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Information and communication technology in agriculture: awareness, readiness and adoption in the Kingdom of Bahrain

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Abstract

Purpose – Information and communication technologies (ICT)-presented technological developments, such as soil sensors, remote sensing, artificial intelligence (AI) and big data, have shown the potential to increase crop output and quality while consuming fewer resources and having a smaller environmental impact. The first step in ushering in a new era of technological advancement in the agricultural sector in the Kingdom of Bahrain is evaluating how prepared farmers and farm owners are to adopt these technologies. Therefore, the current study examines how ICT are prepared, accepted and adopted in agriculture in the Kingdom of Bahrain.

Design/methodology/approach – The study's goals were attained by using both quantitative and qualitative methodologies. A survey was created to learn more about the present state of ICT usage in agriculture, including its awareness, readiness, acceptance and adoption. To strengthen the conclusions and investigate the current situation related agricultural behavior, production and the use of information technology (IT) to support agriculture in the chosen farms, four exploratory field visits were made. Additionally, a strength-weakness-opportunities-threat (SWOT)-threat, opportunities, weakness, strength (TOWS) analysis was performed to evaluate the Kingdom of Bahrain's readiness and long-term plans for implementing ICT in agriculture. On the basis of secondary data, survey data and interview findings, SWOT-TOWS were created.

Findings – The findings revealed insufficient knowledge and awareness about ICT in agriculture. Despite the high level of digital infrastructure readiness in Bahrain, farmers are not ready to adopt sophisticated devices and complex applications such as crop sensing tools, the internet of things (IoT) and AI; however, there is a strong acceptance among farmers to implement new ideas and agriculture approaches.

Originality/value – The Arabian Gulf Countries, which are characterized by an arid environment, sporadic vegetation, weak soil and a lack of water supplies and arable land, have few studies that explore the crucial role of ICT in growing the agricultural sector. Considering the influence of ICT on the provision of more productive agriculture in a challenging and complicated environment, the study contributes to the body of knowledge by conducting an empirical investigation that addresses an urgent issue. The study is considered one of the few in the countries of the Arabian Gulf to address this subject.

Keywords Precision agriculture, Smart agriculture, Food security, IoT, Remote sensing, Information communication technology

Paper type Research paper

Introduction

Technology has become an integral part of our daily lives due to its essential usage and amplified significance in automating processes to complete our tasks. Technology's sensational entry has altered how people perceive, live, work and how businesses and governments perform their daily operations to serve people. With the arrival of technology in

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this digital world, there is a compelling need to utilize technology in the development of the agricultural sector to increase the production and employability of individuals (Kapur, 2018).

Many present-day farms and agricultural processes operate differently than a few decades ago, primarily due to technological advancements, including sensors, devices and machines. These technologies, including hardware and software, are represented through the term information and communication technologies (ICT). It can be defined as the collection, analysis and transfer of data through the combination of computing devices, communication capabilities and software (Bilali & Allahyari, 2018).

ICT covers almost every aspect of our life, including education, the economy, public and private services, and even lifestyles. Therefore, it is considered a crucial element for the sustainable development of citizens and countries. According to the National Institute of Food and Agriculture, ICT developments can potentially improve decision-making in agriculture and enhance farm management techniques. On the other hand, it is essential to keep farmers updated with the latest agriculture technologies and tools through specialized education programs. In the agricultural context, the potential of ICT can be estimated broadly under two leads either as a tool for direct contribution to agricultural productivity or as an indirect tool for empowering farmers to make more informed and quality decisions which will have a positive result on the way agriculture and allied activities are conducted (Patel & Sayyed, 2014). Furthermore, using ICT in different business fields has demonstrated great efficiency in cost and productivity. Therefore, ICT is being adopted in the agriculture business through concepts such as smart farming, precision agriculture and e-agriculture to overcome the challenges surrounding the agriculture sector.

Shortage of natural resources and difficult soil conditions in the Gulf countries are considered a significant challenge to agriculture; however, the emergence of disruptive technologies such as the internet of things (IoT), big data, cloud computing and artificial intelligence (AI) increases the opportunity to improve agriculture productivity and overcoming water and soil challenges.

Circumstances impose a unique pattern on the Kingdom of Bahrain that must be considered when discussing agriculture and food security. While the world competes on the size of the acre productivity, the quality of the crop, the amount of water savings and the preservation of the environment, the conditions (Climate – land area – nature of soil – water scarcity, with an estimation of 90% of fruits and vegetables are imported), represent difficult obstacles to Bahraini progress in this sector.

The traditional approach to agriculture has become a relic of the past. It must be discarded as much as possible in the Kingdom of Bahrain if they want actual development for the sector. Today, robotic solutions can calculate the ideal planting depth for the seed and the considerations of the distances between plants, the amount of water and the supply of sun. So, can technology create solutions to confront the Bahraini situation in all its agricultural intricacies? And to overcome all its difficulties?

Meanwhile, there is a lack of studies that discuss the significant role of ICT in developing the agricultural sector in the context of the Arabian Gulf Countries, which are characterized by arid climate, scattered vegetation here and there, weak soil, and the region largely lacks water sources and arable land. Therefore, it presents a chance to set up this research to add to the body of knowledge with an empirical investigation addressing a pressing problem, such as the influence of technology on the provision of more productive agriculture in a challenging and complex environment. Accordingly, the current study aims to explore the role of ICT in agricultural development in the Kingdom of Bahrain and assess the factors, drivers, awareness and inhibitors of the adoption of ICT in agriculture. The study investigates the acceptance and readiness toward adopting ICT in agriculture in the Kingdom of Bahrain, which will be analyzed from the supply side, which includes farmers, farms owners and agriculture businesses and institutions. This will be identified in terms of

digital readiness, ICT and agriculture literacy, awareness, usage, challenges for adopting ICT and the perception of the impact of ICT in enhancing and improving agricultural sustainability. Moreover, the study will set a future road map to achieving sustainable agriculture by implementing concepts such as precision agriculture and smart farming.

The study is articulated into five sections, including the introduction. The following section highlights the implementation and importance of ICT in agriculture, along with different initiatives worldwide and the ICT as the support tool for agriculture in Bahrain. The research method and data collection are discussed in the third section. In the fourth section, results and discussion are presented – finally, the conclusion proposes recommendations and future steps to enhance the agriculture sector in Bahrain.

Research background

ICT in agriculture

Before the emergence of information technology (IT) and its usage in agricultural development, people primarily depended on traditional farming methods and would also resort to others to provide services. This is referred to as "Traditional Agriculture".

In the 19th century where the rise of the second industrial revolution was the emergence of Agriculture 2.0. This era was characterized by using machines and chemical inputs instead of human power to increase crop production. In the second half of the 20th century, with the increase in ICT adoption among different sectors, came the third agriculture revolution Agriculture 3.0. The excessive amounts of data collected from various sources and the emergence of technologies such as Big Data, Cloud Computing and AI led to the next agriculture revolution, Agriculture 4.0 (Zhai, Martinez, Beltran, & Martinez, 2020).

Agriculture needs viable usage of innovation and technology to quicken the production and employability of people. There are various sorts of innovations that are made to improve efficiency and productivity in the agricultural sector. Parke (2015) stated that the presentation of innovations and logical strategies (progressions) had greatly affected the cultivating segment in the late decades. According to Milovanović (2014), the capability of ICT in the agriculture segment can be utilized, where ICT is used as a device that contributes directly to the efficiency of farming creation. Furthermore, in 2017, the G20 agriculture ministers' action plan recommended and focused on empowering ICT in agriculture to boost the efficiency and sustainability of the food sector (Bilali & Allahyari, 2018).

ICT tools in agriculture were introduced long ago in many countries worldwide. They paved the road toward sustainable farming by allowing real-time information communication even in rural areas. In 1991, in Chennai, India, ICT tools emerged to reach farmers in rural areas through a hub and spokes model. The model aimed to enable the bidirectional transfer of data: farmers–to–hub and hub–to–farmers (Swaminathan & Swaminathan, 2018). Some of the innovative ICT in agriculture are autopilot tractors, crop sensors, variable rate technology (VRT) and Swath control technology, monitoring and controlling crop irrigation systems, field documentation, IoT, precision agriculture and big data.

The evolution of ICT from a simple radio program to machine learning and advanced analytics of agriculture data demonstrated the power of ICT to agriculture business processes in many countries. Training and educating people are the keys to change. ICT extension services are significant factors in improving the socioeconomical life of farmers in rural areas. (Ravindra, Sehgal, & Narasimhamurthy, 2020), Stated that ICT, such as TVs and smartphones, have proven essential in providing Karnataka farmers with valuable information about agriculture inputs. In Pakistan, farmers are convinced that using ICT, such as mobile phones and the internet, will provide better information flyover that directly connects them with agriculture extension services providers. The study concluded that educated farmers are more willing to adopt new technologies and recommended training

extension services providers on using ICT (Aldosari, Alsharaifi, Ullah, Muddassir, & Noor, 2019).

On the other hand, machines and technology are the primary tools to adopt the change. New global positioning system (GPS) tractors and sprayers machines can precisely drive themselves through the field without drivers. One of the main advantages of using auto-steering machines is reducing human efforts with compromising machinery performance. The machines are controlled by real-time kinematic GPS receivers that enhance lateral accuracy when driving in straight lines to less than five centimeters (Morton *et al.*, 2020). Crop management is considered an exhausting and time-consuming operation to be carried out by farmers physically. It includes various tasks such as crop spraying and croup scouting; however, the advance in sensing technologies made such tasks effortless (Clercq, Vats, & Biel, 2018; Mekala & Viswanathan, 2017). Moreover, smart irrigation systems provide a solution for water use efficiency and increase crop production.

Farm management, food scanner and similar data may be classified as big data, given their volume, velocity and variety. As per Wolfert, Ge, Verdouw, and Bogaardt (2017), big data applications in cultivation are not only about primary production yet assume a significant job in improving the production network's proficiency and easing food security concerns.

The IoT refers to the billions of remote devices connected wirelessly to complex networks and forms intelligent architecture such as smart buildings, smart factories and smart schools. IoT has been introduced in greenhouses to enable smart remote control of the cooling and ventilation of the environment based on data collected from CO2, soil, temp and light sensors (Pallavi *et al.*, 2017). The mixture between IoT and AI has been included in many agriculture tasks such as (farm management systems, crop scouting and livestock monitoring) to enhance business process efficiency, improve crop production and promote environmental protection (Alreshidi, 2019).

Moreover, adopting precision agriculture technologies (PATs) is increasing rapidly, specifically in the US market, where farms are vast, and PATs over the cost will be more profitable. Based on market and markets, the PATs market in the US is expected to double between 2018 and 2023; however, the countries with small farms and fewer ICT-educated farmers tend to have a prolonged adoption rate of PATs (Bucci, Bentivoglio, & Finco, 2019).

Despite the agriculture technologies mentioned earlier, knowledge and usage of ICT in agriculture remain poor in many developing countries. This is because many constraints hinder the advance of the agriculture field, including poor ICT literacy, farmers' ignorance of ICT, lack of awareness of ICT advantages, lack of trustworthiness of information generated by digital tools and the scarcity or even absence of programs to introduce the importance of using ICT in the agricultural field (Ravindra *et al.*, 2020; Subashini & Fernando, 2017).

Agriculture in Kingdom of Bahrain

The Kingdom of Bahrain archipelago comprises 40 islands with an area of about 711.9 square kilometers, located in the middle of the Arabian Gulf close to the eastern coast of the Kingdom of Saudi Arabia. Agriculture in the Kingdom of Bahrain was an important sector of the economy. Before the development of the oil industry (1932), date palm cultivation dominated agriculture in Bahrain, producing enough for local consumption and export. At least 23 varieties of dates are cultivated, and the palm's leaves, branches, buds and flowers are used extensively (Albilad, 2012). Bahrain has been known since ancient times for fresh water, fruit trees and palm trees distinguished in the production of dates, as it was known in the past as the country of a million palm trees (Albilad, 2012). However, at the beginning of the eighties, Bahrain began to pay attention to cultivating other crops of vegetables, flowers and trees (Shebeb, 2006).

The contribution of agriculture to the Gross Domestic Product (GDP) is no more than 0.23%. In 2016 employment in the agriculture sector reached only 1.1 % of the total employment (IGA, 2016). Table 1 provides information on the Kingdom of Bahrain's agricultural productivity and the agrarian sector's contribution to the country's economy's development from 2006 to 2018.

Moreover, the agricultural lands in the Kingdom decreased significantly from 1956 (6,460 ha) to approximately 4,230 ha at the beginning of the eighties. According to the statistics provided by the Supreme Council for the Environment, the per capita area available for agriculture dropped from 0.036 ha in 1924 to 0.006 in 2005. There is a minority of large owners of agricultural lands. Individuals and institutions control about 60% of all arable lands by leasing their plots of land to farmers, generally based on three-year contracts. About 2,400 farmers, 70% of whom do not own the land they cultivate.

On the other hand, many farmers/farm owners shifted or mixed from traditional farming and protected farming (greenhouses), which was introduced in Bahrain in 1976 (Bani, 2020). Few recently implemented hydroponic farming systems, and almost two farms in Bahrain adopted aquaponics farming to solve water scarcity and land shortage. Farming processes are controlled manually whether the farm is soil-based (open land or greenhouses) or nonsoil-based (hydroponics or aquaponics). It is unusual to find a farm that uses ambient air and humidity sensors to control cooling and ventilation devices.

Regarding agricultural resources, the Kingdom of Bahrain lacks water suitable for agriculture and irrigation. There is also a challenge in providing pesticides and fertilizers to suit the farmer's needs. In addition, Bahrain relies heavily on importing all crops to cover local needs (El-Khoury, 2016). The urban planning and development authority estimated the total agriculture area in March 2022 as 2.86% of the country's total land area (UPDA, 2022). Based on the special report (millennium development goals) issued by the Bahraini government in 2015, Bahrain is currently a nonagricultural country and relies mainly on imported crops.

ICT can play a vital role in converting barren land into agricultural land with fertile soil. Although Bahrain's climatic conditions do not comply with many crop production requirements, ICT can minimize this obstacle. Bahrain built a durable infrastructure that makes it possible for ICT to be used and integrated in the agricultural industry. Bahrain's market is becoming more and more reliant on ICT, and its use of cutting-edge tools like cloud computing and the IoT has helped it rise to the top of the world rankings for technological empowerment. Additionally, new finance, training and development programs, coordinating efforts, and agricultural and farming techniques of the modern era were introduced. As an illustration, in 2010 it launched the National Initiative for Agricultural Development (NIAD), a program that aims to improve the Kingdom's food security, support farmers and expand the agricultural industry (NIAD, 2019). For farmers in the Hoorat Aali region, the government has also developed a permanent market called the farmers' market to promote regional produce and showcase the advancements made in Bahrain's agricultural sector.

Year	Gross domestic product	Agriculture production	% of the agriculture	Agriculture production (in million BD)
2006	4,109	21.3668	0.52%	11.5
2010	5100.20	28.0511	0.55%	16.4
2016	11974.70	34.9	0.29%	24
2017	12430.10	34.6	0.28%	23.9
2018	12651.10	35.9	0.28%	25.1

Table 1.
National accounts quarterly bulletin

Source(s): National Accounts Quarterly Bulletin (Fourth Quarter 2018, National Accounts), General administration of statistics and population register, information authority

Research methodology

To achieve the study's objectives and ensure data reliability and coverage of all aspects, quantitative and qualitative methods were adopted. As a primary research method, a questionnaire was developed to investigate the current situation regarding the awareness, readiness, acceptance and adoption of ICT in agriculture. The study population comprised of farmers, farms owners and agricultural businesses. The Kingdom of Bahrain has approximately 2,400 farms and a total agricultural workforce of 9,120 (Zawya, 2021). The sample size was calculated using a confidential level of 95% and an interval of 5 and was estimated to be approximately 300. However, due to the Covid 19 situation and the difficulties in reaching such a segment of individuals or even agriculture businesses and farm owners, only 100 responses were collected. The data was collected online, face-to-face or by telephone. The survey instruments for this study were developed using validated items from prior research.

Four exploratory field visits were conducted to enhance the survey's findings to explore the current situation regarding agriculture behavior, production and how IT is being used to support agriculture on selected farms. Within the research context, the chosen farms are referred to as Farm1, Farm2, Farm3 and Farm4. Different sizes, characteristics and cultures were considered for the selection of farms. In addition, a SWOT-TOWS analysis has been conducted to analyze the readiness of the Kingdom of Bahrain for adopting ICT in agriculture and its strategic direction. It was developed based on secondary data, survey results and interviews.

Results and discussion

The primary purpose of this research is to investigate the readiness and acceptance of adopting ICT in agriculture in the Kingdom of Bahrain from the supply side, including the farmers and agriculture businesses and institutions. Therefore, the following section will present the data analysis on the supply perception of the adoption of ICT in agriculture and a separate section highlighting the main points of the exploratory field visits and the SWOT-TOWS analysis.

Demographic profile of respondents

Table 2 shows that most of the respondents have minimal land with a size of fewer than 0.5 ha. Forty per cent of the participants have an estimated whole cultivation land and are adopting traditional farming (75.7%) for planting vegetables (83.8%) and fruits (56.8%).

Land		Cultivation land		Cultivation methods	
<0.5	62.1%	<50%	37.8%	A greenhouse	29.7%
0.5–1	27.0%	50–75%	21.6%	Cultivation without soil	16.2%
>1	10.8%	100%	40.5%	Traditional farming	75.7%
				Others	24.3%
Crops		**Pesticides/year (liter)**		**Fertilizers/year (ton)**	
Dates	35.1%	0–25	56.8%	≤25	32.4%
Aromatic	40.5%	26–50	16.2%	26–50	18.9%
Vegetables	83.8%	51–75	8.1%	51–75	5.4%
Fruits	56.8%	76–100	18.9%	76–100	32.4%
Other	21.6%	>100	0.0%	>100	10.8%

Table 2. Description on the farmers and agriculture business

The result is not surprising as the agricultural areas in the Kingdom of Bahrain are limited, and it has decreased by 0.25% since 1971 (Alayam, 2019).

As part of agriculture behavior by respondents, they use between 0 to 25 L of pesticides yearly and almost use fertilizers for more than 76 tons – some of them use fertilizer for 25 tons or less annually, as shown in Table 2.

Digital readiness is about whether people have the skills to use IT and digital literacy tools to help people determine whether the online information they access is trustworthy. Digital readiness is essential in adopting IT in agriculture as it emphasizes the significant gap between the current state of farmers and the ideal farmer 4.0 (Laurens Klerkx, 2019). Therefore, digital readiness for farmers and individuals investing in the agriculture business was explored in terms of using smart devices, social media, online services and the Internet. Table 3 and Figure 1 present information on the digital readiness of farmers and agriculture businesses. The results revealed that 95% are using a smartphone, 97% are using WhatsApp and 78% are using Instagram. Moreover, over 75% of the farmers use online services and can browse the Internet easily. However, only 50% of the respondents know the differences between hardware and software and can use the computer very well, as shown in Table 3.

Results confirmed that mixed generations in the agricultural society live different lifestyles and mindsets in the Kingdom of Bahrain. Most of the community consists of regular farmers who are low-educated and illiterate and are using only WhatsApp for social communications and conducting their services physically (not using online services). Although they use smart devices, some online services and social media, they have yet to adopt sophisticated devices and applications such as crop sensing, smart irrigation systems, IoT, augmented reality and AI. However, some farmers successfully adopt digital technology, which can be called the "Young Smart Farmers" (Sayruamyat & Nadee, 2019). They are a group of farmers who use smart devices and social media intensively in their daily life and adopt some sophisticated ICT in their agriculture to enhance their productivity (Sayruamyat & Nadee, 2019).

The findings revealed a reasonable awareness and low usage of ICT in agriculture among farmers and agriculture businesses in Bahrain. For example, results in Figure 2 show that there is little awareness of ICT use in agriculture as almost (40%) or less are aware of the agriculture technologies such as database, soil sensors, agriculture remote sensors or

Table 3.
Digital readiness of the farmers

I use the following smart devices		Social media used by farmers	
Smart Phone	95%	WhatsApp	97.30%
Laptop	32%	Instagram	78.40%
Desktop	24%	Snap Chat	29.70%
Tablet	22%	Facebook	18.40%
I do not use smart devices	3%	Twitter	16.20%
		Others	8.10%
		I do not use social media Apps	2.70%

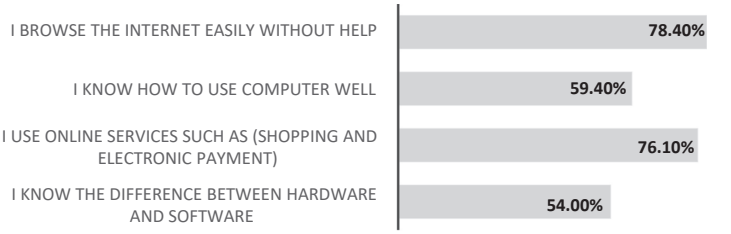

Figure 1.
Digital readiness of the farmers

expressions such as IoT or PA. In addition, most farmers and agriculture business respondents are unaware of the terms; soil sensors, agriculture remote sensing or IoT and big data.

The low awareness of the agriculture ICT has been reflected in the usage of these technologies, as shown in Table 3. The results show that almost less than 40% of the respondents have an internet subscription or feel they need the internet to manage their farm, using remote or soil sensors, special software, or even application to manage their farm. Moreover, they never use special information systems to manage their farm or consider it an important tool to advance their business. However, more than 75% of the respondents are curious about modern farming technologies, often search about them and like to try contemporary technologies to develop their farms, as shown in Table 4.

Subashini and Fernando (2017), state that lack of knowledge in IT and difficulties in using IT are the main obstacles to adopting ICT in agriculture. Table 5 summarizes other challenges farmers and agriculture businesses face in adopting ICT in agriculture. Most of the respondents are facing difficulties in the supportive ICT infrastructure (43.0%), followed

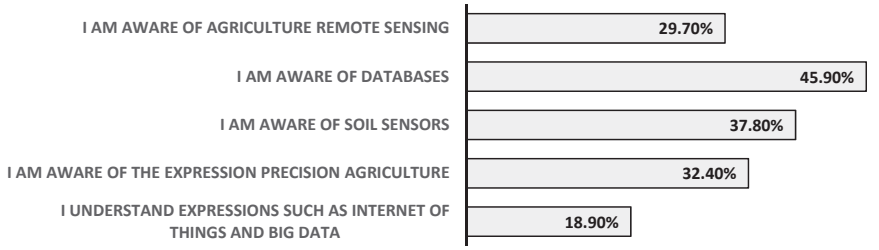

Figure 2. Awareness of farmers on the ICT used in agriculture

I am very curious about how modern farming technologies work	72.90%	I love trying new methods to develop my farm	86.50%
I use computers to manage my farm business	37.80%	I often look for information about new products and technologies in the agricultural field	75.70%
I use special software and applications to manage my farm	35.10%	I have access to the resources I will need to use precision agriculture technologies	40.50%
I need internet to manage my farm	32.40%	I have the resources, the opportunities and the knowledge to use the technologies for precision agriculture	37.80%
I use soil sensors in my farm	27.00%	I use remote sensing for my farm	24.30%
There is a dedicated internet subscription for the farm	24.30%		

Table 4. Usage of ICT in agriculture by farmers

Perception on the difficulties in adopting ICT in agriculture	%
lack of supportive ICT infrastructure	43.00%
Lack of knowledge and experience in using ICT in agriculture	39.10%
Lack of training and support	35.10%
High cost for adopting ICT in agriculture	33.80%
lack of technical support	23.80%
Erratic power supply and fluctuating networks	13.90%

Table 5. Perception on the difficulties in adopting ICT in agriculture

by a lack of knowledge and experience in using ICT (39.10%) and a lack of training and support (35.1%). Moreover, there are additional costs for operating and adopting digital technology, i.e. internet charge, mobile network charge etc. These costs were automatically added to the farm management cost. As mentioned earlier, most Bahraini farmers are considered family farming and not business farming entities. Therefore, the perspective to cost management is different. For example, they do not separate household expenses from the expenses in farming. As a result, farmers may refuse to use or adopt technologies since they realize the additional costs they must pay (Sayruamyat & Nadee, 2019). Government policies and regulations in the Kingdom of Bahrain focus on enhancing agricultural productivity. They provide technical and financial support for individuals and farmers, including ICT services, equipment and agricultural loans (Alwatan, 2020). For instance, the installation of wireless sensor networks and the development of smartphone applications by the government are vital and strategic actions for rapid growth and easy access to information for farmers and planters (Barh & Balakrishnan, 2018). Government support is essential for encouraging individuals' involvement in agriculture and adopting ICT for their productivity; however, most farmers and business agriculture need to be aware of government support and efforts to facilitate their business and enhance their productivity.

Regarding the lack of knowledge and training support, the agricultural sector in the Kingdom of Bahrain receives special attention from the competent authorities by preparing specialized courses to develop human cadres working in the farming industry. NIAD, for instance, intensifies training courses and advanced academic programs to attract the most significant number of agriculture enthusiasts (Alwatan, 2020). NIAD also provides many educational and awareness television (TV) programs in addition to Bahrain international garden show, which provides indirect awareness programs targeting farmers, agriculture businesses and investors. Moreover, most higher education institutions offer different agriculture academic programs. For example, the University of Bahrain provides a bachelor-level program in landscaping and plans to establish a college for agriculture to build national agriculture capacity. Arabian Gulf University offers a master's program in the Program of Desert Farming Techniques and Soilless Agriculture. Moreover, Bahrain Institution for Training offers The Pearson Business Technology and Education Council Level 3 Extended Diploma in Agriculture program, which aims to provide learners with the knowledge and basic skills in agriculture to start agricultural entrepreneurship and business in addition to subsistence purposes. The government offers vital efforts in the Kingdom of Bahrain to facilitate the challenges and difficulties in adopting ICT in agriculture and encourage individuals and businesses to take further steps in benefiting from the available agriculture technologies and ICT.

Table 6 finally identifies the respondents' perception of the impact of adopting ICT in agriculture. More than 50% of the respondents see that ICT can help save time and effort and increase production and income. Furthermore, there is a good perception of the effect of ICT

Table 6.
The impact of adopting ICT in agriculture

Perception on the benefits of using ICT in agriculture	%
Precision farming techniques can provide the necessary information to make better decisions that contribute to reducing resource consumption (such as water, pesticides and fertilizers)	67.5
ICT helps in saving time and efforts	56.8
ICT helps in increasing my production and income	46.7
The data provided by precision farming techniques will reduce the environmental impact on my agricultural activities	40.5
None of the above	40.1
ICT helping me in doing my work (planting, irrigating) more efficient	32.5
ICT helps in improving the quality of my products	31.8

in providing necessary information for better decisions and best resource utilization (67.5%). However, respondents disagree on the impact of precision farming on reducing the environmental factors and disasters on their farms (40%), and almost 40% of them perceived no benefits in using ICT in agriculture. The low perception of the positive impact of ICT on enhancing and improving agriculture productivity is due to the lack of knowledge and awareness of the agriculture ICT and the low level of adoption of ICT in agriculture.

Exploratory field visits

The explored field visits were conducted during COVID 19 pandemic and the lockdown in the country; therefore, accessing farms in any area was not easy. However, the permission from NIAD has simplified the access to the selected farms and provided an excellent opportunity to get information from the owners. Around 4 to 6 hours have been spent on each visit. In addition, a short interview was conducted with the farm's owner during the visit. The visits were analyzed based on the description of the farm and the adoption and awareness of the ICT in agriculture, as shown in Table 7.

Although few field visits were explored, they confirmed the survey's findings (the primary research method). The analysis of the field visits confirmed both low awareness, usage and adoption of ICT in agriculture among the farms' owners and businesses. It shows that while some of the farms' owners are aware of some irrigation and sensors in addition to the advantages of the ICT in enhancing their productivity, other farms' owners lack knowledge of the available ICTs for agriculture and never use them. Some of the explored farms use temperature and humidity sensors to collect data on the plants' situation. However, most of the data and the plants' control are done manually, as shown in Table 7.

SWOT-TOWS analysis for strategic options for adopting ICT in agriculture in Kingdom of Bahrain

SWOT Analysis is a strategic analysis method used to evaluate the "strengths", "weaknesses", "opportunities" and "threats" involved in an organization, a plan, a project, a person or a business activity. It is a tool used to measure the internal factors presented as strengths and weaknesses of an organization (along with the external aspects of opportunities and threats that may support or undermine the implementation of new projects (Parra-López *et al.*, 2021). It helps to choose the most matching strategies and strategic options that allow the enterprise to perform its duty and develop concerning the interaction between its internal and external environment.

Adding the relationship between the internal and external factors makes TOWS a much more helpful matrix than a standalone SWOT and an obvious next step. While the SWOT is considered an internal-external analysis, the threat-weakness-opportunity-strength is the other way around and is derived from the SWOT as an external-internal analysis tool. The TOWS matrix is used to develop strategic options for new projects, and it is generated considering the following strategies (Parra-López *et al.*, 2021):

SWOT and TOWS methods were applied to evaluate the effectiveness of ICT adoption in the agricultural sector in the Kingdom of Bahrain. The analysis will help to identify the strategic directions for adopting ICT in agriculture for farmers and business agriculture in the Kingdom of Bahrain. The analysis moreover helps cover all aspects related to the agriculture sector in Bahrain, which will improve the adoption process. It is derived from field visits (Table 7), observations and the statistical data provided through the literature, as shown in Tables 8 and 9.

The SWOT analysis revealed that agriculture in the Kingdom of Bahrain awaits a promising future, as there are many opportunities for developing agriculture. The emerging agriculture IT and advanced infrastructure can directly contribute to agricultural

Interviewer	Description of the farm	ICT adoption in agriculture	Awareness on ICT adoption in agriculture
Farm 1	15,000 ha (ha) of land divided into 12,000 ha cultivated using traditional agriculture methods and 3,000 ha cultivated using Aquaponics agriculture Aquaponics is a circular economy solution that is based on two basic systems: Aquaculture and hydroponics. The solution is built upon recirculating the water between fish tanks and plants' growing area, where plants will convert the toxic residues of fish (ammonia and nitrates) into valuable nutrients and purify the water on its way back to fish tanks	Within the 12,000 ha, farm 1 uses plain traditional farming, no automated practices nor technology usage Moreover, the authors noticed that no sensors were attached to the fish tanks. The data were collected manually 2 to 3 times a day; however, there were temperature and humidity sensors on the Aquaponics planting area. The data gathered manually or through the sensors were not kept for future referencing nor analyses	They believe using automation for irrigation and sensors to control the soil quality, and input are unnecessarily redundant costs, indicating a lack of knowledge of the technology advantages
Farm 2	A small protective cultivation area (1 ha) containing a mixture of fruits, vegetables and ornamental crops. The farm depends on the hydroponic method that uses the automatic air-conditioning system for temperature control The owner of the farm mentioned the main challenge they face, which is the shortage of fertilizers Farm 2 depends heavily on fertilizers since they do not use soil; this type of agriculture will be more sustainable when the inputs are controlled efficiently	Automatic Air-Conditioning System	The owner of the farm is an average educated person that has a little knowledge about ICTs related to hydroponic farming. However, he expressed his willingness to experiment with these technologies in line with the needs of his farm
Farm 3 and Farm 4	are small to medium-size farms in Bahrain 0.5 ha and 2 ha, respectively. The farms are based on traditional soil farming and both divided into protective and open land cultivation The shortage of fertilizers and pesticides reported as a common challenge between both farms	None (pure traditional farming)	The owners of the farmers' education are between elementary and intermediary, and they have no knowledge about ICTs in agriculture. The owner of farm 4 stated that he does not trust technology, and he runs his farm based on experience and practice

Table 7.
Field visits analysis

Strengths	Weaknesses
• The adoption and implementation of modern agriculture practices such as hydroponics and aquaponics • Level of awareness and experience regarding suitable agricultural methods among farmers • The new generation of farmers is more ICT oriented • Academic and professional agriculture programs and certificates	• Low ICT literacy among Bahraini farmers • Lack of knowledge about ICTs in agriculture • Nonexistence of a market information system • Lack of reliable data • Inadequate water management and harsh soil conditions • Insufficient use of ICTs for agricultural purposes
Opportunities	**Threats**
• The establishment of the Bahraini space agency (remote sensing • Community and governmental support through different programs and organizations such as NIAD • Resilient ICT infrastructure • Sufficient domestic energy supply • Strategic geographical location for exports in the region • Strong financial support • Advanced information technology (IoT, AI, Data Science, Big Data and etc.) • Relatively low labor cost • Digital native and digitalization and digital transformation	• Relative high prices of technologies • Lack of technology experts • Land scarcity and growing population • Low return over investment (ROI)

Table 8.
SWOT analysis for the readiness for adopting ICT in agriculture in Kingdom of Bahrain

productivity and indirectly empower farmers to make informed, quality decisions that will positively impact the way agriculture and allied activities are conducted. However, the weakness or challenges, such as low ICT literacy among Bahraini farmers and lack of reliable data, create barriers to exploiting such opportunities, specifically those related to ICT.

Therefore, TOWS analysis was conducted to set a relationship between the internal and external elements and provide the best ways to assess, create, compare and finally decide upon the strategic strategies to utilize inner strengths to make optimum use of the external opportunities available to the agriculture sector in the Kingdom of Bahrain. In other words, farmers and agriculture businesses must utilize their strengths to cash in on potential opportunities. For instance, by cooperating with financial intuitions such as the Bahrain Development Bank (BDB), they can take advantage of the available and emergent IT and expand their usage of modern agriculture practices. Moreover, they have to detect various alternatives to look past the weaknesses and take control of the opportunities in the course. For example, investing in ICTs education for farmers and agriculture-related technologies will produce a new generation of agriculture technology experts.

Conclusion and recommendations

One of the first nations in the Middle East to implement digital transformation is the Kingdom of Bahrain, which has done so in education and several other sectors, such as health care, government and business. The Kingdom of Bahrain's advancement in agriculture offers people and farmers a supportive environment. The development of the farming field has greatly aided the improvement of the agricultural sector. The study found that there are numerous chances for improving agriculture; therefore, the future of agriculture in the Kingdom of Bahrain seems optimistic. Emerging IT technologies like big data, IoT, cloud

	Opportunities	Threats
Strengths	S-O (Strengths – Opportunities): aim to maximize both by mutually benefit from each other (Max – Max) • Cooperation with financial intuitions such as the Bahrain Development Bank (BDB) will aid the expand and usage of modern agriculture practices • Incorporating ICTs courses into the agriculture certifications offered by educational institutions such as Bahrain Training Institute (BTI) will improve the level of awareness among farmers and pave the way to more ICT farming practices	S-T (Strength – Threats): how to utilize the internal strengths to minimize external threats (Max – Min) • Encouraging the adoption of modern agriculture practices such as hydroponics, which supports vertical farming as a solution to limited farm size • New generations of farmers are more technology oriented; this can open new careers in the agriculture sector related to ICTs • Hydroponics initial setup cost is relatively high, however at the long run and with the implementation of ICTs such as Internet of Things (IoT) the cost of human labor, fertilizers and pesticides will be avoided
Threats+	W-O (Weaknesses – Opportunities): Seize external opportunities to overcome weaknesses (Min – Max) • NIAD as a support organization for the agriculture sector facilitates partnership with educational institutions to provide specialized courses in ICTs for farmers • Inducing agriculture related governmental entities and farmers to implement emerging technologies such as Big Data and cloud computing to improve data integrity, reliability and accessibility • Strong ICT infrastructure in Bahrain enables telecommunication companies to easily provide reliable network coverage for every farm	W-T (Weaknesses – Threats): controlling internal weaknesses to mitigate threats (Min – Min) • Utilizing ICTs to build a market information system (MIS) to help farmers efficiently manage their expenses • Investing in ICTs education for farmers and agriculture related technologies will produce a new generation of agriculture technology experts • Enhancing data reliability through emergent technologies will enhance production for small farms as well as large ones

Table 9.
TOWS analysis for the strategic directions for adopting ICT in agriculture

computing and AI will offer a supportive infrastructure and creative agricultural environment for enhancing the development of agriculture and helping to overcome some of the challenges agriculture faces, such as water scarcity, climate change and soil issues.

Despite the remarkable transformation and the crucial work being done to develop the agriculture sector, many problems still prevent farmers from taking advantage of the opportunities presented by digital solutions. These problems include low ICT literacy among farmers, a lack of a curriculum for farmers to raise their level in the IT field (educational issues), farmers' ignorance of the smart agriculture tools being used around the world, and the pervasive belief that farmers are incapable of using modern technology. It is also clear that there is a lack of communication among farmers, citizens, government initiatives and others that support the growth of the agriculture industry.

With the help of policymakers, an action plan must be developed to address these issues and integrate ICT into Bahrain's agriculture industry. To encourage more citizens and residents, the government should offer various incentives, including installing technologies at discounted prices, professional technical support, affordable power supply and network fluctuation monitoring. On the other hand, it should increase usage and awareness of ICT adoption in agriculture and turn that usage into actual utilization. ICT services for

agricultural production should be developed to be suitable for all users considering all age groups to promote increased utilization. By enhancing agricultural output, reducing resource consumption and raising the GDP, the Kingdom of Bahrain will attain agricultural sustainability.

The study is a component of ongoing research that involves three sequential approaches: (1) examining ICT adoption and knowledge levels in Bahrain's agricultural sector, which the current study did, (2) developing a resilient infrastructure based on training programs and workshops to increase farmers' ICT literacy, and (3) ICT for agriculture diffusion using emerging technologies like IoT and big data. The second approach is an action plan to change farmers' agricultural practices and attitudes while raising their understanding of the use of ICT in agriculture. The workshops and training programs will introduce various agricultural technologies and their advantages while enhancing the farmers' ICT capabilities. They are transitioning from primary computer use to the gradual adoption of precision farming technologies like soil sensors and collecting and analyzing agricultural data. Additionally, it will assist farmers in developing and putting into practice affordable agrarian technical solutions appropriate for Bahrain's environment in terms of the country's limited agricultural acreage and farmers' circumstances.

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