وزارة البيئة والمياه والزراعة
Ministry of Environment Water & Agriculture

Innovation in the Agriculture sector in Saudi Arabia

Technology Adoption Roadmap

His Royal Highness Prince Mohammed bin Salman

Crown Prince، Prime Minister، Chairman of the Council of Ministers، and Chairman of the Supreme Committee for Research، Development، and Innovation

"Our ambition for Saudi Arabia is to become a global leader in research، development، and innovation with an annual investment equivalent to 2.5% of GDP in 2040. This will diversify and add 60 billion Saudi Riyals (US$ 16 billion) to the economy in 2040 while creating high-value jobs in science and technology."

Statement by His Excellency the Minister of Environment, Water, and Agriculture

The Kingdom's leadership believes in the importance of research and innovation to build a knowledge economy and achieve true diversification of the state's resources، especially in the vital، priority sectors of environment، water، and agriculture. The Ministry of Environment، Water، and Agriculture aims to enable partners across the innovation ecosystem to stimulate and localize technologies to provide effective sustainability solutions within the Ministry's sectors.

His Excellency Eng. Abdulrahman Abdulmohsen AlFadley

Statement by His Excellency the Vice Minister of Environment, Water, and Agriculture

The innovation ecosystem enjoys unlimited support and keen interest from our wise leadership، may God support them. The Ministry of Environment، Water، and Agriculture has taken several steps to enable innovation، including establishing a deputyship for research and innovation to help find innovative solutions for issues related to sustainability of natural resources، environmental protection، meeting basic water and food needs، and achieving economic and developmental outcomes.

His Excellency Eng. Mansour bin Hilal Al Mushaiti

Eng. Ahmed Saleh Aiadh AlKhamshi

Deputy Minister for Agriculture Affairs

Statement by His Excellency the Deputy Minister for Agriculture

The agricultural sector is one of the most vital sectors in the world, and the importance of this sector increases with the emerging global changes and challenges. The agricultural sector affects the whole world, as it is responsible for providing food, preserving rural communities, and managing the vast majority of agricultural lands. It also extends to managing animal and fisheries wealth. In the Kingdom, the agricultural sector plays significant economic and social roles, contributing around 4.3% to the non-oil GDP, employing close to 350,000 people, and forming a core foundation for the Kingdom's future growth and a major pillar of Vision 2030.

The sector has unique characteristics, where harsh and unsuitable environmental conditions like water scarcity and hot weather affect its processes and outputs. Recognizing the extreme importance of this sector for food and water security, the government of the Kingdom is committed to supporting this sector in various ways, carrying out multiple organizational reforms to create a sustainable environment that stimulates growth, and restructuring the sector to serve national ambitions. These measures have resulted in several accomplishments, including a major reduction in the use of non-renewable groundwater, decreasing from 19 billion cubic meters in 2015 to about 10 billion cubic meters in 2022. The food self-sufficiency rate exceeded 50% in 2022, representing a significant leap towards achieving our food security.

In recent years, the Ministry of Environment, Water, and Agriculture focused on organizational reforms and sector restructuring aligned with future aspirations within Vision 2030, which contributed to the sector's evolution. It will continue to do so, God willing, to realize national ambitions and targets. The Ministry believes the agricultural sector is now more ready to benefit from the innovative solutions offered by modern technologies for further productivity and resilience. The Ministry also recognizes this approach can transform sectoral challenges into opportunities, God willing, thereby contributing to higher levels of food and water security.

The roadmap for adopting innovative technologies in the agricultural sector affirms the Ministry of Environment, Water, and Agriculture's commitment to harness innovation to elevate the sector. This initiative establishes a strategic vision for integrating advanced technologies into agricultural practices and setting new standards for efficiency, sustainability, and productivity. As we look to the next phase with great ambition and optimism, this roadmap will serve as a guiding reference to direct the Ministry's and all stakeholders' efforts in the fields of agricultural technology and innovation, to bring about the desired shift towards a sustainable and prosperous agricultural sector.

Dr. Abdulaziz bin Malik Al-Malik

Deputy Minister for Research and Innovation

Statement by His Excellency the Deputy Minister for Research and Innovation

Many countries have focused on developing their technological and innovative capabilities, as it is a key enabler for sustainable economic growth. It helps increase the competitiveness and productivity of various economic sectors and provides effective solutions to many pressing challenges. The Kingdom of Saudi Arabia has given remarkable attention to technology and innovation in various vital sectors. His Royal Highness Prince Mohammed bin Salman, Crown Prince, Prime Minister, Chairman of the Council of Ministers, and Chairman of the Supreme Committee for Research, Development, and Innovation, announced the aspirations and national priorities for research, development, and innovation in Saudi Arabia for the next two decades. These are based on four key priorities, including environmental sustainability and basic needs. This reflects Saudi Arabia's commitment to sustainably provide for the basic human needs of water and food by developing environmentally friendly technologies for water supply and desalination, and modern and sustainable techniques for food production and the expansion of green areas.

The urgent need to adopt technology and innovation in the agricultural sector in Saudi Arabia stems from the necessity to strike a healthy balance between increasing food production — which is essential to achieve self-sufficiency and food security, support steady economic growth, and reduce the agricultural trade deficit — and ensuring the sustainability of scarce water resources in the long term and avoiding damage to the local environment.

Recognizing the importance of adopting technology and innovation, the Ministry of Environment, Water, and Agriculture established a Deputyship for Research and Innovation within its organizational structure to activate the Ministry's role within the institutional framework and national governance model for the research, development, and innovation sector. It has developed an executive institutional research and innovation strategic plan to make the environment, water, and agriculture system the most ready and capable to embrace and develop innovative technologies and practices. One of the most important components of this plan, which our report discusses, is the strategic focus on adopting priority innovative technical solutions to meet the needs of the agricultural sector. This will serve as a guide for institutional interventions and initiatives to ensure optimal steering of efforts and resources.

The Ministry of Environment, Water, and Agriculture followed a carefully designed methodology to analyze, demand, and identify available supplies of the most important innovative solutions for the agricultural sector that should be focused on in the short- and medium-term. It detailed the waves of their adoption and widespread dissemination in a technology adoption roadmap for the agricultural sector in the Kingdom. This methodology relied on several criteria, including expected impact of technology deployment, its ability to address challenges facing the agricultural sector, and ease of adoption, with a focus on the most mature, deployment-ready technologies. After piloting and adaptation to suit local conditions, these technologies can be broadly disseminated in the sector. This roadmap was developed through integration, cooperation, and support from various stakeholders and in alignment with relevant national strategies for the environment, water, agriculture and research, development and innovation sectors. The process involved dozens of policymakers and experts specialized in agricultural innovation.

The purpose of publishing this report is to inform all stakeholders in the agricultural ecosystem, including pioneering and emerging companies, R&D centers, and non-profit organizations, about the Ministry's strategic direction in this sector. This information will assist them in making informed decisions and developing their own customized plans and policies enlightened by the promising opportunities outlined in this report for incorporating technology and innovation into their operations and systems. This will have the greatest impact, God willing, in elevating the national agricultural system.

About the Report

This report is one of three reports issued by the Ministry of Environment, Water, and Agriculture on technology adoption in its sectors in the Kingdom. It aims to identify ready technologies contributing to solving sectoral challenges in the Kingdom and outlining the Ministry's executive plan in this regard.

Agricultural Innovation in the Kingdom of Saudi Arabia

Environmental Innovation in the Kingdom of Saudi Arabia

Water Innovation in the Kingdom of Saudi Arabia

About the Ministry of Environment, Water, and Agriculture

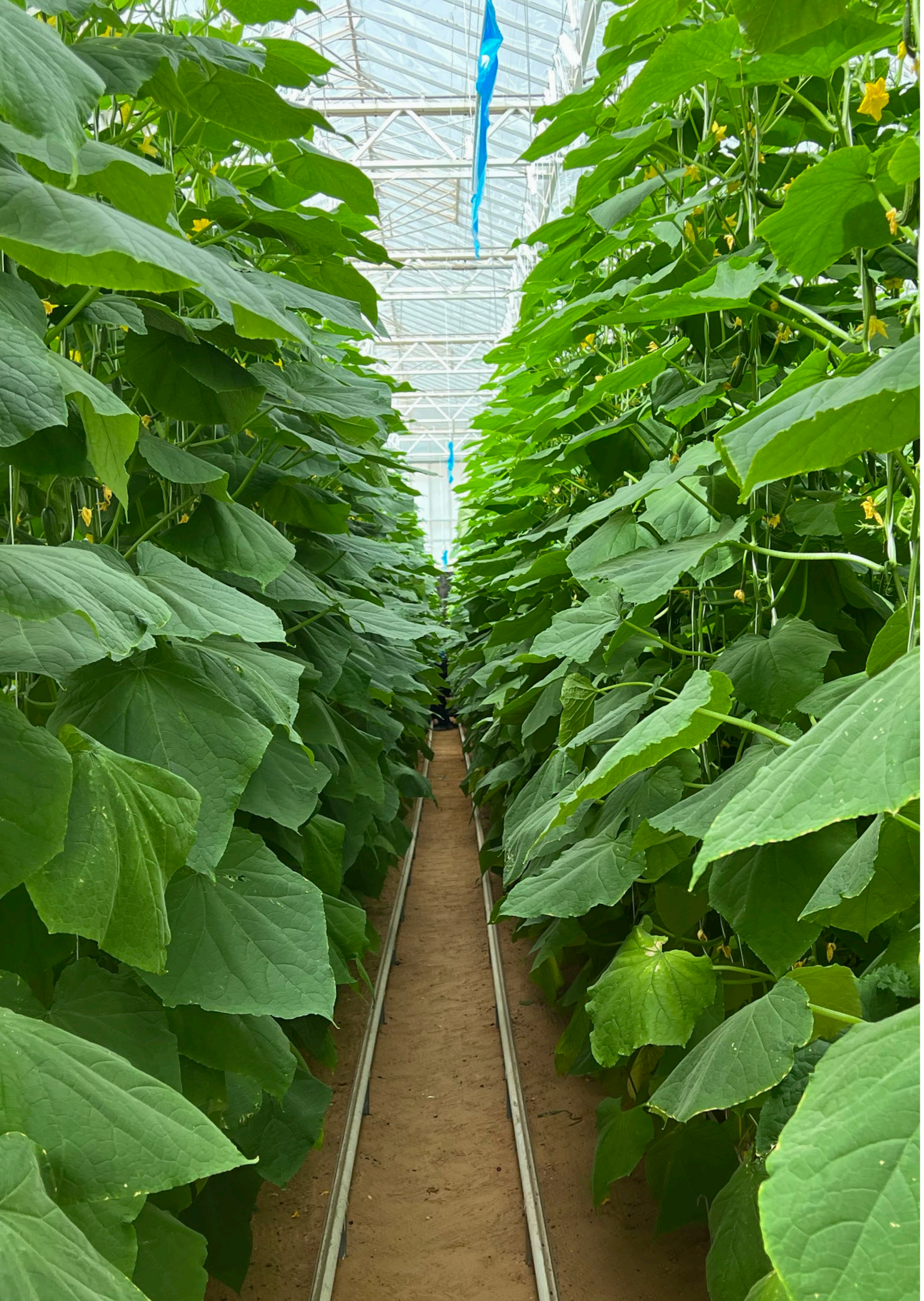
The Ministry of Environment, Water, and Agriculture in the Kingdom of Saudi Arabia is responsible for regulating and implementing all aspects of the Kingdom's policies in the environment, water, and agriculture sectors. The Ministry implements environmental, water, and agricultural plans and programs at the national level, with a focus on sustainability and value creation. Its contribution to the national economy has increased through various programs, especially in food security, water provision, and environmental protection.

Vision

Sustainable environment and natural resources that achieve water security, contribute to food security, and improve quality of life.

Mission

The Ministry strives for excellence in developing and implementing comprehensive policies, effective strategies, and improved services. It aims to achieve prosperity and sustainability in the fields of environment, water, and agriculture by actively involving the private sector and other relevant entities.



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Executive Summary

Technology and innovation is playing an increasing role in achieving national targets in the environment, water and agriculture sectors. Adopting technology and innovation in the agricultural sector is becoming essential, given the ambitious national goals for the sector. To accomplish these objectives, it is crucial to widely implement innovative technologies and practices to address sectoral challenges into opportunities.

This report sheds light on the Ministry's executive plan to promote adoption of innovative technologies and practices in the agriculture sector, and the strategic focus towards adopting priority innovative products and solutions to meet the most pressing needs in the agricultural sector. This will serve as a guide for institutional measures and initiatives to ensure the optimal steering of efforts and resources.

The Ministry followed a detailed methodology to select priority technologies in the agriculture sector. This process began by analyzing the demand side for technology and innovation by examining the challenges faced by the agricultural sector across the value chain and within subsectors. Additionally, the Ministry considered the expected impact of technology and innovation adoption on addressing these challenges. On the supply side, the Ministry surveyed an extensive segment of available technology and innovation solutions and refined them based on several criteria. From this, the Ministry generated a segment of technologies and innovations that are ready for adoption and scaling up. These selected technologies have the potential to make the greatest impact and offer quick and effective solutions to the most pressing challenges in the agricultural sector in the short and medium term.

This effort involved more than a hundred policymakers and technology and innovation experts, identified more than 45 challenges and opportunities, and selected over 100 individual technologies categorized into 24 technology families. Based on this, 10 technology families were chosen for the agriculture sector, half of which will be adopted in a first "high priority" activation wave until 2025, and the other half in a second, subsequent wave. A third, future wave will involve the adoption of broader technologies beyond the initial 10 identified ones. The first-wave technology families are irrigation and water management technologies, integrated aquaculture farm management, protected agriculture and controlled environment, food preservation and waste valorization, and unmanned aerial vehicles (drones) and satellite imagery technologies. This report covers these five families in detail by introducing them and explaining the demand and supply drivers and current barriers to their widespread adoption. The report further touches on the technologies of the subsequent second and third waves, which the Ministry intends to adopt between 2025 and 2030.

The Ministry aims to implement several institutional initiatives to adopt and disseminate priority technologies in the agricultural sector in partnership with relevant stakeholders. These initiatives were developed after a comprehensive survey and analysis of existing efforts in the agricultural sector. The goal is to achieve the ambitious future aspirations for this sector within Vision 2030. This includes aligning with the national research, development, and innovation agenda and understanding the Ministry's role within the institutional framework governing it. Additionally, the initiatives consider the current state of technology adoption and innovation activities in the agriculture sector, and the state of technology adoption enablers such as available infrastructure, human resources working in the agricultural innovation ecosystem, and policies and regulations supporting technology adoption and innovation in the sector. It also utilized best practices of sectoral and national innovation policymaking recommended by several international organizations.

The priority measures to promote technology and innovation were identified, with the aim of achieving four main objectives:

- Directing and coordinating efforts: This involves overseeing and managing the plans, efforts, and resources allocated to adopting technology and innovation in the agriculture sector. The focus is on addressing sectoral challenges in line with national research, development, and innovation priorities and the relevant national strategies.
- Enhancing collaboration and partnerships: The goal is to improve connections and cooperation between stakeholders engaged in technology and innovation adoption within the agriculture sector. This collaborative approach aims to foster partnerships, leverage synergies, exchange expertise, and share knowledge. It also seeks to raise awareness of the agricultural ecosystem's achievements in integrating technology and innovation into their plans and operations to create positive momentum and ensure the sustainability of these efforts.
- Stimulating technology demand: This involves increasing the interest and demand for technology products and innovative solutions within the agriculture sector. It includes measures and incentives designed to boost the sector's willingness to adopt available technology solutions, ensuring that the supply of technology aligns with the demand.
- Building research and innovation capacities: This objective focuses on strengthening the research, development, and innovation capabilities within the agriculture sector. The aim is to ensure a sufficient and continuous local supply of technology products and innovative solutions.

Development of algae biotechnology, King Abdullah University of Science and Technology

Introduction

Technology and innovation are among the most important drivers of economic growth, primarily by enhancing the productivity of various sectors. This significance is particularly relevant to the agricultural sector, given the challenges of population growth and an increasing demand for agricultural products. The call for innovation in the agricultural sector in the Kingdom is even more pressing due to its unique challenges, including the preservation of non-renewable water resources and the arid climate.

Agricultural innovation has several motivations, including traditional economic drivers like increased productivity, competitiveness, and contribution to GDP, as well as strategic drivers like self-sufficiency and higher food security. Global events such as the COVID-19 pandemic and geopolitical tensions further underscore the importance of resilient food supplies.

Agricultural technology and innovation contribute in many ways, such as providing improved crop varieties and enabling sustainable practices that have become indispensable in adapting to resource scarcity and climate change. Innovation also plays a supporting role in improving agriculture and rural development, which impacts societies overall, with clear results in improved livelihoods, reduced poverty, and less migration to urban areas.

The global agricultural sector has undergone several transformations in recent decades, with a growing emphasis on the integration of technology and innovation into agricultural practices. This trend can be attributed to two primary reasons:: Firstly, there is a growing demand for innovative technologies and practices to address the mounting challenges faced by the agricultural sector.

These challenges include water scarcity, supply chain disruptions, climate change, food security, and increasing the sector's contribution to the country's economic mix.. Secondly, the supply of innovative solutions has expanded rapidly due to advancements in technology. This surge in technological development has opened up promising opportunities to enhance efficiency, increase productivity, and promote sustainability in agricultural processes. For instance, digital technologies now offer effective solutions to various agricultural problems, advances in materials science have addressed soil and fertilizer issues, and biotechnology has provided natural solutions for managing agricultural pests.

Evidence shows the impact of technology and innovation on the productivity of the global agricultural sector and improved performance of agricultural systems. Despite declining agricultural workforces compared to past decades, sectoral productivity doubled thanks to technology and innovation, raising agriculture's contribution to the global economy. For instance, modern technologies in the United States doubled agricultural output threefold between 1948 and 2017 without a corresponding increase in inputs. This shift used technologies such as GPS and yield monitoring devices. These advancements not only enabled growth in production but also resulted in cost savings and a reduction in environmental degradation.

It is unsurprising that this momentum towards innovation in the agricultural sector persists on both the demand and supply sides, especially since market research has shown that some promising technologies can accomplish numerous global targets.

For example, studies on water management have demonstrated that automated/smart irrigation systems can save up to 20% of water utilized in wheat cultivation compared to traditional irrigation methods,[1] while research shows that protected agriculture and controlled environment technologies can use up to 93% less water per kilogram for some crops compared to drip irrigation in open fields.[2]

Furthermore, trends in the agricultural technology market show a clear direction for the sector when it comes to the adoption of technology and innovation.

The market value of IoT and smart sensors is expected to reach:

$33.6 billion by 2032 from $13.6 billion in 2022 at a 9.8% CAGR.

The drone market for agriculture is expected to grow from:

$1.1 billion in 2022 to $7.19 billion in 2032.

Finally, the global agricultural biotechnology market is projected to reach:

$242.17 billion by 2032 from $106.62 billion in 2022.[3]

These global successes demonstrate the benefits countries gain from focusing on technology and innovation, underscoring their importance in agriculture as a major contributor to food security. It is worth noting in this context that the top performing countries in innovation indicators are also the highest ranked in food security indicators,[4] confirming the close correlation between innovation and achieving food security.

Figure No. [1] shows the most important products the Kingdom produces in the three main areas of the agricultural sector [crops, livestock and fish, and food]

Figure 1: An overview of the agriculture sector in the Kingdom of Saudi Arabia

Crops

800K Tons Wheat	944K Tons Fruits
3050K Tons Vegetables	1610K Tons Dates

Livestock and Fish

5900K Tons Poultry	190K Tons Fish
312K Tons Cattle	2180K Tons Sheep

Food

2380K Tons Dairy products	361K Tons Eggs

Source: Ministry of Environment, Water and Agriculture, Statistical Book, 2022

1 Hussein M Al-Ghobari et al, "Automated Irrigation Systems for Wheat and Tomato crops in Arid Regions", Water SA Journal, 2017

2 Elly Nederhoff and Cecilia Stanghellini, "Water Use Efficiency of Tomatoes in Greenhouses and Hydroponics, Practical Hydroponics & Greenhouses", 2010

3 Infopulse, "7 Agriculture Trends", 2023

4 Analysis of "WIPO" Global Innovation Index and "The Economist" Global Food Security Index

Figure No. [2] below shows the current aspirations of the agricultural sector and their classification according to three main areas: Crops, livestock and fish, and food. These aspirations were set based on the results of analyzes of national strategies and extensive meetings with stakeholders.

These aspirations will address the diverse challenges facing the agriculture sector — in the areas of crops, livestock and fish, and food, and will generally contribute to improving sustainability, cost and accessibility.

Figure 2: Overview of challenges and opportunities for the agriculture sector

However, the agricultural sector needs more investment in research and development, not just in the Kingdom but globally. Different countries have varying agricultural goals and challenges. It is therefore important to focus efforts on technologies that address local problems and contribute to achieving national targets. This requires continuous monitoring of the national context and linking it with the latest technological and innovative developments in the agricultural sector, as well as coordinating national efforts towards unified goals that add value to this sector. In addition, a supportive framework is required which includes regular updates to systems, a conducive environment for innovation, and a comprehensive examination of any obstacles. Providing ongoing support and guidance is essential to drive progress in this critical sector.

The government of the Kingdom of Saudi Arabia has given utmost importance to innovation in its vital sectors, believing that technology and innovation are key enablers for the growth of these sectors, including the agricultural sector. This falls under the national innovation priority of environmental sustainability and basic needs, which is one of the four priorities announced by His Royal Highness the Crown Prince and Prime Minister Prince Mohammed bin Salman. Recognizing the tremendous impact of technology and innovation and the necessity of adopting them to achieve future aspirations, the Ministry of Environment, Water, and Agriculture established a Deputyship for Research and Innovation within its organizational structure to activate the Ministry's role within the national frameworks governing the research, development, and innovation sector.

The Ministry has begun implementing its research and innovation strategic plan extending until 2030, with the aim to integrate technology and innovation into its systems and operational processes across the value chain of the environment, water, and agriculture sectors. This will make the environment, water, and agriculture system the most ready and capable to embrace and develop innovative technologies and practices.

The Kingdom has succeeded in efficiently managing its agricultural system in a manner that ensures sustainability of its vital resources and its water and food security. The development and implementation of a comprehensive national strategy for the sector, with ambitious aspirations under Vision 2030, has helped in this regard. Agricultural GDP exceeded 100 billion riyals for the first time in 2023, and production of protected agriculture vegetables increased from 270,000 tons in 2015 to more than 600,000 tons in 2022.[5] Developing alternative fish feeds in aquaculture has resulted in cost savings exceeding 30%, with potential annual cost savings reaching more than 1.5 billion riyals annually.[6] The Kingdom has also achieved self-sufficiency in 15 types of vegetables and many animal products at rates exceeding 80%.[7]

The Ministry of Environment, Water, and Agriculture has initiated structural reforms, regulatory policies, and established new entities to drive progress. The next pivotal factor for advancing the Ministry's sectors is innovation. Innovation holds the potential to enhance efficiency, increase productivity, and raise the sector's economic contribution. The case studies in the following pages point to one global and two local examples where innovation was decisive in providing effective solutions.

5 GASTAT, "Agricultural Production Survey Publication", 2021
6 Seafoodsource "Biotech startup NovFeed addressing East Africa›s aquafeed shortage", 2023
7 GASTAT, "Agricultural statistics report", 2022.

Global Success Story

The benefits of using drone and artificial intelligence (AI) technologies for strategic crops and orchards in the United Kingdom

Two leading technology research institutes in the United Kingdom have highlighted the integration of drone technology with AI for agricultural purposes. This innovative combination has the potential to transform the field of agriculture through the use of advanced computer vision, machine learning, and 3D mapping techniques.

The collaboration between the two institutes focuses on the synergy between drones and AI in agriculture. By leveraging advanced computer vision, machine learning, and 3D mapping, the collaboration explored drones' capabilities in crop farming and fruit orchards. This innovative approach presents the possibility to increase efficiency and sustainability in this sector. Firstly, the study demonstrated major improvements in efficiency. The main goal of the collaboration was to accelerate inspection activities, which traditionally consume significant time and resources.

By using drones, they were able to assess more than 20% of the orchard within minutes. Additionally, the study showcased the ability to enhance orchard productivity by 10%, using aerial imaging. This imaging also to helps detect early disease and thus increases crop productivity by 25%. Secondly, the study demonstrated the potential for a major contribution to sustainable agricultural practices, aligning with global efforts to combat climate change. The technology played a role in reducing food waste by up to 50%, lowering carbon emissions, and reducing the use of chemicals. The reduction in chemical use was made possible through drone spray applications, which help decrease expensive pesticide and fertilizer use by 25-35%. Overall, this collaboration highlights the broader impact of integrating drone and AI technology in agriculture, paving the way for a more efficient and sustainable future in farming.

Local Success Stories

Aquaculture Development Program

Floating cages in the Aquaculture Development Program, Ministry of Environment, Water and Agriculture, King Abdullah University of Science and Technology and private sector entities

The Aquaculture Development Program further aims to improve the survival rates of aquaculture species and reduce feed costs by 30% or more annually, achieving savings of more than $400 million.

The Aquaculture Development Program was launched in collaboration between the Ministry of Environment, Water, and Agriculture, King Abdullah University of Science and Technology, and private sector entities. These included Saudi Agricultural & Livestock Investment Company, NEOM, Saudi Company for Fishes, Aqua Bridge, Saudi Company for Seafood, Network of Aquaculture Centers in Asia Pacific, Tabuk Fish, and National Aquaculture Group.

The program aims to improve the feed conversion ratio and growth rates for existing and new aquaculture species in Saudi Arabia. The program utilizes alternative feed technology, which falls under integrated aquaculture management. Key activities include: Evaluating current commercial feeds and potential alternative feeds, conducting digestibility trials on alternative feed ingredients and ensuring they meet the broad requirements of different fish species, testing enhanced feed formulations in a controlled environment, and testing enhanced feeds in production environments. Measurable outcomes of this program include reducing feed costs by more than 30% in aquaculture, resulting in potential annual cost savings of more than $400 million (approximately 1.5 billion riyals).

A laboratory within the Aquaculture Development Program, the Ministry of Environment, Water and Agriculture, King Abdullah University of Science and Technology, and private sector entities

Local Success Stories

Badir Smart Farm

The Badir Smart Farm program is the first smart agriculture program based on hydroponic vertical farming in Riyadh. The program focuses on using the latest technologies to localize imported crops in a more efficient, clean and sustainable manner. The crops of this aquaponic farm (growing plants in water instead of soil) are characterized by rapid growth and maturation, as they grow twice as fast as conventional crops due to automated climate control, smart energy management, and specialized LED lighting. Farm products include basil, edible flowers, herbs, lettuce, and microgreens. The farm has its own program, called iFarm Growtune, which allows continuous high-precision temperature monitoring and management of all farm operations, from demand forecasts to sales in simple steps. The program also provides clear instructions for farm staff and harvest monitoring. Project outcomes include growing all crops using 100% renewable energy, consuming 65% less water compared to traditional farms, and producing crops free of any pollutants, pesticides and herbicides.

These successes can be applied on a wider scale to increase the level of agricultural sustainability, by adopting technologies that contribute to achieving national targets, and using a systematic approach focusing on improving productivity, sustainability, and resilience. Adopting technologies should not be limited to individual innovations, but rather extend to establishing an interconnected, evolvable system where its components can communicate to increase effectiveness and optimize utilization of all expertise and technologies.

Reverse osmosis purification device in the Badir Smart Farm program, Badir Farm

Purpose of the Report

The Ministry aims through this work to develop a strategic scope built on the agricultural sector's needs and oriented towards adopting readily available technical solutions to meet those needs. The Ministry seeks for this scope to guide institutional interventions and initiatives to ensure optimal steering of efforts and resources.

The report thereby presents a roadmap for deployment-ready technologies that the Ministry of Environment, Water, and Agriculture plans to adopt, starting from identifying the problems facing the Kingdom in the agricultural sector, moving to the technologies addressing them, and ending with executive programs enabling adoption of these solutions.

The roadmap illustrates the path the Ministry aims to take in adopting technologies, with objectives including confirming the availability of solutions for many of the challenges facing the agricultural sector, and clarifying the Ministry's strategic direction for stakeholders playing vital roles in realizing Saudi Arabia's ambition towards a sustainable agricultural sector. The next section links stakeholders with this report.

Glass and air-conditioned greenhouses using the latest technologies to control the internal environment of the farm, Mishkat

Relevant Parties

The innovative technologies deployment roadmap is the culmination of intensive efforts led by the Ministry of Environment, Water, and Agriculture with support and contributions from all agricultural system stakeholders, including government institutions, the private sector, startups, research centers and universities, and investors.

More than 120 experts and specialists from relevant entities, representing about 30 organizations, contributed to this report. The project team analyzed over 50 survey responses on sectoral technologies, aligned these technologies with more than 10 national strategies, and organized several workshops and meetings to gain a deeper understanding of stakeholders' perspectives.

Various entities can benefit from this report, including:

1 **Government institutions:** These are responsible for providing regulatory and strategic support, enabling an environment for innovation, and ensuring policy and standard alignment with sustainable agricultural growth objectives. While this report provides an overview of technologies expected to be adopted in the Kingdom over the next few years, several governmental entities play a role in facilitating the adoption of these technologies in various aspects, such as enabling technology providers to enter the Kingdom, and ensuring regulatory tools enable implementation of these advanced technologies.

2 **Private sector:** The private sector is a key partner in this endeavor, playing various roles in adopting advanced technologies, including importing mature technologies into the Kingdom, localizing and developing them, and propagating them locally. Additionally, the agricultural private sector is targeted to implement these technologies in its systems and operations. As a major representative of the demand side targeted in this report, it is the driver towards agricultural sector sustainability and increased effectiveness.

3 **Innovative startups:** These small emerging enterprises have sufficient knowledge to comprehend advanced technologies and implement them on the ground. They have the agility to absorb medium-term technology investments with economic impact. They can also access specialized innovation financing tools like venture capital funds. Such enterprises play an essential role in introducing technologies into markets, since innovation is at the core of their sectoral activity, and their intermediary position between scientific and sectoral systems.

4 **Research centers and universities:** They contribute to creating and developing technologies in the agricultural sector, including researching on applied advanced technologies, adapting these technologies to suit the local environment, and developing them to increase their effectiveness in the future.

5 **Investors:** These include national and private investment funds, angel investors, financial institutions, and more. They play pivotal roles in technology adoption such as financing and monetary support. They mitigate risks for innovators by enabling them to introduce new products despite high uncertainty. They provide expertise and guidance for innovators using their market experience, facilitate market access through commercial and industrial networks, and lend credibility to innovators with markets by adopting their innovations. They also enable innovators to scale locally and internationally.

The effect of using diffused glass as a cover for greenhouses, National Center for Sustainable Agriculture Research and Development "Estidamah"

Methodology for Technology Adoption Roadmap

Designing an accurate and adaptable technology deployment roadmap is a complex task for several reasons, including the accelerating pace of technological advancement and market demands. Developing a roadmap for adopting innovative technologies requires anticipating future technology trends and aligning them with long-term national ambitions, which poses a challenge in the fast-changing technology landscape.

Several factors contribute to this complexity. These include the necessity to anticipate emerging technologies and seamlessly integrate them with existing systems. Effective resource allocation, along with the capacity to remain flexible in response to new information or market shifts, adds another layer of complexity. Additionally, ensuring alignment among stakeholders introduces further organizational complexities. Consequently, the technology deployment roadmap must balance future visions and adaptability with the sector's current state, making its design a delicate process.

Overview

The comprehensive approach to developing a technology deployment roadmap consists of three core components: First, assessing the scale and nature of demand for technology solutions through close communication with sectors to understand their challenges and demands. Second, identifying technologies suitably matched to sectors at large, resulting in more than 100 technologies across 24 families or families for the agriculture sector. Third, agreeing on technology priorities based on two key criteria: impact on challenges, for instance the technology's ability to address sectoral challenges, and ease of adoption of these technologies in the Kingdom. Adoptability is critical, since a key goal of the technologies is to address the most pressing challenges. Therefore, how quickly a technology could be deployed was an important factor in prioritizing technology adoption, resulting in waves for adoption. The following subsections focus on these three components.

Demand Side for Technologies

Demand for technical solutions in the agriculture sector is driven by several factors, including the challenges for this sector, most notably the harsh environmental conditions, including water scarcity and hot weather. Transforming this sector also requires finding technical that can facilitate this transformation. Additionally, the sector has witnessed the introduction of several regulations in recent years aimed at organizing it, and it needs innovative solutions in the coming years to align it with national ambitions. Finally, this sector plays an important and strategic role for the Kingdom as it deals with food and water security, which require national entities to work together and consider all available solutions.

Therefore, it was necessary for the technology adoption roadmap to be based on these national challenges and urgent needs (demand side) as well as the opportunities available at the same time (supply side). To that end, extensive efforts were undertaken, in close cooperation with the sectors, to identify and characterize the most important challenges. Existing aligned national strategies tailored to local requirements as well as sectors' ongoing efforts greatly facilitated the work.

To reach the scale and nature of demand for technical solutions, the report began by characterizing the sectors and dividing them into several segment according to their value chain. In the agriculture sector, these segments were crops, livestock and fish, and food. The report then precisely determined the challenges for each segment, assessing the potential of technical solutions for each. Finally, the report connected the challenges with the corresponding technologies, concluding in the creation of maps that represent the demand for technical solutions.

Cultivation of saffron using vertical agriculture, National Center for Sustainable Agriculture Research and Development "Estidamah"

Supply Side for Technologies

Efforts to find technical solutions for the agricultural sector have been ongoing for decades, and these solutions vary according to regional needs and national orientations. Many attempts have been made to align available agricultural technologies with these needs. Since there are a large number of available agricultural technologies and some may not be suitable in all cases for national needs, it was necessary to develop an approach that enables classifying readily available technologies and matching them with sectoral needs in the Kingdom, to identify priority technologies, and then design strategic initiatives to enable their adoption.

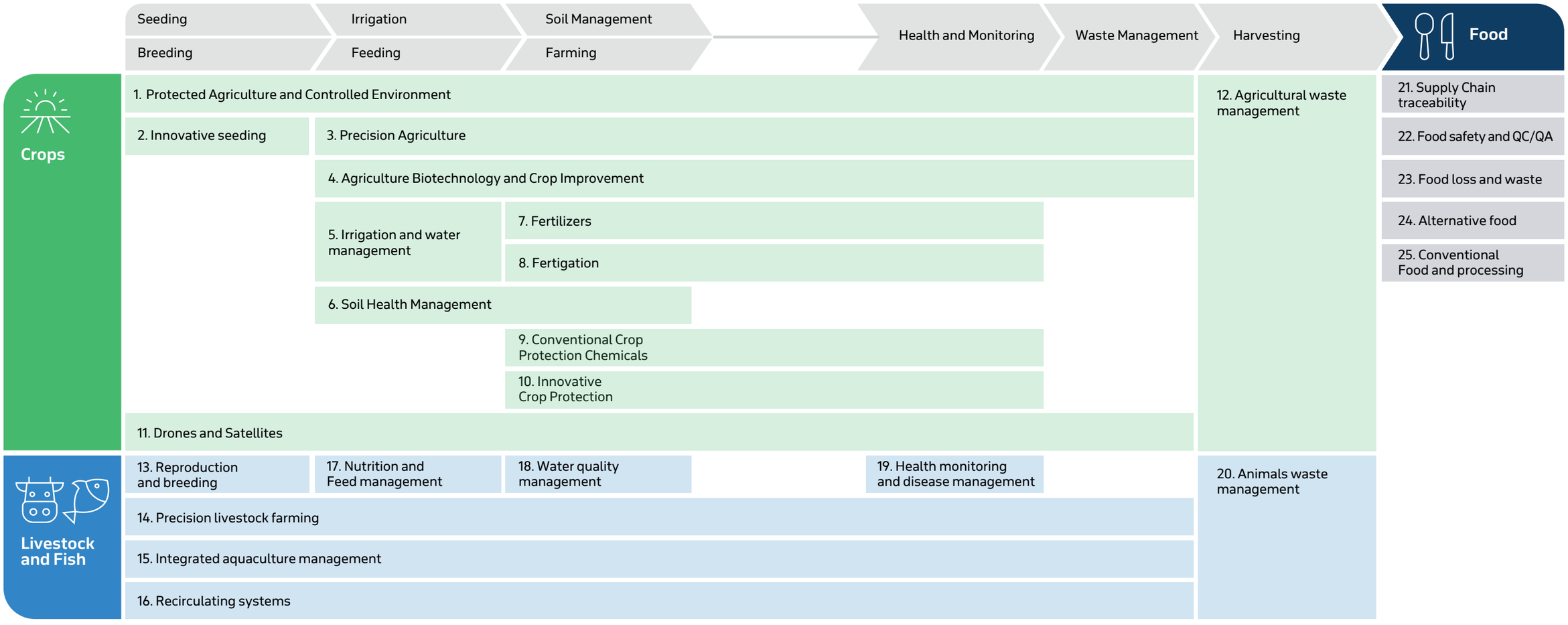
To facilitate classifying these technologies, the approach used identified an extensive segment of agricultural technologies, then categorized them into families of technology families, with each family addressing similar problems. For example, all technologies providing irrigation solutions are grouped into one family, even if they differ in their technical fields, such as materials science, digital applications, biotechnology, or others. More than 100 technologies in the agriculture sector were

reviewed by specialized experts, who contributed to classifying them into 24 technology families, before these technologies were evaluated according to the urgency and priorities of the challenges they address and the ease of their adoption.

When determining technology priorities and waves — which is necessary to ensure that the most relevant technologies are adopted for the most pressing challenges — demand and supply for each technology were considered.. During this process, technologies that are easier to adopt were prioritized, particularly those with the potential for growth and expansion within the Kingdom.. Thus, this report assessed the enablers associated with these technologies based on available facts and information, with the results reviewed by experts and stakeholders.

Figure No. [3] below shows the technological framework, categorized in 24 families — arranged vertically according to each segment (crops, livestock and fish) and horizontally according to the elements of the value chain in the agricultural sector and identifying technologies in the food segment for both crops, and livestock and fish.

Figure 3: Technological framework for the agriculture sector



Source: Technological Foresight Center at King Abdulaziz City for Science and Technology

Technology Assessment

In the technology assessment stage, it was important to first determine the criteria for evaluation. After studying several technology evaluation methods and applying them to current national requirements, it was clear that the two most important criteria to achieve the desired purpose were expected impact of technology deployment, and ease of adoption in the Kingdom. The impact of technologies is measured through indicators like contribution to achieving sector strategy targets, potential to address local and global challenges, and potential role in the Saudi market (for instance, increasing productivity or competitiveness). Ease of implementation is measured through indicators like the ability to adopt these technologies in the Kingdom based on current infrastructure, availability of supply chains, presence of supporting regulations, potential for localization through human capabilities, awareness of the technologies' functions and benefits, and capacity to absorb the technology.

A comprehensive evaluation of the identified technologies was conducted, focusing on the expected impact of those technologies and the ease of implementation. Impact criteria measure the role that the selected technology will play in the sector's strategy, address challenges, and meet market requirements, while ease of implementation criteria examine the time required for the technology to enter the market, barriers to entering the market, and localization possibilities. As shown in Figure No. [4] below

Figure 4: Evaluation of technology families

Impact potential		Ease of implementation	
Assessment at technology family level		Assessment at technology level, aggregation at technology family level	
Strategic fit to KSA	• Alignment with sector strategies (objectives.programs. initiatives) and priorities • Contribution to solve sector challenges	**Time to market**	Assessment of total time to market for technologies
Global challenges	Contribution to solve global pressing challenges	**Entry barriers**	Assessment of technology -related entry barriers: • Existing Infrastructure and Supply Chain • Regulatory • Deployment complexity
KSA market demand	Potential contribution to KSA market: • Revenue increase • Cost reduction • Productivity improvement	**KSA localization potential**	Assessment of localization potential: • Adaptability • Existing capabilities • Awareness

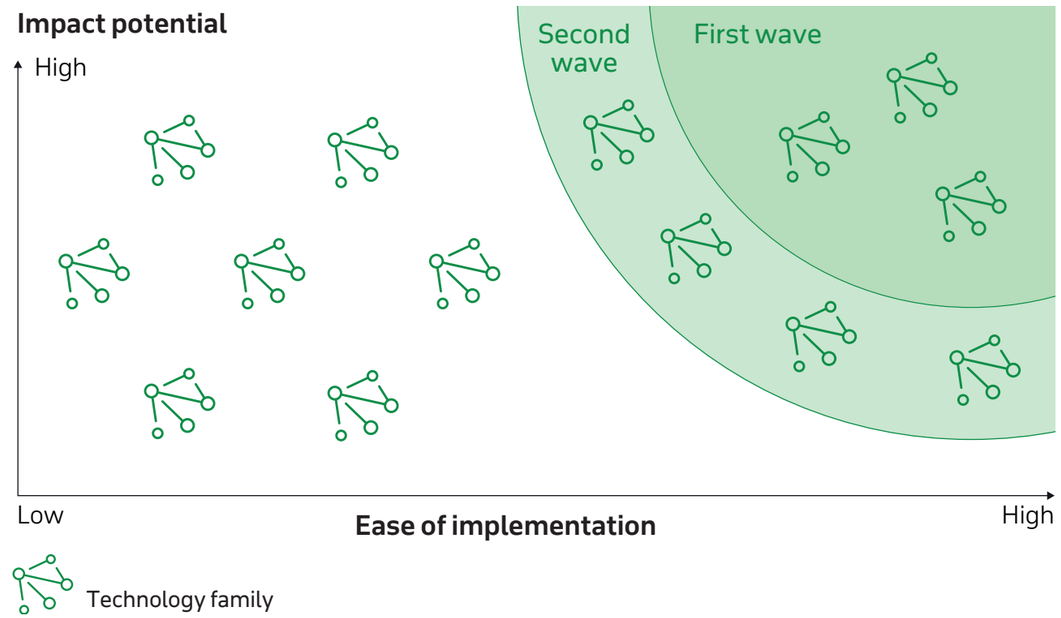
Based on these two criteria, all technology families were evaluated by experts across the aforementioned metrics, and these assessments underwent several analyzes, subsequently categorizing the technologies into three families according to impact level (high or medium) and ease of adoption (easy to implement or implementable) — starting with the high impact, easy to implement group, while the other families would follow after addressing factors affecting their evaluation.

After developing a preliminary list of high priority technologies for adoption, this list was extensively reviewed and validated by specialists and stakeholders to ensure evaluation accuracy and alignment with sector expectations — scientific experts evaluated the technical considerations, and stakeholders looked at regulatory and industry perspectives. This stage utilized several review methods according to the metrics and reviewers, including individual meetings, specialized surveys, and workshops where multiple parties could come together for discussion.

It is worth mentioning that all these methods compiled reports from workshops, minutes of meetings, and survey data for the purpose of utilizing them in future projects or when re-evaluating technologies in the future if necessary.

Figure No. [5] shows the positioning of technology families and their deployment based on impact potential and ease of implementation criteria. The focus will be on adopting the technology families included in the first wave, and then the second wave of adoption will be focused on.

Figure 5: Evaluation of technology families



Priority Technologies

The technology waves were defined based on the methodology mentioned in the previous section, with the first wave comprising five technologies targeted for adoption in 2024 and 2025. The second wave also consisted of five technologies targeted for adoption starting 2025. The broader third wave between 2026 and 2030 will be considered based on readiness for adoption.

This report provides details on the first wave of technologies planned for adoption in 2024 and 2025, discussing the demand side (the challenges these technologies help address), the supply side (the capabilities the Kingdom has in these technologies), major challenges they may face during adoption, and finally the means to adopting them. The first wave included the following technology groups:

1. Irrigation and water management
2. Integrated aquaculture farm management
3. Protected agriculture and controlled environment
4. Food preservation and valorization of waste
5. Unmanned aerial vehicles (drones) and satellite imagery

Irrigation and water management

Overview

Irrigation and water management technologies comprise a range of technologies aimed at improving water use efficiency, increasing irrigation efficiency, and effectively managing water resources. They target reducing wasteful water use in irrigation and identifying optimal technologies for each plant and soil type. These include linear move irrigation (a mechanical irrigation system that waters crops in a straight line using sprinkler mechanisms), center pivot irrigation (a mechanical irrigation system for large fields or circularly patterned crops using sprinklers, which is suitable for flat lands), drip/partial irrigation (an irrigation system delivering water directly to plant roots in small, controlled quantities using a network of pipes dripping or trickling water), and smart irrigation (systems with sensors, weather data, and internet connectivity to monitor and adjust irrigation schedules based on real-time conditions).

Demand drivers

Saudi Arabia is among the most water-scarce countries globally, ranking eight worldwide, with non-renewable groundwater comprising about 80% of water consumed in agriculture. With increasing pressure on groundwater reserves, adopting modern irrigation and water management technologies is critical for the sustainability of this sector.

Irrigation and water management technologies provide water savings compared to open irrigation systems. For example, drip or partial irrigation can lead to a 10-15%[8] reduction in water use while increasing crop productivity by up to 35%[9] for some crops, compared to traditional irrigation methods.

Global demand is also rising significantly, as evident from the drip/partial irrigation technology market, which will more than quadruple in value over the next decade, from $15 billion in 2022 to $64 billion by 2032.[10]

8 EPA Water Sense, "Saving Water with Micro irrigation", 2023

9 R. Kumar, S. Kundu, B. Kundu, N.K. Binu, M. Shaji, "Emerging typology and framing of climate-resilient agriculture in South Asia", 2021

10 Morgan Stanley, "Sustainability Report", 2022

Using drip irrigation technique to grow lettuce

Supply drivers

The Kingdom has existing projects and clear interest in irrigation and water management, which played a key role in determining technology priorities in this report. For instance, institutions like King Abdullah University of Science and Technology and Taibah University, alongside private companies like Almarai, are involved in major R&D activities on irrigation and water management technologies. Advanced technologies exist in the Kingdom, with increasing adoption of technologies like linear move and drip/partial irrigation.[11] Notably, a dedicated entity for this field is the National Water Company, which has undertaken initiatives and projects to reduce agricultural water consumption, like supplying farmers with water-conserving devices, developing the SCADA system for irrigation project management and operation, establishing a technical center to improve irrigation practices and methods, and launching awareness campaigns supporting sustainable irrigation.

Barriers to adoption

Barriers to enabling irrigation and water management technologies can be summarized as follows: first, educating the agricultural ecosystem about the effectiveness of these technologies which increase productivity and reduce consumption of groundwater for which the National Water Company launched its aforementioned awareness campaign; second is the cost of these technologies, estimated at around $1,000 per hectare,[12] third is the competition these technologies face from cheaper, unrenewable groundwater access for some farmers; and finally the weakness of the local industry for irrigation pipelines suited to national needs.

11 Ghanim, Abdulnoor, "Water Resources Crisis in Saudi Arabia Challenges and Possible Management Options an Analytic Review", 2019

12 Feed the Future, "Drip Irrigation in Smallholder Markets: A cross-partnership study", 2016

Integrated aquaculture farm management

Overview

Integrated aquaculture farm management involves a set of technologies and practices for managing aquaculture operations that integrate components like site selection, species integration, nutrient cycling, water management, and biosecurity. It works to promote sustainable and efficient aquaculture production while minimizing environmental impacts. These technologies include cages (fish or shellfish raised in mesh enclosures suspended in natural waters like lakes, rivers or coastal areas), flow-through systems (continuous flow of water to farmed fish or other aquatic organisms where water is sourced from natural or artificial water bodies, then flows through culture tanks), and aquaponics (an integrated system of aquaculture and hydroponics, where fish and plants are raised together in a symbiotic environment; fish waste provides nutrients for plant growth, plants help purify the water).

Demand drivers

Aquaculture production in Saudi Arabia is expected to grow rapidly over this decade, from 0.14 million metric tons annually in 2022 to 0.5 million metric tons annually by 2030.[13] This is enabled by the Red Sea's suitability for aquaculture and broader government measures, while global demand is expected to grow at a slower rate, rising from 91 million tons in 2022 to 114 million tons by 2032.[14]

Supply drivers

Saudi Arabia has adopted several national programs to promote aquaculture and fisheries, including the National Program for Aquaculture Development, in collaboration with King Abdullah University of Science and Technology and several private sector companies like Tabuk Fish, Saudi Fisheries Company, Naqua, Tharawat, Jazan Energy and Development and others. Some national universities and research institutes also undertake research programs on aquaculture technologies, and there are several ongoing private sector initiatives, including startups. For instance, the Red Sea Development Company developed a new intensive aquaculture system leveraging biotechnology to improve water quality, treat waste, and prevent disease, aiming to reach over 5,000 tons of production focused on seabream and shrimp.

Barriers to adoption

Despite significant investments in aquaculture in the Kingdom, capital expenditure is one of the biggest barriers for integrated aquaculture farm management technologies, due to the need for relatively specialized, large-scale infrastructure. This report identified investment as a barrier given the importance of this technology, the need for greater investments as its economic viability is proven and present across companies, and the evident gap between limited supply and high demand.

13 Ministry of Environment, Water and Agriculture, National Agriculture Strategy, 2020
14 OECD/FAO, "OECD-FAO Agricultural Outlook", OECD Agriculture statistics, 2021

An integrated shrimp production project using aquaculture, Naqua

Protected agriculture and controlled environment

Overview

Protected agriculture and controlled environment encompasses technologies that enable growing plants in a defined space with control over conditions like temperature and humidity. This allows increased food production, water conservation, and adapting to unfavorable environmental conditions like the Kingdom's hot climate. It is suitable for vegetable crops and includes all types of artificial protection such as greenhouses (with direct climate and humidity control like HVAC systems or indirect control like fabric and plastic coverings), hydroponics or soilless agriculture (protected agriculture technology bypassing soil structure to support roots and grow crops directly in nutrient-rich water), aeroponics (growing plants in air or mist environment without using soil or aggregate medium), and vertical farming that enables agriculture in urban areas (growing crops in completely enclosed environments on vertical racks using artificial lighting and full control over environmental conditions).

Demand drivers

The Kingdom aims to produce 3.4 million tons of vegetables by 2030.[15] This may accelerate adoption of protected agriculture and environmental control technologies. Studies show these technologies save water by 20-25%[16] in vegetable cultivation.

The global market for these technologies is expected to grow from $74 billion in 2022 to $387 billion by 2032, at a CAGR of 18%.[17] Key drivers for this increase are rising demand for vegetables and the ability to grow crops in harsh climatic conditions.

Supply drivers

The Kingdom is witnessing significant R&D efforts in protected agriculture and environmental control technologies. For example, the National Center for Sustainable Agriculture Research and Development (NCARD) is undertaking multiple research projects on greenhouses and vertical farming. Additionally, some research institutions like King Abdullah University of Science and Technology and King Abdulaziz City for Science and Technology have launched major research programs on greenhouses. The private sector (including for example Red Sea Farms, AeroFarms, Mushkah, and Neom Foods) is also developing experimental and commercial solutions.

Agricultural Development Fund (ADF) programs contribute to accelerating adoption of greenhouse solutions, within its investment plan valued at over $1 billion by 2025.[18]

Barriers to adoption

Current adoption of protected agriculture and environmental control technologies is limited due to reasons like high initial infrastructure costs, operating expenses required to control the climate in greenhouses, which may have led to a stereotypical perception about greenhouses causing lack of awareness of the latest developments in this technology. As a result, local production using this technique is relatively limited.

15 Ministry of Environment, Water and Agriculture, National Agriculture Strategy, 2020
16 KAUST, "Controlled Environment Agriculture (CEA) in the KSA", 2022
17 GlobeNewswire by notified, "Controlled Environment Agriculture Market", 2023
18 Ministry of Environment, Water and Agriculture, 2023

Protected agriculture, National Center for Sustainable Agriculture Research and Development "Estidamah"

Food preservation and valorization of waste

Overview

Food loss and waste is a major issue in the food sector, and technologies addressing it provide solutions like converting it into useful applications, delaying food spoilage, deterioration or contamination, and extending food shelf life. They enable reducing food losses and greenhouse gas emissions, especially methane. For instance, these technologies can increase the shelf life of food products from seven to 14 days.[19] These technologies can be broadly classified between innovative food preservation and food loss and waste valorisation. Innovative food preservation methods include high pressure processing, edible coatings, smart packaging, pulsed electric fields (using high voltage electric pulses to kill bacteria), and plasma technology (exposing food to ionized gases at low temperatures). Food loss and waste valorisation includes composting (treating food waste into nutrient-rich fertilizer) , anaerobic digestion (breakdown of organic waste in the absence of oxygen by bacteria decomposing the organic matter), and insect bioconversion (using insects like black soldier fly larvae to consume and transform food waste into valuable insect biomass).

Demand drivers

Food wastage in the Kingdom is estimated at around 33%[20] or 4 million tons in 2018, exacerbating current food security challenges. As the Kingdom aims to increase self-sufficiency, addressing food loss and waste is imperative.

Global food loss and waste is projected to grow from 1.3 billion tons in 2020 to 2.0 billion tons by 2030 (4% CAGR),[21] primarily driven by market and consumer behavior, limited supply chain efficiency, and inadequate storage facilities.

Supply drivers

Saudi R&D efforts on food loss and waste technologies are still nascent. A few national R&D programs currently focus on innovative food preservation (from Taibah University and King Faisal University). However, food loss and waste valorisation can benefit from additional R&D efforts, especially in composting and anaerobic digestion. For composting, research institutes are undertaking R&D activities (for example, King Abdullah University of Science and Technology), alongside the private sector (including Tadweer Environment Holding Company [Tadweer], Saudi Environmental Works Company [Sewa]). For anaerobic digestion, research institutes are active in R&D efforts (King Abdullah University of Science and Technology, King Abdulaziz City for Science and Technology, King Saud University), with private sector participation.

Barriers to adoption

The primary barrier for innovative food preservation is the need to develop a market for the technologies, build local technical capabilities in this area, and evolve associated regulations and standards. For food loss/waste recycling, barriers directly relate to the limited supply side, with low demand for converted products due to weaker economics versus current traditional offerings in markets.

19 M. Palumbo, G. Attolico, V. Capozzi et al., "Emerging Postharvest Technologies to Enhance the Shelf-Life of Fruit and Vegetables: An Overview", MDPI, 2022
20 Saudi Grains Orgnization, "Saudi FLW Baseline", 2019
21 Food and Agriculture Organization (FAO), "GLOBAL FOOD LOSSES AND FOOD WASTE", 2011

The combination of UV sterilization and pneumatic packaging significantly extends the shelf life of a variety of foods. Dumdum Secrets, King Abdullah University of Science and Technology

Unmanned aerial vehicles (drones) and satellite imagery

Overview

Unmanned aerial vehicles (UAVs or drones) bring several advantages to the agriculture sector, especially since they can be remotely controlled or pre-programmed to fly autonomously. Drones provide a wide range of services in agriculture, from improving water usage, increasing irrigation efficiency, to more effectively managing water resources. They also enable other advanced applications like crop health monitoring (using aerial imagery to assess crop health and identify potential issues), soil monitoring (analysing soil conditions for nutrient levels, moisture content, overall health) or application accuracy (such as for spraying fertilizers, improving resource usage).

Satellites offer additional applications like remote sensing (gathering data about the earth's surface without direct physical contact), advanced imagery (using sophisticated imaging techniques to enhance monitoring) or communications (facilitating data transfer between different components of an agricultural system).

Demand drivers

Drone and satellite technologies represent solutions to a wide range of challenges in the agriculture sector, enabling improved crop productivity in irrigation, soil monitoring, crop health management, and efficiency gains. They are directly suitable for medium to large-scale farms.

The global agricultural drone market is expected to grow from $1.8 billion in 2022 to $23.2 billion by 2032 (CAGR of 29%),[22] driven by real-time crop health monitoring and mapping field insights. Similarly, the global satellite imagery market in agricultural activities is expected to grow from $516 million in 2022 to $1,083 million by 2032 (CAGR of 8%),[23] with crop health monitoring, soil mapping and forestry among the top applications.

Supply drivers

Current research into drone and satellite applications in agriculture remains limited. However, institutions like King Abdullah University of Science and Technology and Taibah University are engaged in R&D activities on drone and satellite technology applications in agriculture.

Adoption of drones and satellites in agriculture and other sectors in the Kingdom is notably restricted, owing to regulatory constraints detailed in the next section.

Barriers to adoption

Efforts to use drones in crop management are currently limited due to several regulatory constraints. The Ministry is expected to work with regulators on developing regulations in the coming period. Availability of satellite imagery requires engaging with satellite data providers and precise identification of agricultural areas targeted for improvement. Overall, deficient R&D efforts and regulatory constraints lead to limited adoption of these technologies.

22 Business Wire, "The Global Market for Agriculture Drones", 2022

23 Business Wire, "Global and Regional Satellite Imaging for Agriculture Market", 2023

Remote sensing tools for mapping and monitoring plant health using a drone, King Abdullah University of Science and Technology

Broader scope technologies

In addition to the five priority technology families in the first implementation wave, 19 other technology families have the potential to mitigate sector challenges in Saudi Arabia. These technologies support both specific initiatives (so are tailored for adoption of those technologies) as well as more methodical, holistic initiatives.

The following sections provide an overview of the strategic and implementation plans, covering all suitable technologies for the agriculture sector, in addition to the specific initiatives outlined above for the five technology families in the first wave.

Ministry's Executive Plan for Adopting and Disseminating Technologies

The Ministry of Environment, Water, and Agriculture conducted a review and analysis of existing efforts in the agriculture sector to achieve the sector's ambitious future aspirations under Saudi Vision 2030. The analysis covered: Priorities, aspirations, and the National Agriculture Strategy, in addition to the National Research, Development, and Innovation Agenda, the current state of technology adoption and innovation activities in the agriculture sector, and the state of technology adoption and innovation enablers such as available infrastructure, human capabilities working in the agricultural innovation ecosystem, and policies and regulations supporting technology adoption and innovation in the sector.

Based on this, current challenges and gaps were identified. Drawing on best practices in sectoral and national innovation policymaking recommended by international organizations including the Food and Agriculture Organization of the United Nations, the Organisation for Economic Co-operation and Development, and the United Nations Conference on Trade and Development (references?), the scope of priority institutional measures to promote technology adoption and innovation in the sector was defined to achieve four main goals:

1

Directing and coordinating plans, efforts and resources allocated to adopting technology and innovation in the agriculture sector. The focus is on addressing pressing sectoral challenges, in line with national research, development, and innovation priorities and relevant national strategies.

2

Improving connection and cooperation between stakeholders active in adopting technology and innovation in the agriculture sector to enhance partnerships and synergies within the sector and share knowledge. The goal is also to raise awareness of the agricultural ecosystem's efforts and successes in embedding technology and innovation in their plans and operations to create positive momentum and ensure the sustainability of these efforts.

3

Stimulating demand for technology products and innovative solutions adoption in the agriculture sector and improving demand responsiveness to available technology supply through deliberate measures and targeted incentives.

4

Building research, development, and innovation capacities in the agriculture sector to ensure sufficient and continuous local supply of technology products and innovative solutions.

Therefore, the Ministry will implement four institutional initiatives encompassing several carefully designed sub-programs:

Initiative to Technology Adoption and Innovation Steering and Coordination in the Agriculture Sector, which aims to

- Establish a transparent and effective governance framework defining the roles and mechanisms required to identify priority innovative solutions aligned with national and sectoral priorities, and engage stakeholders in the ecosystem through aligning objectives and enabling effective information exchange and collaboration to sustain technology adoption and innovation activities in the sectors.
- Develop a mechanism to direct funding from various entities towards technology adoption and innovation activities in the environment, water and agriculture sectors undertaken by public and private entities in the ecosystem, in a performance-based manner considering alignment with priority innovative solutions for the environment, water, and agriculture sectors, and balancing institutional and project financing.
- Develop and activate tools to measure and monitor the performance of the agriculture ecosystem in technology adoption and innovation, and provide evidence-based visions and recommendations on the current state of technology adoption and innovation activities in the sector to support decision-making processes.
- Develop an institutional technology foresight program to provide regular insights on potential technologies and innovative solutions that might be suitable to address challenges and leverage opportunities in the agriculture sector, and support planning processes and institutional policy proposals.
- Collaborate with the Research, Development, and Innovation Authority to prepare detailed implementation plans for national research, development and innovation tasks relevant to the agriculture sector.

Initiative to Improve Collaboration and Raise Awareness on Technology, Innovation, and Entrepreneurship in the Agriculture Sector, which aims to

- Develop a framework for initiating and managing technology adoption and innovation partnerships in the agriculture sector with various potential partners including government, private, research and innovation entities locally and internationally, enhancing the efficiency of such partnerships and achieving their intended goals.
- Develop a digital platform containing support programs, research projects, advisory services, Research, Development and Innovation (RDI) outputs and technology adoption, news, events, and success stories. This will support communication and connection in the ecosystem.
- Plan and launch competitions and awards for technology adoption and innovation, in collaboration with relevant entities, to promote a culture of research, development, innovation, and technology adoption, and disseminate success stories in the sector for inspiration.
- Raise awareness on the efforts of the environment, water, and agriculture ecosystem in technology adoption and innovation by publishing periodic reports on prominent platforms about the agriculture innovation ecosystem's key achievements and aspirations.
- Organize events and exhibitions to provide a platform for local and international R&D entities and technology providers to showcase their products to potential investors and buyers, facilitating partnerships and encouraging innovation and uptake of the latest technologies in the agriculture sector.

Initiative to Stimulate Demand for Innovative Products and Solutions in the Agriculture Sector, which aims to

- Review and develop legislative environments to address existing barriers constraining demand for agriculture Research, Development and Innovation (RDI) technologies and solutions, through coordination with regulators.
- Validate priority agriculture technologies and innovations by testing them in real environments for adaptation and deployment suitable for widescale local rollout.
- Propose mechanisms and policies to incentivize demand for priority agriculture Research, Development and Innovation (RDI) technologies and solutions.
- Increase technology absorptive capacity of end-users in the agriculture sector to improve adoption of innovative products and solutions and boost market demand.

Initiative to Build Agriculture Research, Development, and Innovation Capabilities to Ensure Sufficient Local Supply of Innovative Solutions, which aims to

- Strengthen the entrepreneurship ecosystem in the agriculture sector, including developing mechanisms to attract financing and investment towards emerging sector companies, establishing entrepreneur communities, addressing information barriers and regulatory challenges faced by entrepreneurs, and tracking emerging company and market performance in the sector.
- Facilitate the establishment of dedicated agriculture entrepreneurship spaces and entrepreneurship support programs encompassing incubators, accelerators, startup studios, co-working spaces and technical assistance clinics, in collaboration with relevant stakeholders at national and sector levels.
- Establish intermediary innovation organizations to bridge the gap between the agriculture sector and research/academia, such as technology development centers, technology valleys, technology transfer offices, etc.
- Develop institutional policies and frameworks for technology management and intellectual property protection in the agriculture sector, and collaborate with the Saudi Authority for Intellectual Property to develop relevant national IP policies pertaining to the sector.
- Collaborate with relevant stakeholders in the education and skills development ecosystem to launch tailored programs focused on developing capabilities that contribute to technology adoption and innovation in the agriculture sector, and develop institutional programs to build specialized skills of Ministry of Environment, Water, and Agriculture employees through tailored training programs.

Conclusion

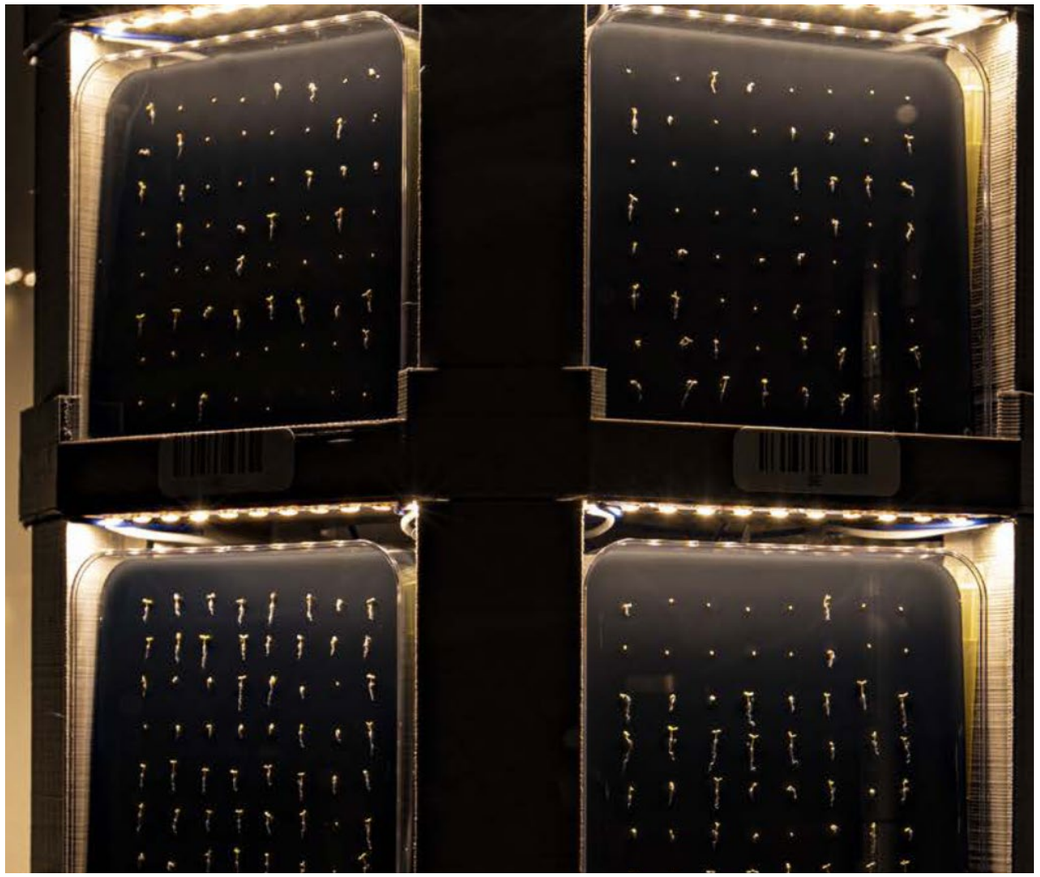
Technologies play a critical role in addressing challenges faced by the agriculture sector, including the pressing need to increase productivity, conserve natural resources, adapt to arid environmental conditions and water scarcity, and deal with agricultural diseases and pests while maintaining ecological balance. Innovative technologies enable finding sustainable solutions to these problems, as well as create numerous opportunities to increase the agriculture sector's contribution to economic output and achieve high levels of food and water security.

This report sought to demonstrate the role of technology adoption and innovation in solving challenges in the Kingdom's agriculture sector, citing international and local examples of agricultural innovation where technologies played a decisive role in providing solutions. Its key objective was to map the challenges faced by the Kingdom in the environment, water and agriculture sectors to readily available technology solutions, and outline the Ministry's implementation plan to adopt and deploy these technologies in the short and medium term.

The report followed an objective methodology to produce a list of technologies with high readiness that provide solutions for the agriculture sector, starting by identifying the challenges faced by this sector in the Kingdom, dividing the sector into four families: crops, livestock and fish, and food. It then looked at available technologies and categorized them into technology families according to these sector segments before prioritizing them based on the impact of these technologies and the ease of their adoption and deployment. This resulted in three technology waves that the Ministry intends to adopt in the coming years.

Given the complexity of the environment, water, and agriculture ecosystem, and the multitude of stakeholders in the agriculture sector, the report considered the national and sectoral strategies of the agriculture and national innovation ecosystems. It also incorporated the perspectives of the Ministry's sector representatives, through a series of meetings and workshops with more than 30 entities, taking into account the views of over 120 experts and specialists at all preparation stages.

In publishing this report, the Ministry of Environment, Water, and Agriculture has several objectives. Firstly, it aims to demonstrate its strategic direction towards adopting technologies that address sectoral challenges. It also seeks to explain its implementation plan to deploy these technologies. The report defines its four key objectives: Steering and coordinating plans, efforts, and resources allocated to technology adoption and innovation in the agriculture sector within a focused strategic scope. This scope targets the resolution of sectoral challenges. Improving connectivity and cooperation between players in the agriculture research, development, and innovation ecosystem. This cooperation aims to build positive momentum in the sector, ensuring the sustainability of efforts. Stimulating demand for adopting innovative products and solutions in the agriculture sector. This includes improving the sector's responsiveness to available supply through targeted interventions and incentives. Building agriculture research and innovation capabilities to ensure sufficient and continuous supply of innovative products and solutions. The final aim is building agriculture research and innovation capabilities to ensure sufficient and continuous supply of innovative products and solutions.



The AI-powered imaging system called "BaL XelpituM"Rapid automated phenotyping of seed germination and root growth, King Abdullah University of Science and Technology

The Ministry firmly believes in the importance of collaborative work and its necessity to achieve national targets, and invites all its partners across agriculture sector stakeholders to contribute to the implementation of this plan. The Ministry aspires for this report to be an enabler in adopting innovative solutions that help overcome challenges faced by ecosystem players, and make possible the realization of ambitions and national targets for the environment, water, and agriculture sectors.

Finally, the Ministry of Environment, Water, and Agriculture expresses its sincere gratitude to all who contributed to this report, including its ecosystem partners, the team of experts who offered their invaluable expertise, and the dedicated efforts of the Research and Innovation Deputyship team in developing and editing this report.

Appendix

A sample of growing lettuce using hydroponics, National Center for Sustainable Agriculture Research and Development "Estidamah"

Localization and definition of technologies

	English Technology Group	English Description	English Technology Examples
1	Protected agriculture and controlled environment (PACE)	Modern farming method creating controlled spaces for crop cultivation. It involves artificial protection, regulating conditions like temperature and moisture.	Vertical/Urban Farming Hydroponics Aeroponics Plasticulture/ Row cover/ Polytunnel Integrated greenhouse (including IoTs, innovative cooling systems, and desalinated water usage)
2	Innovative seeding	Technologies and approaches used in agriculture to improve the process of planting seeds and enhance seed production	Mechanical seeding Seeds bio-bank/seeds production
3	Precision agriculture	Robotics and other automated solutions for different processes automation across value chain	Targeted pesticide spraying Robotics for pollination Laser scarecrows Self-driving tractor
4	Agriculture biotechnology and crop improvement	Genetic modification for desired traits development in plants (for example, crop yields, draught/pest resistant crops)	Mutation breeding Radiation testing Bio-nanotechnology Molecular diagnostics Molecular breeding
5	Irrigation and water management	Range of systems designed to optimize water use, enhance irrigation efficiency, and effectively manage water resources	Subsurface irrigation Micro/drip irrigation Smart irrigation (including automation, data analytics, AI, valves) Soil moisture sensors and IoTs
6	Soil health management	Technologies that help reduce water evaporation, regulate moisture level, optimal tillage	Light intensity Intercropping High density plantations Permaculture Agrivoltaics Water absorbents Moisture and fertility conservation Cover crops Conservation tillage Crop residue management Double cropping Sequential cropping Crop residue protection

	Arabic Technology Group	Arabic Description	Arabic Technology Examples
1	الزراعة المحمية والتحكم البيئي	أسلوب زراعي حديث يقوم بإنشاء مساحات محكمة لزراعة الإنتاج النباتي. يتضمن حماية اصطناعية وتنظيم ظروف الزراعة مثل درجة الحرارة والرطوبة	الزراعة العمودية الزراعة المائية الزراعة دون تربة الأغطية القماشية والبلاستيكية البيوت المحمية (الأخضر أو الدفيئة) المتكاملة (بما في ذلك إنترنت الأشياء، وأنظمة التبريد المبتكرة، واستخدام المياه المحلاة
2	الزراعة والبذور المبتكرة	التقنيات والأساليب المستخدمة في الزراعة لتحسين عملية زراعة البذور وتعزيز إنتاج البذور	البذر الميكانيكي البنك الحيوي للبذور/إنتاج البذور
3	الزراعة الدقيقة	الروبوت والحلول الآلية الأخرى لأتمتة العمليات المختلفة عبر سلسلة القيمة	رش مستهدف للمبيدات الحشرية روبوت للتلقيح فزاعات الليزر جرار ذاتي القيادة
4	التقنية الحيوية الزراعية وتحسين المحاصيل	التعديل الوراثي لتطوير السمات المرغوبة في النباتات (مثل إنتاجية الإنتاج النباتي ومقاومة الجفاف/الآفات)	تكاثر الطفرات اختبار الإشعاع تقنية النانو الحيوية التشخيص الجزيئي التعديل الجيني
5	الري وإدارة المياه	مجموعة من الأنظمة المصممة لتحسين استخدام المياه، وزيادة كفاءة الري، وإدارة الموارد المائية بفعالية	الري تحت السطح الري الجزئي/بالتنقيط الري الذكي (بما في ذلك الأتمتة، وتحليلات البيانات، والذكاء الاصطناعي، والصمامات، وما إلى ذلك) أجهزة استشعار رطوبة التربة وإنترنت الأشياء
6	إدارة صحة التربة	التقنيات التي تساعد على تقليل تبخر الماء، وتنظيم مستوى الرطوبة، والحرث الأمثل، وما إلى ذلك.	شدة الضوء التحميل أو الزراعة البينية مزارع عالية الكثافة الزراعة المعمرة نظام الزراعة الكهروضوئية ماصات الماء الحفاظ على الرطوبة وخصوبة التربة محاصيل التغطية حراثة حافظة إدارة بقايا المحاصيل زراعة ثنائية المحصول زراعة محاصيل متسلسلة حماية بقايا المحاصيلي

	English Technology Group	English Description	English Technology Examples
7	Fertilizers	Technologies that help feed plants more efficiently like release-controlled fertilizers, nano-fertilizers	Nano-fertilizers (nano-capsulated) Soil mycorrhizal technologies Microbial solutions (biofertilizers) Controlled release fertilizers Enhanced efficiency fertilizers
8	Fertigation	Technologies that help feed plants with a combination of nutrients through an irrigation system	Liquid fertigation Solid fertigation Micro/Drip fertigation Subsurface drip
9	Conventional crop protection chemicals	Chemical substances designed and utilized in agriculture to protect crops from threats like pests, diseases, and unwanted plants	Herbicides Insecticides Fungicides Nematicides
10	Innovative crop protection	Genetically modified pests, pest-resistant plants Microbial solutions — biopesticides (bacteria, fungi)	Genetic engineering for pest resistance Biopesticides RNA interference Microbial solutions
11	Drones and satellites	Drones are remote-controlled flying devices for tasks like surveillance and delivery. Satellites, orbiting in space, enable global communication, weather monitoring, and navigation	Crop health monitoring Soil monitoring Advanced imagery Remote sensing Communication
12	Agricultural waste management	Technologies to transform crop residuals into useful products/energy using different methods	Windrow composting Static pile Container composting Anaerobic composting Combustion and thermal conversion Bio-refining processes Biochemical conversion

	Arabic Technology Group	Arabic Description	Arabic Technology Examples
7	الأسمدة	التقنيات التي تساعد على تغذية النباتات بشكل أكثر كفاءة مثل الأسمدة التي يتم التحكم في إطلاقها، والأسمدة النانوية، وما إلى ذلك	الأسمدة النانوية (محفوظة بكبسولات نانويه) تقنيات فطريات التربة المحاليل الميكروبية (الأسمدة الحيوية) الأسمدة المتحكم بتحريرها الأسمدة معززة الكفاءة
8	التسميد بالري	التقنيات التي تساعد على تغذية النباتات بمزيج من العناصر الغذائية من خلال نظام الري	التسميد السائل التسميد الصلب التسميد الجزئي / بالتنقيط التنقيط تحت السطح
9	المواد الكيميائية التقليدية لحماية المحاصيل	المواد الكيميائية المصممة والمستخدمة في الزراعة لحماية الإنتاج النباتي من التهديدات مثل الآفات والأمراض والنباتات غير المرغوب فيها	مبيدات الأعشاب المبيدات الحشرية مبيدات الفطريات مبيد الممسودات
10	حماية المحاصيل المبتكرة	الآفات المعدلة وراثيا، والنباتات المقاومة للآفات. المحاليل الميكروبية — المبيدات الحيوية (البكتيريا والفطريات)	الهندسة الوراثية لمقاومة الآفات المبيدات الحيوية تدخل الحمض النووي الريبي الحلول الميكروبية
11	الأقمار الصناعية والطائرات بدون طيار	الطائرات بدون طيار هي أجهزة طيران تتحكم عن بعد لأغراض مثل المراقبة والتوصيل. الأقمار الصناعية، التي تدور في الفضاء، تمكن الاتصال العالمي ورصد الطقس والتنقل، وتلعب أدوارًا حيوية في مختلف الصناعات	مراقبة صحة المحاصيل مراقبة التربة الصور المتقدمة الاستشعار عن بعد الاتصال
12	إدارة النفايات الزراعية	تقنيات تحويل مخلفات الإنتاج النباتي إلى منتجات/طاقة مفيدة باستخدام طرق مختلفة	التسميد بالتكويم كومة ثابتة التسميد بالحاويات التسميد اللاهوائي الاحتراق والتحويل الحراري عمليات التكرير الحيوي التحويل البيوكيميائي

	English Technology Group	English Description	English Technology Examples
13	Reproduction and breeding	Classical breed management, genomics of livestock for desired traits (for example, yield)	Animal genomics Gene editing in animals In-vitro fertilization DNA marker assisted selection (MAS) Gene prediction Genetic annotation Artificial insemination Automated insemination Breeding optimization
14	Precision livestock farming	Robotics and other automated solutions for different processes automation across livestock/fishery value chain	Mechanical hatching Automated feeding Precision feeding Automated cleaning Carcass processing Automated packaging systems
15	Integrated aquaculture management	Development of multiple fish species in controlled space farms (such as caged)	Alternative fish feed (for example, fish feed for algae and bacteria) Floating cages Recirculating systems Flow through systems Aquaponics Other supporting technologies (such as IoTs and sensors, biotech)
16	Recirculating systems	Closed-loop systems that recycle and treat water, minimizing the need for water exchange on a fish farm	Innovative water purification Oxygenation systems Innovative filtration systems
17	Nutrition and feed management	Technologies to reduce costs of animal feed or substitute it (for instance algae feeding)	Extrusion technology Alternative Proteins (insects) Crop residues Algae feeding Natural feed enzymes Pelleting
18	Water quality management	Technologies to monitor and manage water content (such as phytoplankton, nutrient, oxygen levels)	Aeration systems UV Sterilization Purification

Arabic Technology Examples	Arabic Description	Arabic Technology Group	
التعديل الجيني في الحيوانات التحرير الجيني التلقيح الاصطناعي التلقيح الآلي شرح الجينوم التخصيب في المختبر التحديد بمساعدة علامة الحمض النووي الجينوم الحيواني	إدارة السلالات الكلاسيكية، وعلم جينوم الماشية للسمات المرغوبة	التكاثر والانتاج	13
الفقس الميكانيكي التغذية الآلية تغذية دقيقة التنظيف الآلي معالجة الذبيحة أنظمة التغليف الآلي	الروبوت والحلول الآلية الأخرى لأتمتة العمليات المختلفة عبر سلسلة قيمة الثروة الحيوانية/المزارع السمكية	تربية المواشي النموذجية	14
أعلاف الأسماك البديلة (مثل الطحالب والبكتيريا) أقفاص عائمة أنظمة إعادة تدوير المياه أنظمة التدفق الزراعة المائية المركّبة (أكوابونيكس) التقنيات الداعمة الأخرى (مثل إنترنت الأشياء وأجهزة الاستشعار والتقنية الحيوية)	تنمية أنواع مختلفة من الأسماك في المزارع المائية مع التحكم بالبيئة	الإدارة المتكاملة للاستزراع المائي	15
تنقية مبتكرة للمياه أنظمة الأكسجة أنظمة مبتكرة للترشيح	أنظمة الحلقة المغلقة التي تعمل على إعادة تدوير المياه ومعالجتها، مما يقلل الحاجة إلى تغيير وتجديد المياه في مزرعة الأسماك	أنظمة إعادة التدوير	16
تقنية البثق أو النبط بروتينات بديلة (الحشرات) بقايا المحاصيل علف الطحالب إنزيمات أعلاف طبيعية تكوير	تقنيات لترشيد تكاليف أعلاف الحيوانات واستبدالها وما إلى ذلك (من قبيل علف الطحالب)	إدارة التغذية والأعلاف	17
أنظمة التهوية التعقيم بالأشعة فوق البنفسجية التطهير	تقنيات مراقبة وإدارة المحتوى المائي (مثل مستويات العوالق النباتية والمغذيات والأكسجين وما إلى ذلك)	إدارة جودة المياه	18

	English Technology Group	English Description	English Technology Examples
19	Health monitoring and disease management	Innovative vaccines and vaccination methods, digital and automated solutions in biosecurity	Rotational grazing Electric fencing Weather stations Vaccines and vaccination Innovative biosecurity
20	Animals waste management	Different technologies to capture and utilize livestock biogas and biomaterials waste	Covered anaerobic lagoons Plug flow digester Two-stage digestion
21	Supply chain traceability	RFID tags, GPS tracking, etc. to trace agriculture/food products across the value chain	Blockchain traceability/ smart depository Traceability sensors/devices
22	Food safety and QC/QA	Technologies to increase shelf life of foods, reduce/eliminate disease risk, including testing instruments and methods	High-pressure processing Innovative methods and combinations Cold plasma technology
23	Food preservation and extraction of value-added from food waste	Technologies to preserve food for longer storage times, and treat food waste into useful applications (for instance energy production)	Composting Anaerobic digestion Insect-based conversion High pressure processing Edible coating Innovative packaging Pulsed electric field Plasma technology
24	Alternative food	Involve innovative methods in food production and consumption that deviate from conventional approaches	Insects farming Lab-grown foods 3D food printing Cultured diary Plant-based meat alternatives

	Arabic Technology Group	Arabic Description	Arabic Technology Examples
19	مراقبة الصحة وإدارة الأمراض	اللقاحات وطرق التطعيم المبتكرة والحلول الرقمية والآلية في الأمن الحيوي	الرعي الدوراني تسييج كهربائي محطات الطقس اللقاحات والتطعيم الأمن الحيوي المبتكر
20	إدارة النفايات الحيوانية	تقنيات مختلفة لالتقاط واستخدام الغاز الحيوي للماشية، ونفايات المواد الحيوية، وما إلى ذلك	البحيرات اللاهوائية المغطاة الهضم بسد التدفق الهضم على مرحلتين
21	إمكانية تتبع سلسلة التوريد	وسوم تحديد الهوية بموجات الراديو DIFR، وتتبع نظام تحديد المواقع العالمي SPG، وما إلى ذلك، لتتبع المنتجات الزراعية/الغذائية عبر سلسلة القيمة	تتبع البلوك تشين/ المستودع الذكي أجهزة استشعار/أجهزة تتبع
22	سلامة الأغذية ومراقبة الجودة/ ضمان الجودة	تقنيات لزيادة فترة صلاحية الأغذية، وتقليل مخاطر الأمراض أو القضاء عليها، بما في ذلك أدوات الاختبار وطرقه	معالجة الضغط العالي طرق وتجميعات مبتكرة تقنية البلازما الباردة
23	حفظ الأغذية واستخراج قيمة مضافة من الفاقد	تقنيات لزيادة العمر الافتراضي للأغذية وتقنيات لتحويل النفايات الغذائية	التسميد العضوي الهضم اللاهوائي التحويل القائم على الحشرات استخدام الضغط المرتفع أغلفة صالحة للأكل التعبئة والتغليف المبتكر المجال الكهربائي النبضي تقنية البلازما
24	الأغذية البديلة	أساليب مبتكرة في إنتاج واستهلاك الطعام تتجاوز الطرق التقليدية	استزراع الحشرات أغذية المختبر اللحوم البديلة التخمير الدقيق الطباعة ثلاثية الأبعاد للأغذية

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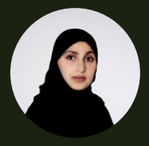

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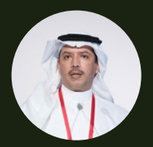

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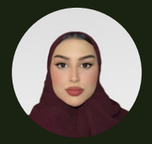

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