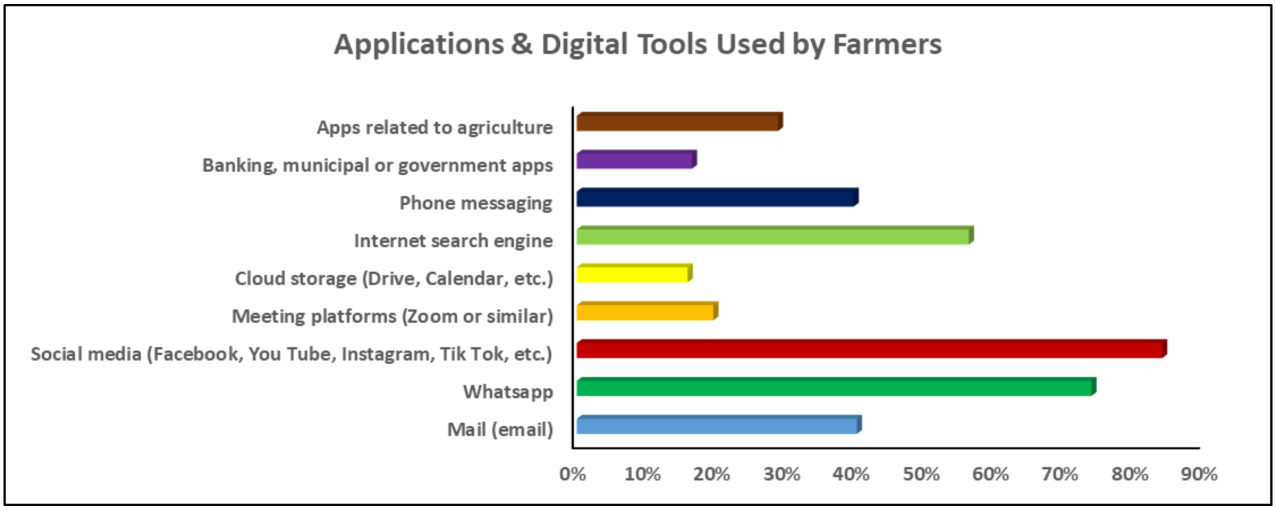

Figure 8: Most of applications and digital tools that are used by farmers.

When farmers asked about reasons for using these different digital tools and applications, most of respondents 69% and 65% indicated that they are using digital tools and applications to communicate with family, friends and other close people, and to stay informed about agricultural innovations, experiences of other farmers and seminars and meetings, respectively. It seems other reasons for using digital tools and applications were close to each other as indicated by respondents where 35% of respondents indicated that reasons to connect with public and financial services, 34% of respondents indicated that reasons to promote and sell products, 34% of respondents indicated that reasons for entertainment and informative purposes, 33% of respondents indicated that reasons to obtain training and conduct online courses, and 31% of respondents indicated that reasons for meetings, as shown below in Figure 9.

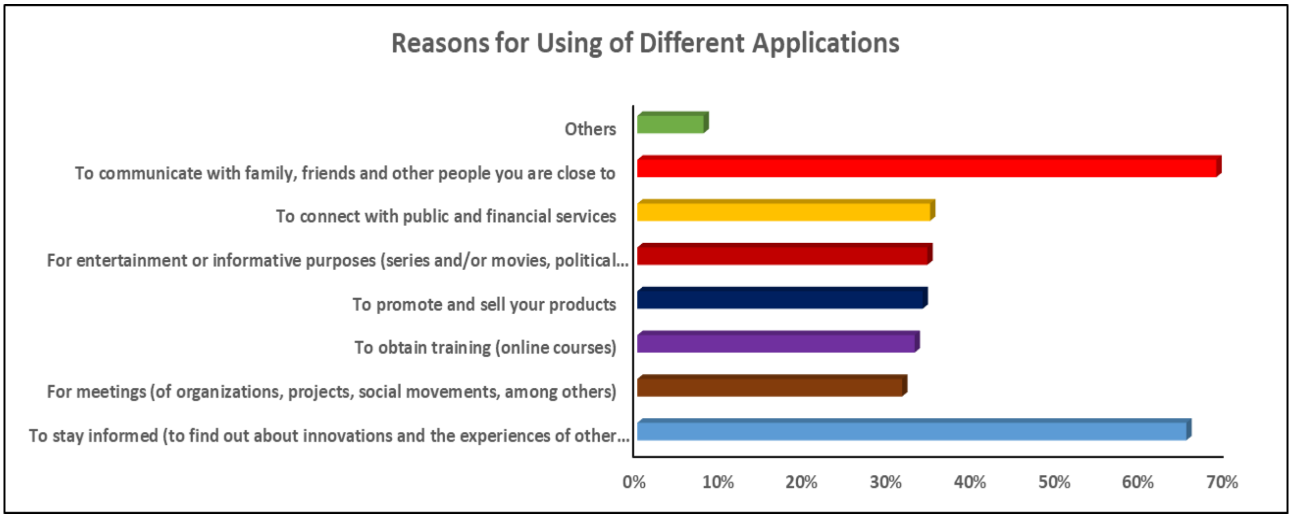

Figure 9: Reason for using of digital tools and applications by farmers.

When asked specifically about types of used applications and services in agriculture, the majority of respondents 60% indicated that they are using rural extension services or technical advisory services as shown below in Figure 10. A very low percentage of respondents 21% who indicated that they do not use any, and this followed by 12% of respondents who indicated that they are using another type of applications and services and 9% of respondents who indicated that they are using information and data from sensors, satellite, drones etc. for decision making and farm management purposes.

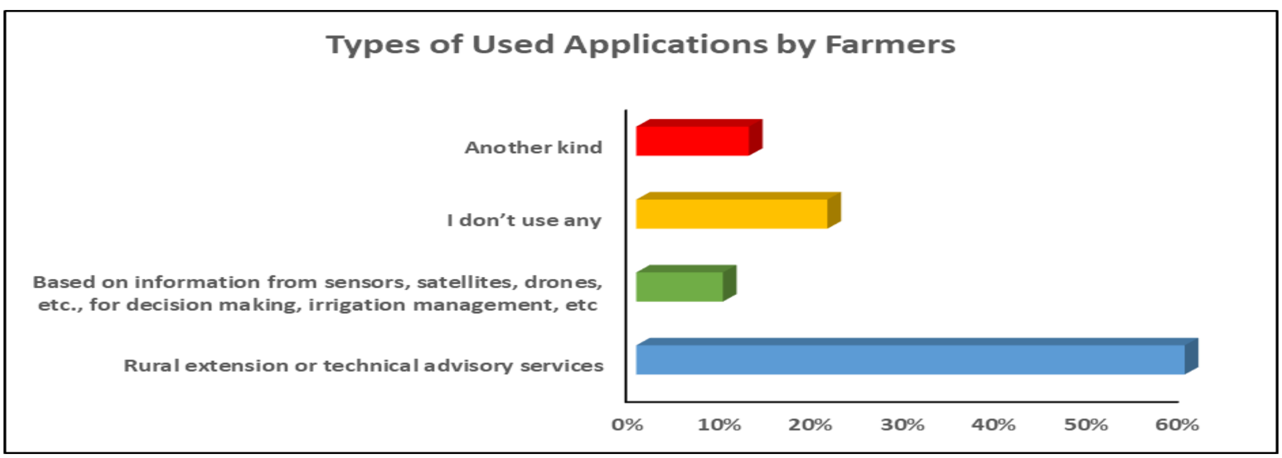

Figure 10: Types of used applications and services by farmers.

When respondents asked about providers of applications and services in agriculture, the majority of respondents 55% indicated that use of digital tools for agricultural extension and advisory services provided by government organizations as shown below in Figure 11. There was 20% of respondents who indicated that use of digital tools for agricultural services provided by private sectors, and another 20% of respondents who indicated that they do not use any of these services. There was also 11% of respondents who indicated that use of digital tools for agricultural services provided by non-government organizations, and 10% of respondents who indicated that use of digital tools for others.

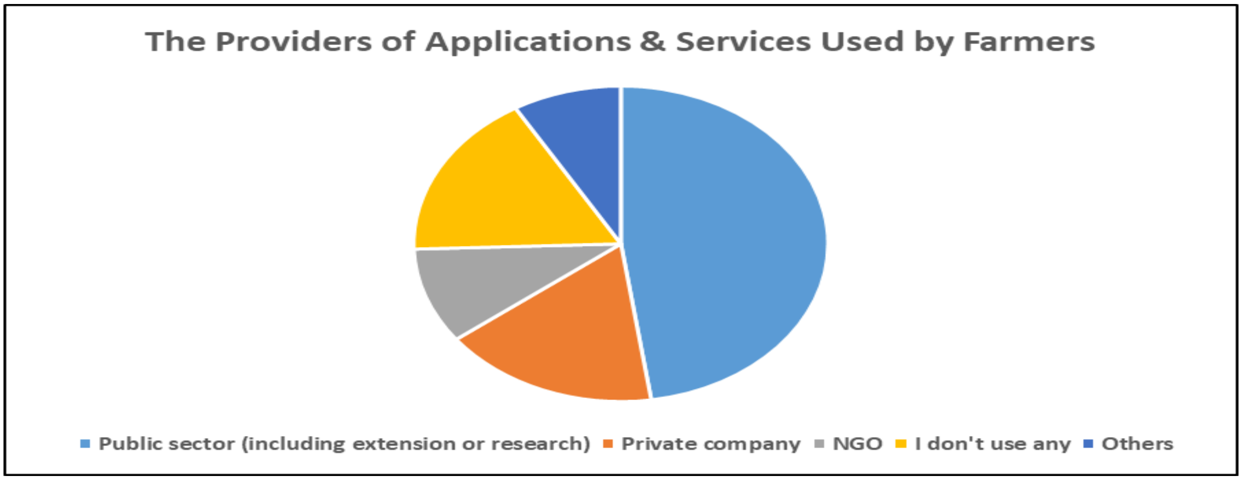

Figure 11: Providers of applications and services that farmers use for agricultural extensions.

Respondents were asked about challenges farmers encounter when using digital information and services where high percentage of respondents 45% indicated that they can not find important services or information for them. 34% of respondents indicated that they find information, but it is hard to understand or this information is available in another language, 27% of respondents indicated that there were interesting information and services, but these were paid and farmers have a problem of affording such information and services and these are copyrighted, 21% of respondents indicated that services or information were not related to what they need and do not meet their real needs, 20% of respondents indicated that trust issue of information and data, 19% of respondents expressed concerns about the data related to the farm or the crops, 14% of respondents indicated none of the above mentioned challenges encounter, 13% of respondents indicated there were other challenges, 12% of respondents indicated that there were issues of understanding of the contractual conditions and these conditions were not fair as shown below in Figure 12.

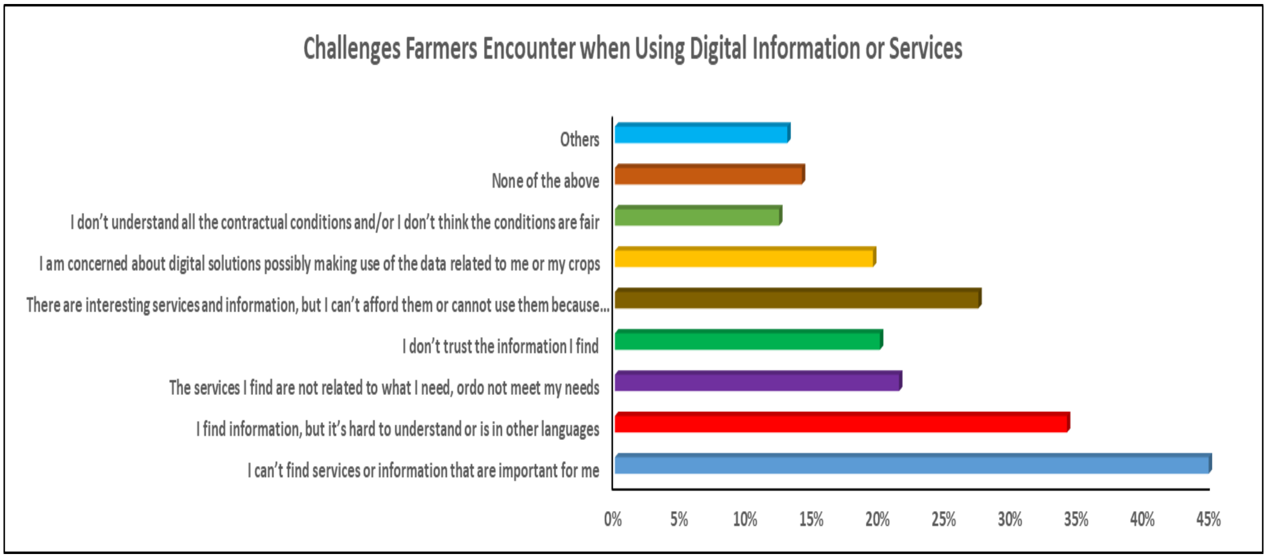

Figure 12: Challenges that farmers are encountering when using digital information and services.

Here we compare between the current uses and expected uses of digital agriculture which can help us understand the potential impact of these technologies on agriculture and food systems. By looking at current uses, we can see how digital agriculture is currently being implemented and what benefits it is providing to farmers. This can help us identify areas where digital agriculture is already making a positive impact and where it may be most useful in the future. At the same time, by examining the expected uses of digital agriculture, we can see the potential for further innovation and improvement in the agricultural sector. This can help us anticipate future developments and plan for how digital technologies can be best used to address upcoming challenges such as climate change, food security, and sustainable agriculture. By comparing the current and expected uses of digital agriculture, we can also identify any gaps or areas where more research and development are needed. For example, if current uses of digital agriculture are primarily focused on precision agriculture and data analytics, we may need to explore other potential applications, such as supply chain management or consumer engagement. Overall, this is important for understanding the potential impact of these technologies and for identifying opportunities for further development and innovation in the agricultural sector. When respondents asked about the current uses of digital agriculture, the majority of respondents 78% indicated that to check out weather forecast, 60% indicated that to consult market information such as prices and quantities, 55% indicated that to receive information related to agricultural production or technical advice, respectively. This followed by a medium percentage of respondents 36% indicated that to buy agricultural inputs, equipment or contract services, 34% indicated that to collect data on cultivation, soil, precipitation, temperature etc., respectively. A very low percentage of respondents indicated other uses such as keeping records of production, cost and sale, managing automatic irrigation, turning on and off lights, heating, cold room temperatures, accessing loans from financial institutions, and making payments for purchases or receiving money owed for sale as shown below in Figure 13. However, when respondents asked about the expected uses of digital agriculture, the majority of respondents 80% indicated that to make better use of water, fertilizers, and pesticides. High percentages of respondents 55% indicated that to have access to products and services available from government organizations and research institutions for efficient use of production, 53% indicated that to measure plots and water in the soil and to detect diseases and insects, 47% indicated that to improve access to formal credit, 45% indicated to receive technical assistance, 42% indicated that to receive early warning and information about climate, and 41%, indicated that to find out new buyers and improve the sale prices of production, respectively. A low percentages of respondents 35% indicated that to receive training, 34% to lower the cost of purchasing inputs, 26% to improve producers' associations, cooperatives, and trade associations, 25% to certify and trace agricultural products, 24% to record measurements and implement automated, data-based production decisions, and 34% to improve products quality, respectively, as shown below in Figure 14.

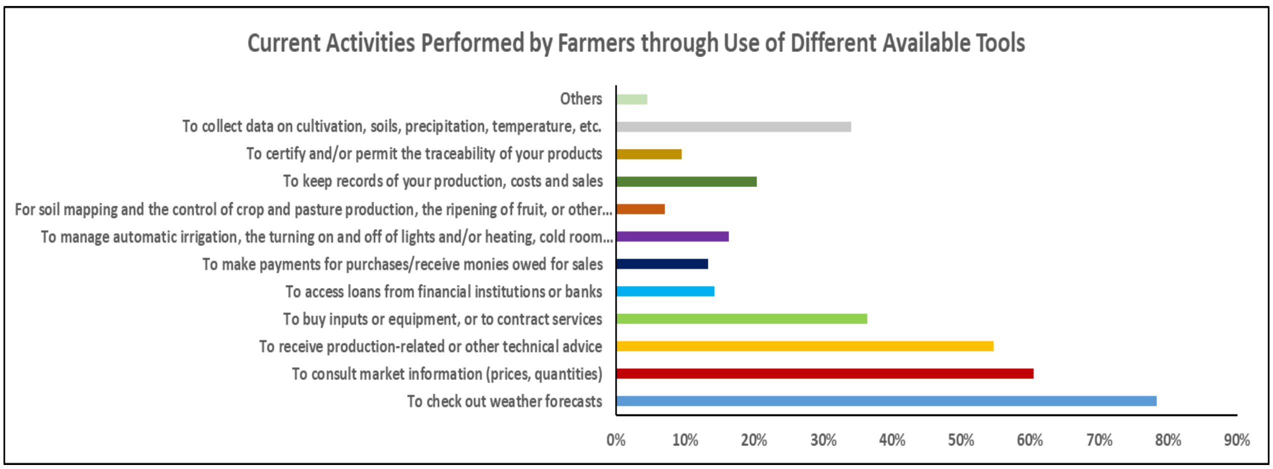

Figure 13: The current uses and activities by farmers through use of different tools of digital agriculture.

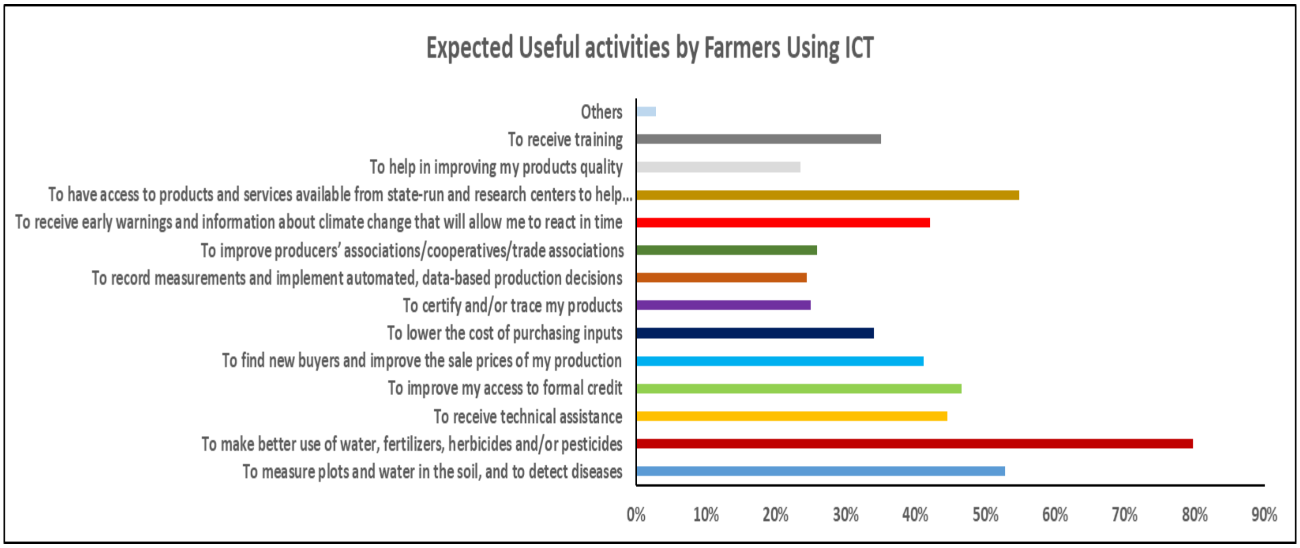

Figure 14: The expected uses and activities by farmers using information and communication technology.

As shown below in Figure 15, members of the family, agricultural technicians, agronomists and available services in the local area are key resources for consultation and strengthening of knowledge about digital technologies for farmers. The majority of respondents 54%, 45%, 31% indicated the above mentioned resources, respectively.

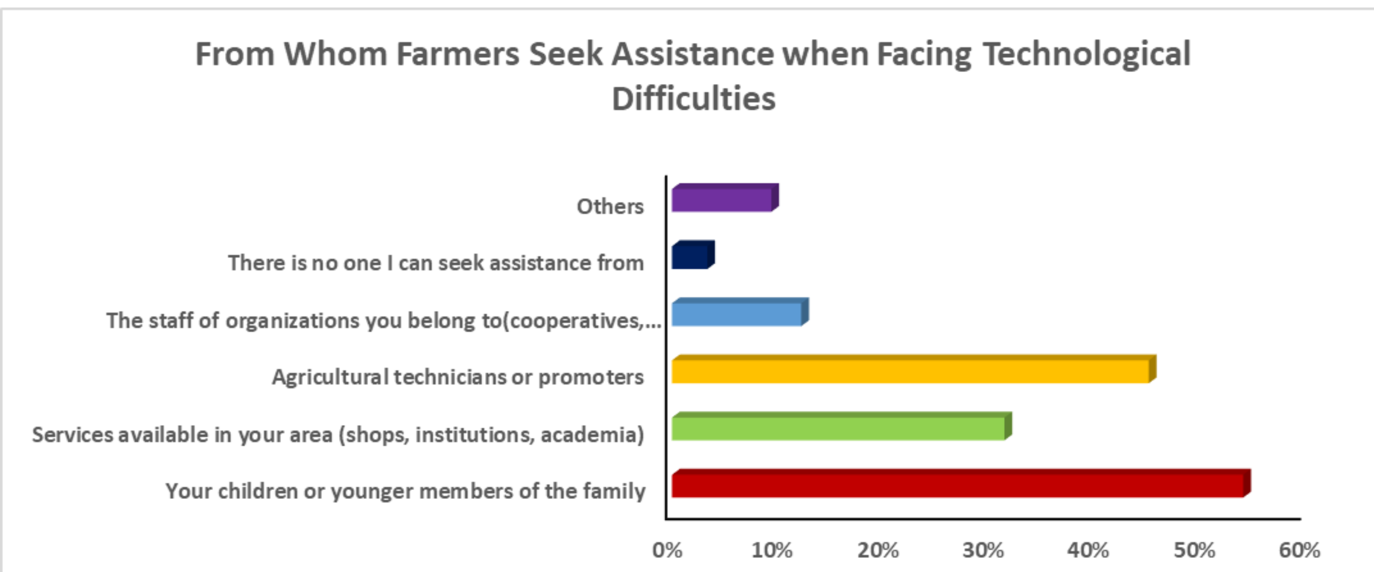

Figure 15: Key resources for consultation in case of technical difficulties face farmers.

4.4 Discussion and Conclusion

Digital agriculture has emerged as a critical tool in enhancing the productivity and sustainability of agriculture in the Near East and North Africa (NENA) region. In recent years, there has been a significant increase in the adoption of digital technologies by farmers, entrepreneurs, agronomists, extension agents, and other stakeholders in the agricultural sector. One of the key findings of this study on digital agriculture in the NENA region is that the adoption of digital technologies can lead to improved productivity, increased efficiency, and reduced costs. For example, the use of precision agriculture technologies such as drones and satellite imagery can help farmers to optimize their use of fertilizers, water, and other inputs, leading to higher yields and lower costs. Similarly, the use of digital innovation platforms such as mobile apps and online marketplaces can help farmers to access information, connect with buyers, and access credit and other financial services. Another important finding is that the adoption of digital technologies can also lead to improved sustainability outcomes. For example, the use of digital technology tools can help to reduce the environmental impact of agriculture by minimizing the use of inputs such as fertilizers and pesticides. Similarly, the use of digital innovation platforms can help to reduce food waste by enabling farmers to connect with buyers and sell their produce more efficiently.

However, there are also challenges associated with the adoption of digital technologies in the NENA region. These include limited access to digital infrastructure and services, low levels of digital literacy among farmers and other stakeholders, and concerns around data privacy and security. The findings of this study demonstrate that there is a complex relationship between the uses of digital agriculture and the education levels of farmers. Furthermore, the adoption and effective use of digital agriculture technologies require certain levels of knowledge and skills. Farmers with higher education levels may be more likely to have the necessary skills and knowledge to adopt and use these technologies effectively. They may also have greater access to information and resources related to digital agriculture, such as internet connectivity and training programs. On the other hand, farmers with lower education levels may face challenges in adopting and effectively using digital agriculture technologies due to limited access to information and resources, as well as limited technical knowledge and skills. This can result in a digital divide between farmers with different education levels, which may widen existing economic and social disparities. Therefore, it is important to promote access to education and training programs that focus on digital agriculture for farmers of all education levels. This can help to bridge the digital divide and promote the effective use of digital agriculture technologies, leading to improved agricultural productivity, sustainability, and livelihoods for farmers. We have noticed that there was low participation of women in the study. Although women play important roles in agriculture and food security and constitute a large percentage of agricultural labor force. Furthermore, we have observed that there was not a significant variation between men and women who responded to the questionnaire in regard to the use of devices, digital tools and applications, and general use of digital agriculture. Gender analysis and approach are crucial in the use of digital agriculture to ensure that everyone benefits from the technology. This is also critical for designing digital agriculture tools and services that work for both genders. For example, women may have different farming practices than men, which could impact how they use digital tools. However, women may have limited access to digital technology due to factors such as financial constraints, lack of knowledge or skills, and cultural or societal barriers. Ensuring that both men and women have equal access to digital agriculture tools and services is essential for promoting gender equity and therefore, gender analysis and approach in digital agriculture can be key elements for further studies in the future.

In conclusion, digital agriculture has the potential to transform agriculture and revolutionize farming practices in the NENA region, by enabling farmers to make better decisions based on real-time data, leading to improved productivity, sustainability, and resilience. However, addressing the challenges associated with the adoption of digital technologies will be crucial in realizing these benefits. This will require a multi-stakeholder approach that involves governments, private sector actors, and civil society organizations working together to improve access to digital infrastructure and services, build digital literacy, and ensure that data privacy and security concerns are addressed. To move forward with digital agriculture, governments in the region can take the following steps: 1) governments can invest in building digital infrastructure such as internet connectivity and mobile networks, to ensure that farmers have access to digital tools and platforms, 2) governments can provide training and support to farmers to help them understand how to use digital tools effectively, and to make the most of the data that is available to them, 3) governments can encourage collaboration between farmers, researchers, and technology providers to foster innovation and drive progress in digital agriculture, 4) governments can address policy and regulatory issues related to data privacy, ownership, and access, to ensure that farmers are able to use digital tools without fear of losing control over their data, 5) governments can provide financial support to farmers and technology providers to help them adopt digital tools and technologies, and to promote innovation in the sector, and 6) governments can foster public-private partnerships to leverage the expertise and resources of both the public and private sectors to drive progress in digital agriculture. Overall, the key to successful implementation of digital agriculture in the NENA region is a coordinated effort between governments, farmers, and technology providers, with a focus on building digital infrastructure, providing training and support, addressing policy and regulatory issues, providing financial support, and fostering collaboration and public-private partnerships.

References

FAO, IFAD, UNICEF, WFP, and WHO (2018) The state of food security and nutrition in the world: building climate resilience for food security and nutrition.

GSMA (2018) The mobile economy. London: GSMA.

GSMA (2018) Enabling rural coverage: regulatory and policy recommendations to foster mobile broadband coverage in developing countries. London: GSMA.

Cole S. and Fernando A. (2016) Mobilizing agricultural advice: technology adoption, diffusion and sustainability. Harvard Business School Finance. Working Paper 13–047.

World Economic Forum (2018) Innovation with a purpose: The role of technology innovation in accelerating food systems transformation.

Deichmann U., Goyal A., and Mishra D. (2016) Will digital technologies transform agriculture in developing countries? World Bank Policy Research. Working Paper no. 7669.

Nakasone E. and Torero M. (2016) A text message away: ICTs as a tool to improve food security. Agricultural Economics, 47, no. S1, 49–59.

Jouanjean M. (2019) Digital opportunities for trade in the agriculture and food sectors. OECD Food, Agriculture and Fisheries. Papers No. 122.

World Bank (2017) ICT in agriculture: connecting smallholders to knowledge, networks, and institutions. Washington, DC: World Bank.

Varangis P., Kioko M., Spahr M. (2014) Access to finance for smallholder farmers: learning from the experiences of microfinance institutions in Latin America. Washington, DC: World Bank.

World Bank (2019) Future of food: harnessing digital technologies to improve food system outcomes. International Bank for Reconstruction and Development. www.worldbank.org.

Birner R., Daum T., and Pray C. (2021) Who drives the digital revolution in agriculture? A review of supply-side trends, players and challenges. Applied Economic Perspectives and Policy, 43(4):1260-1285. DOI: https://doi.org/10.1002/aepp.13145.

GSMA (2020) Digital agriculture maps: state of the sector in low and middle income countries. London, United Kingdom. Available at https://www.gsma.com/r/wp-content/uploads/2020/09/GSMA-Agritech-Digital-Agriculture-Maps.pdf.

Rijswijk K., Klerkx L., Bacco M., Bartolini F., Bulten E., Debruyne L., Dessein J., Scotti I., Brunori G. (2021). Digital transformation of agriculture and rural areas: a socio-cyber-physical system framework to support responsibilisation. Journal of Rural Studies, 85:79-90. DOI: https://doi.org/10.1016/j.jrurstud.2021.05.003.

Ksibi O. (2019) Article de presse, Le ministre de l’agriculture tunisien : LA TUNISIE COMPTE RATTRAPER SON RETARD EN MATIÈRE DE DIGITALISATION AGRICOLE, l'atelier sur “Les technologies numériques en Agriculture : comment accélérer la transformation numérique de l’agriculture tunisienne?

https://proalimentarius.com/article/samir-attaieb-la-tunisie-compte-rattraper-son-retard-en-matiere-de-digitalisation-agricole

Mabrouk H., Feurer D., Massuel S., Ben Jema F. (2018) Un exemple de l'utilisation des drones dans la gestion technique d'un verger de pêcher Tunisie. Watch Letter - Lettre de veille du CIHEAM, CIHEAM, 2017, Rural Innovation and Digital Revolution in Agriculture, 38. ffhal-01780674f. https://hal.archives-ouvertes.fr/hal-01780674.

FAO (2020) L'innovation numérique au service de la promotion de l'agriculture 4.0 dans la région Proche-Orient et Afrique du Nord.www.fao.org.

Web Manager Center (2019) Coconut: Un robot agricole 100% tunisien pour libérer l'agriculteur des tâches répétitives.https://www.webmanagercenter.com/2019/10/01/439520/coconut-un-robot-agricole-100-tunisien-pour-liberer-lagriculteur-des-taches-repetitives/

Web Manager Center (2021) https://www.webmanagercenter.com/2021/06/26/469852/farmer-to-farmer-est-la-premiere-plateforme-numerique-de-vulgarisation-agricole-en-tunisie/

Gdoura K. (2020) A la découverte d'Atlas, le robot agricole tunisien par la Start up Ezzayra.http://www.tunelyz.com/2020/08/atlas-robot-agricole-tunisie-ezzayra.html.

Blaise L. (2020) En Tunisie, l'agriculture fait sa révolution numérique : Capteurs installés dans les conduits d'irrigation et dans le sol, colliers émetteurs au cou des vaches… Le monde agricole tunisien est en pleine mutationhttps://www.lemonde.fr/afrique/article/2020/09/16/en-tunisie-l-agriculture-fait-sa-revolution-numerique_6052455_3212.html

Groupe de la banque africaine de développement (2022) En Tunisie, les drones survolent les terres et donnent des ailes aux agriculteurs. https://www.afdb.org/fr/success-stories/en-tunisie-les-drones-survolent-les-terres-et-donnent-des-ailes-aux-agriculteurs-51135.

Web Manager Center (2018) Agriculture: Lancement de l'application mobile Plantix en Tunisie. https://www.webmanagercenter.com/2018/06/23/421410/agriculture-lancement-de-lapplication-mobile-plantix-en-tunisie/

Tekiano (2022) L'application mobile kolfadestinée aux agriculteurs tunisienshttps://www.tekiano.com/2022/01/17/application-mobile-kolfa-destinee-aux-agriculteurs-tunisiens/

Suleiman A. (2021) Digital transformation in the agricultural sector: foreseeing the opinion of vegetable farmers in an Egyptian village. The Arab Journal of Agricultural Sciences, The Arab Foundation for Education, Science and Arts. Vol. 4, p. 11, pp. 113-140.

El-Sawy A. (2020) Agriculture: Coding farms of 12 types of vegetables and fruits using satellite technology, Al Mal Newspaper. https://almalnews.com

Adel I. (2021) Agriculture: implementing e-possession in 12 governorates and distributing one million cards to the farmer. Akhbar Al-Youm Gate. https://m.akhbarelyom.com/news/newdetails/

FAO (2020) Agriculture and FAO launch an initiative to implement digital agriculture in Egypt, http://www.fao.org/egypt/news.

Trendov N.M., Varas S., and Zeng M. (2019) Digital technologies in agriculture and rural areas summary document. FAO, Rome.

Egyptian Center for Economic Studies (2020) Sectoral analysis of the impact of COVID-19 on the Egyptian economy. Part 2, Cairo: Egyptian Center for Economic Studies (ECES).

Organization for Economic Co-operation and Development (2021) Africa's development dynamics 2021: digital transformation for quality jobs. Paris: OECD.

Kamel S. (2021) The potential impact of digital transformation on Egypt. Working Paper No. 1488. The Economic Research Forum (ERF). Technical workshop: The potential of digital tools to support farmers in Egypt: lessons learned and way forward.

World Food Program (2022) Jordan Country Brief, Retrieved online: https://www.wfp.org/countries/jordan

Green Growth National Action Plan 2021-2025 (2020) Agriculture sector, Amman, Jordan.

Jordan Economic Growth Plan 2022-2018 (2021) The Economic Policy Council. Retrieved online: http://extwprlegs1.fao.org/docs/pdf/jor170691.pdf

World Bank (2020) Retrieved online: https://databank.worldbank.org/source/world-development-indicators

World Bank (2022) Retrieved online: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519

World Bank (2018) The role of food and agriculture for job creation and poverty reduction in Jordan and Lebanon. Retrieved online: https://www.semanticscholar.org/paper/The-role-of-food-and-agriculture-for-job-creation/b90e19a1b6ea01a3b907535303c488a294eca411#paper-header

Ministry of Agriculture (2022) National strategy for agricultural development 2020-2025. Retrieved online: https://moa.gov.jo/AR/Pages/

Department of Statistics (2021) The unemployment rate for the fourth quarter of 2020. Jordan.

FAO (2019) Rural transformation-key for sustainable development in the near east and North Africa. Overview of Food Security and Nutrition 2018. Cairo. 80 pp.

Jordan Investment Commission (2017) Available at: <https://www.jic.gov.jo/wp-content/uploads/2018/07/Sector-Profile-Agriculture-Final-Mar-2018-JIC-HAS-020418-1.pdf>

Bahn R. A., Juergenliemk A., Zurayk R., Debroux L., Broka S., Mohtar R. (2021) Digital revitalization of the agri-food sector in Mashreq. Focus on Iraq, Jordan, and Lebanon. Washington, DC: World Bank.