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Smart and Environmentally Friendly Design of a Vegetable Growing Farm for Qatar (M4 Tech Farm)

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Declaration

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Abstract

For millennia, agriculture has been a crucial component of food production and a key driver of total economic development for communities all over the world. In the past, agriculture in hot, dry nations like Qatar experienced many difficulties, with a lack of water for irrigation being the main issue. This has historically significantly impeded Qatar's economic growth, which has historically been heavily focused on exploitation of resources, pearl mining, and only more recently, the exploitation of its oil and gas deposits, which has resulted in Qatar's immense wealth. This paper provides an outline of the agricultural difficulties that Qatar faces, focusing on their adaptation to the country's arid climate and potential solutions. In accordance with Qatar National Vision 2030, the Qatari government, a new initiative to build the m4 Tech Farm, a vegetable farm in Qatar, with the goal of enhancing the agricultural sector's contribution to the country's economy. The vision of M4 Tech Farm is to apply the most recent scientific advancements in vegetable growing to the State of Qatar to increase the quality of the agricultural sector's output in an ecologically friendly and cutting-edge manner. Given that food security and sustainability in modern agricultural areas are important needs for Qatar's future generations, the organization's mission is to provide exceptional agricultural services and plan modern agricultural regions optimally. The primary goal of m4 Tech Farm is to provide an environment that is suitable for high-yield production while safeguarding crops from unfavorable weather conditions. m4 Tech Farm also offers proper regulation and control of the various climatic factors by utilizing the most recent control techniques, cutting-edge measurement, communication infrastructures, and smart management systems, thus providing the ideal environment for crop development. To facilitate the shift to sustainable precision agriculture, the major purpose of this research is to give a thorough knowledge framework of the farm development in Qatar. By utilizing monitoring methods, artificial intelligence, and communication infrastructure in the agriculture industry by adopting smart farms, this study may provide useful supporting information to decisions. Lastly, this paper offers suggestions for how to implement the farm.

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1. Introduction and Motivation

1.1 Background

Global food security, better nutrition, the eradication of poverty, and Qatar's general economic progress are all made possible by the continued development of agriculture. Food security is a complicated, multifaceted phenomena that includes the essential elements of food availability, access, consumption, and supply stability for all people. A nation's overall food security is determined by the circumstances of all of its residents. As a result, the availability of resources is currently under pressure due to a number of concerns including climate change, population expansion, economic development, and dietary changes. Food production may be threatened by climate change due to altered weather patterns that affect both plant and animal productivity, in addition to the decline in crop yields, infectious diseases and pests are prevalent, and environmental events occur frequently. The proposed remedy for this problem is the development of new technology trends that relate to agriculture. This would address several issues involving Qatar, particularly enhancing food security, better nutrition, and the country's general economic development.

1.2 Problem Statement

Qatar has a hot, dry desert environment. Hyper-arid nations like Qatar are known for their little summer precipitation, high summer temperatures, high summer humidity, high summer solar radiation, poor soil, and strong summer winds. The production of food is severely hampered by these natural factors, and in Qatar, agriculture has historically only been practiced from October to April [1, 2]. In addition to the high humidity, direct sunlight radiation, poor soil, and strong winds that are encountered in Qatar's harsh climate, these climatic factors pose significant challenges for the country's agricultural productivity [3, 4]. Figure 1 depicts the 10-year average temperature over an annual cycle; temperatures begin to rise in March, reach their peak in July, and then begin to fall in August.

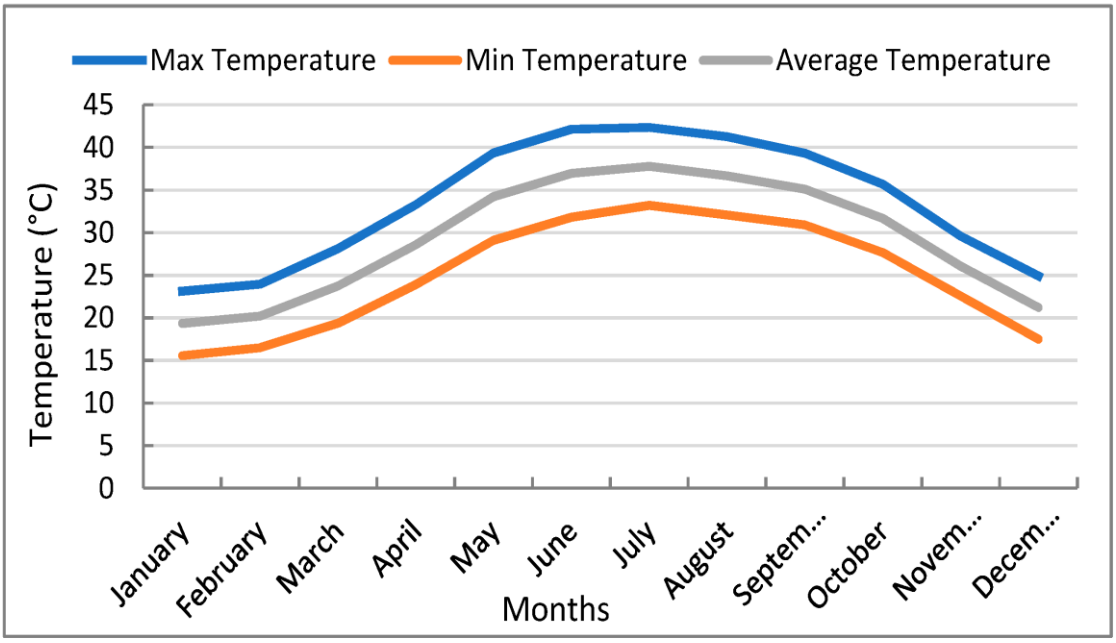

Figure 1.2-1: Qatar's average temperature over a ten-year period [3, 4].

Technology is the way to go when resolving climate issues to have an overall higher level of agricultural production. To start, m4 Tech Farm will have an indoor vertical farming which can boost crop yields, overcome land constraints, and possibly lessen the environmental effect of farming by reducing supply chain trip distance [1, 2]. Given that Qatar has a limited amount of land, indoor vertical farming employs stacking techniques that increase the amount of crops while taking up less space. This method also creates a closed, controlled environment that enables us to address the issue of the weather, which addresses both the space and climate issues that Qatar faces.

According to [3, 4], the soil of the State of Qatar is of poor agricultural quality since it is typically arid, shallow, has a coarse texture, and retains little water. Soil will not be an issue because this farm will use vertical farming techniques, which are unusual in that some setups don't need soil for plants to flourish. Most are either hydroponic (vegetables are grown in a bowl of nutrient-rich water) or aeroponic (water and nutrients are routinely sprayed on the plant roots). Artificial grow lights are utilized in place of natural sunshine [2, 5].

Agriculture depends heavily on the availability of water; hence it is crucial for farms to manage water levels. Water storage is a serious issue in Qatar because there aren't enough freshwater resources there. In 2010, Qatar had only enough drinking water to last for around 48 hours, which prompted the government-owned water utility company Kahramaa to invest in storage facilities [1, 2]. M4 Tech Farm uses drones (UAVs) that are remotely operated and fly over crops to combat the issue of water availability. These drones can help us understand the status of the crops, including whether there is any water shortage, the condition of the crop, and other issues [1, 2]. Since everything is being monitored and managed and data is being transferred to the M4 Tech Farm cloud, these drones might assist the farm in controlling the water level, making it more sustainable. Tech Farm M4 All of the data and images that are gathered by our field drones are stored in the Cloud, which can be easily accessed from any device to obtain all the information required. This makes it very easy to obtain information and makes it quick for a person to act on that information, which could lead to an increase in efficiency and effectiveness.

1.3 Project Significance and Impact

The population of Qatar is expected to rise significantly over the next several years, and the country will host numerous major sporting events, including the FIFA World Cup and other upcoming events. Qatar is still seen as an emerging nation that is still developing. The FIFA World Cup, which might have a significant impact on Qatar's entire environment, is one of the major difficulties and a significant cause for concern. Since Qatar is a developing nation overall and the agricultural sector is growing, there is significant potential for the sector to contribute to efforts to increase national food security, increased agricultural productivity, improved field conditions, water management, and other factors. Technology improvements, such as those in sensors, gadgets, machines, and information technology, have significantly changed how M4 Tech Farm operate in comparison to those from a few decades ago. Technology is essential in a nation like Qatar where agriculture is difficult owing to several variables that make it difficult. Robotic systems, precision agriculture, temperature and moisture sensors, aerial imagery, and GPS technology are all often used by M4 Tech Farm. These cutting-edge tools help enterprises operate more profitably, effectively, safely, and ecologically friendly.

1.4 Aims and Objectives

I. To utilize cutting-edge technologies and practices to cultivate a diverse array of premium vegetables.
II. To implement advanced farming techniques, such as data storage and analytics to optimize crop yields and resource utilization.
III. To contribute to Qatar's food security and self-sufficiency by cultivating locally grown vegetables and conducting research and development on new technologies and techniques to enhance the farm's sustainability and efficiency.
IV. To establish partnerships with local restaurants, markets, and other food retailers to sell produce directly to consumers and promote the farm's sustainability and produce quality.
V. To engage with the local community and educate them about sustainable agriculture practices, while also creating job opportunities and supporting the local economy through the farm's operation.
VI. To utilize sustainable and efficient irrigation techniques, including advanced sensors and automation, to minimize water usage and optimize crop growth.
VII. To provide a reliable and high-quality source of locally grown vegetables to contribute to Qatar's food security and sustainability.
VIII. To foster partnerships and collaborations with other stakeholders, such as research institutions, local farmers, and government agencies.
IX. To contribute to the economic development of Qatar by generating revenue and creating job opportunities in the agricultural sector.

2. Design Requirements

The proposed solution must strictly adhere to a variety of constraints and design criteria to achieve an optimal, sustainable, and efficient outcome. These constraints and criteria will play a crucial role in determining the success of the project and helping it to achieve its objectives of creating a technologically advanced and environmentally friendly farm design. By adhering to these constraints and criteria, the project team can identify the most suitable solution and ensure that it is implemented effectively in order to accomplish its aspirations of becoming a smart and ecologically sound farm.

2.1 Design Constraints

I. Budget: The project's budget should not exceed 800 million $.

II. Technical Constraints:

- The farm should utilize advanced technologies and practices to cultivate a diverse array of premium vegetables.
- The farm should implement precision farming techniques, such as data storage and analytics to optimize crop yields and resource utilization.
- The farm should be designed with environmentally friendly materials and practices, such as recyclable steel and organic farming methods.
- The farm should be designed with natural disaster resilience in mind, such as against lightning.
- The farm should adhere to all safety regulations to ensure the safety of workers and the environment.

III. Schedule: The assigned schedule to finalize the design of the farm is within a period of 5 years from the starting date and the project planning must consider Qatar's 2030 vision as a point of reference.

IV. Lifespan: The farm's design, if properly maintained, should have a lifespan of at least 200 years.

V. Technologies: The farm should utilize the most recent available technologies in site investigations, energy supply and efficiency, wastewater, and water management.

VI. Reliability: The reliability of the farm's design (building lifespan, potential failures) should be thoroughly studied and measured for future planning.

VII. Environmental Impact: When selecting building materials for the farm's design, their properties and environmental impact must be thoroughly researched.

VIII. Aesthetics: The farm should be aesthetically pleasing while ensuring that its design does not violate any rules or offend any local or international groups.

IX. Environmental constraints: Qatar is located in a desert region, and there may be environmental constraints and challenges associated with developing a sustainable farming operation, such as limited availability of water and other natural resources.

X. Geographical constraints: Qatar is a small country with a relatively small land area, and there may be geographical constraints and challenges associated with finding suitable land and infrastructure to support a vegetable-growing farm.

2.2 Design Standards

I. ISO 21010:2018 - Agriculture and forestry - Precision agriculture - Vocabulary

II. ISO/TS 19142:2013 - Agriculture and forestry - Geographic information - Data quality measures for agricultural applications

III. Smart irrigation standards:

a. ISO/TS 19160:2016 - Agriculture and forestry - Smart irrigation systems

b. ISO/IEC 15004:2018 - Information technology - Sensors and actuators - Internet of Things (IoT) - Communication and data exchange - Part 4: Data modeling for irrigation control systems. Part 5: Data modeling for water quality monitoring.

IV. Greenhouse standards:

a. ISO 14001:2015 - Environmental management systems - Requirements with guidance for use

b. ISO 22000:2018 - Food safety management systems - Requirements for any organization in the food chain

V. Sustainable design standards:

a. ISO 15686-2:2014 - Buildings and constructed assets - Service life planning - Part 2: Service life planning of building elements and components

VI. Food safety standards:

a. ISO/TS 22002-1:2009 - Prerequisite programs on food safety - Part 1: Food manufacturing

2.3 Criteria for success

I. Understand the need for a sustainable, high-tech farming operation in Qatar, and assess the potential benefits and challenges of developing such a farm.

II. Define a problem statement that considers the need for the farm, the potential challenges and constraints, and the goals and objectives of the project.

III. Collect information about existing farming technologies and sustainable design principles and evaluate their potential relevance and applicability to the project.

IV. Generate ideas for solutions to the design problem, identifying the key components of the farm and analyzing their merit.

V. Identify critical design parameters and evaluate alternative designs using specific criteria for productivity, sustainability, efficiency, and adaptability.

VI. Optimize the farm design to meet the requirements for productivity, sustainability, efficiency, and adaptability.

VII. Prepare a presentation and written report to present the design to the government and other stakeholders and seek support for its adoption and implementation in Qatar.

3. Proposed Solutions

Idea Generation (Search for Solutions) - Alternative Solutions (Analyze each potential solution)

Table 1:

List of the latest technology used in agriculture (to meet the word smart and environment friendly)	
Aquaponics & Hydroponics in smart farming technology [6]	Hydroponics and aquaponics are farming techniques that grow crops without chemicals and pesticides entirely using natural pest management methods and biological fertilizers. Using this approach, the agricultural ecosystem is optimized in terms of energy and nutrients.

	The application of fertilizer increases the organic carbon content in the soil, causing significant emissions of CO_2. In addition to reducing nitrous oxide and methane emissions from the land, Aquaponics & Hydroponics ideas will also benefit farmers. As a result, this strategy has long-term benefits for water, local species, land, the environment, and farmers.
Permaculture in smart farming technology [7]	Permaculture aims to develop agricultural ecosystems that can sustain themselves. This farming technique develops agricultural systems that work in harmony based on crop diversification, resilience, natural production, and land sustainability. But since the early 1980s, permaculture has developed into a holistic idea that encompasses much more than just agriculture. A global ethical method for creating interconnected systems based on the idea of sustainable development is called permaculture. For human activities, natural ecosystems are essential.
Robots and drones [8, 9]	Robots and drones can help agriculture in a variety of ways, such as increasing productivity, decreasing costs, and raising crop yields. For example, robots and drones could replace manual labor in the planting of seeds and plants in fields, which would be more accurate and efficient. Robots can detect and remove weeds from fields in addition to weeding, freeing up human laborers for other jobs and boosting crop production. Additionally, as robots and drowns can be equipped with sensors and sprayers to apply pesticides precisely and with fewer chemicals, potentially lowering the danger of chemical exposure, robots and drones can be useful in the application of pesticides.
Using Renewable Energy Resources	An estimated 35% of all GHG emissions are attributed to agriculture and food production. As a result, solar, hydro, and wind farms should supply energy to agricultural equipment. In this way, pumps and heating systems are powered by solar panels. Farmers can also use hydroelectricity produced by a nearby river to

	power farming equipment. To find the most affordable alternative energy sources, farmers should compare energy prices online.
Crop Rotation & Polycultures [10]	Crop rotation is an agricultural practice that involves producing several crops on the same land over the course of several seasons. The likelihood of plant and vegetable illnesses can be decreased with this technique. Furthermore, this approach reduces the number of pesticides and chemical fertilizers necessary to be regarded as environmentally benign.
Weather Tracking [8]	The variations in weather and climate are perhaps the most significant aspect of soil quality that affects agriculture and farmers; thus, farmers should always have a basic awareness of the weather in the agricultural region and its potential variations throughout the year. Along with the numerous smartphone applications that offer agricultural technology information on heat, rain, and impending frost so farmers may take the necessary precautions to reduce potential loss or damage.
Management Zones & VRA maps features [12]	**Single-layer analytics Zones Map can be built using satellite images, topography, soil sampling, high-density sensors, yields, or as applied datasets.** The engine does the following: • Detects and removes noise automatically, • Merges small polygons into the nearest larger polygon, • In every zone polygon, only the minimum number of points is kept • Ensures that all agricultural equipment and machinery can be used with VRA maps. • Information on yields • Data collected through remote sensing • topography • Soil data

The cloud data storage	Cloud storage enables farmers to store and access vast amounts of data remotely using any device with an internet connection, it can be used in agriculture to handle data linked to numerous elements of farming, including data storage and management. This may consist of information gathered by sensors, drones, and other agricultural technologies, as well as records of crop yields, weather patterns, and soil conditions. Additionally, collaboration as cloud storage enables farmers to exchange data and work with other stakeholders, such as agronomists, researchers, and extension agents. This can aid in enhancing decision-making and enhancing farming techniques. In addition to data analysis, cloud storage offers access to strong computational capabilities that can be utilized to analyze and understand data. This can assist farmers in seeing trends and patterns and informing their choices about pest control, fertilizer, irrigation, and other farming-related decisions.

3.1

1. Precision agriculture: This involves using technology, such as GPS and sensors, to monitor and manage crops and soil on a very precise level.
2. Drones: These are small, unmanned aerial vehicles that can be used for a variety of tasks in farming, such as surveying crops, applying pesticides, and monitoring irrigation.
3. Smart irrigation systems: These use sensors and other technology to monitor soil moisture levels and automatically adjust irrigation systems to provide the optimal amount of water for crops.
4. Variable rate technology: This allows farmers to apply seeds, fertilizer, and other inputs at different rates depending on the specific needs of different areas of their fields.
5. Climate-controlled greenhouses: These use technology to regulate temperature, humidity, and other factors to create optimal growing conditions for crops.
6. Vertical farming: This involves growing crops in stacked layers, often in a controlled environment, to maximize the use of space and reduce the need for land and water.

7. Robotic farm machinery: This includes a variety of robotic equipment, such as tractors and harvesters, that can be used to perform tasks such as planting and harvesting crops.
8. Livestock monitoring: This involves using sensors and other technology to monitor the health and wellbeing of livestock, such as by tracking their movement and behavior.
9. Precision livestock farming: This uses technology, such as sensors and cameras, to monitor individual animals and provide them with the optimal diet and care.
10. Blockchain technology: This is a type of distributed ledger technology that can be used to track the provenance of food and other agricultural products, providing greater transparency and traceability.

3.2 Alternatives Assessment

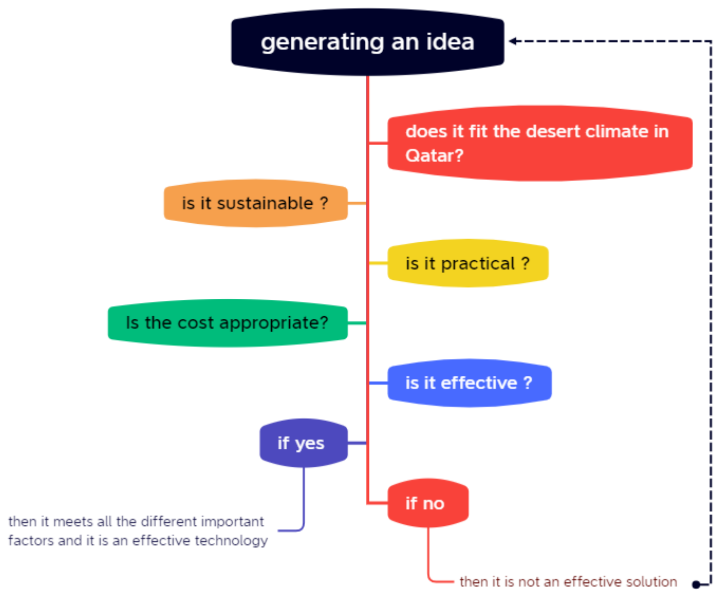

Figure 3.2-1: Assessment flowchart.

Criteria for Choosing Technologies:

- Relevance to Qatar's agricultural needs and goals
- Feasibility and practicality of implementation
- Potential impact on the environment and sustainability
- Available resources and funding
- Expertise and technical support

- Potential for long-term success and scalability

Figure 3.2-1 shows the mind map that is used to evaluate different technologies and determine which ones are the most suitable for Qatar's unique agricultural context.

3.3 Choose the best solution - Proposed Design (Detailed Design)

1. M4 Indoor Vertical Farm

As was already said, Qatar has a difficult environment that is primarily affected by the country's harsh and arid climate, poor soil, inadequate fertilizer, constrained area, and unfavorable temperature. To overcome these difficulties, the first suggested concept includes an indoor vertical farm. Greenhouses are high-tech indoor farming inventions, which are increasingly gaining popularity. Many have enhanced their germination and yields by managing light, temperature, fertilizer, and other growth factors in an enclosed space. This has also helped to address Qatar's agricultural concerns. Since indoor farming uses specific technology that control temperature, humidity, light waves, and gases to promote the growth of specific plants, medications, and foods, this will have a favorable impact on Qatar's agriculture, especially in terms of climate change. Additionally, the use of pesticides and herbicides may not be necessary in indoor farms. Urban farms can now adopt the agricultural industry's criteria for preventive maintenance thanks to technology. With the use of vertical farming, which is a method of urban food production that produces produce vertically rather than on a single, horizontal plane like conventional or greenhouse farming may do, Qatar can also solve its space problem. The main advantage is the capacity to produce more food in a smaller area, particularly in metropolitan settings where space is at a premium, like Qatar. Vertical farming is frequently seen in skyscrapers or converted warehouses in urban areas. In Figure 2, the design primarily focuses on the stacking method, which provides more room for plants to grow while also utilizing all available space, allowing for the growth of more crops in a smaller amount of space. To help us understand the circumstances of these crops, it also has regulated lighting and air conditioning.

2. M4 Hydroponics Farm

The second design suggestion addresses practically all of Qatar's agricultural issues, including those related to poor soil, water supply, climate, temperature, sunlight, etc. The first issue that M4 Hydroponics Farm addresses is the poor soil in Qatar. Hydroponic farming avoids utilizing soil and instead grows all plants in water, which could address the issue of inadequate soil. Additionally, since all our crops will be hydroponically reliant, our farm may be able to address Qatar's water shortage. All the water used in farming is recycled, which has two benefits: first, it reduces the quantity of water needed, and second, it makes farming as sustainable as possible because the water is preserved and utilized for future crops. Currently, growing seasons and geographical areas are undergoing significant change because of shifting temperatures and growing circumstances. There are many locations where farming simply isn't possible, even in "normal" settings (such deserts, concrete jungles, etc.). One of the countries with a huge desert and a dry environment is Qatar, where it may be impossible to grow anything there. Using M4 hydroponic farm, however, the farm will be in indoor container systems that may be set up in all localities and regions. It is quite simple to put up the container, which can be transferred from one location to another and fits anyplace. It's also feasible to locate a farm just behind eateries that demand food that is picked just moments ago. Plants spend more time growing upward and less time and energy developing large root systems to look for nourishment since roots are drenched in all the nutrients they require. Hydroponic systems consume less water than conventional soil-based ones. This is since closed systems aren't susceptible to the same evaporation rates. Additionally, the water used in hydroponic systems may be purified, replenished with nutrients, and supplied back to plants once again, allowing water to be recycled continuously rather than being lost!

3. M4 Data storage

Agriculture is getting more difficult and more complicated in the modern world. Agriculture is a challenge and is becoming more complex because of the ongoing effects of climate change, water shortages, and natural disasters. Unawareness of the conditions that the crops are in is a major problem for people involved in agriculture. Farmers frequently inquire, "Is this amount of water enough for this crop?" Is the exposure to sunlight sufficient for these crops? What temperature will allow these plants to grow most successfully? and more inquiries, demonstrating that these crops are not treated accurately. Nevertheless, this problem could be resolved by utilizing technology and Big Data, where the m4 Farm would have Big Data technology that will make these farmers understand the correct condition of each crop and will make them able to treat every crop in the most accurate manner by determining the needed water, the needed temperature, the right amount of sunlight exposure, and more. Granular information on rainfall patterns, water cycles, fertilizer needs, and other topics is made available to farmers by big data. They can use this information to make wise choices about when to harvest and what crops to plant for maximum profit. Making the right choices ultimately increases crop yields. With the help of big data, farmers can better manage this by being advised on when, where, and how much pesticides to use. Farmers can follow rules set by the government and limit the use of chemicals in food production by closely monitoring it. Additionally, because crops aren't destroyed by weeds and insects, this increases profitability. In addition to maximizing farm machinery and overseeing the farm's supply chain, this approach will not only address the issue of accuracy but also make farming more sustainable because there would never be any resource waste, such as water supply.

4. Drones and robotics

Drones and robots are increasingly being used in agriculture to perform a variety of tasks. Here are a few examples of how drones and robots are being used in agriculture:

- Planting: Some drones are equipped with seed dispensers that can be used to plant seeds in fields. This can be particularly useful in areas that are difficult for humans to access, or in fields with uneven terrain.
- Crop monitoring: Drones equipped with cameras or other sensors can be used to monitor crop health and identify areas that may need additional attention, such as areas with pests or diseases. This can help farmers make more informed decisions about how to manage their crops.
- Irrigation: Drones or robots equipped with sensors can be used to monitor soil moisture levels and automatically adjust irrigation systems to ensure that crops are getting the right amount of water.

- Pesticide application: Drones can be equipped with spray nozzles to apply pesticides or herbicides to crops. This can be more efficient and less labor-intensive than applying these products manually.
- Harvesting: Some robots are being developed to assist with tasks such as fruit and vegetable picking. These robots are equipped with sensors and gripping mechanisms that allow them to identify and pick ripe produce.

Overall, drones and robots can help make agricultural tasks more efficient and less labor-intensive, potentially improving crop yields and profitability and efficiency for farmers.

Figure 3: The green house with robots.

Figure 4: The grocery shop side 1.

Figure 5: The grocery shop side 2.

Figure 6: The field with drones.

Figure 7: The green house.

4. Conclusion and Discussion

The agricultural industry in Qatar is examined in terms of its historical history and prospects for future growth. More specifically, it examines the factors influencing the agriculture and food production systems in Qatar and evaluates their effects. The availability of land with suitable soils has historically been the issue that has hampered the development of productive agricultural and horticultural systems the most. This is a result of Qatar's harsh environment, which is characterized by hot summers, little precipitation, a shortage of freshwater resources, and a little amount of available land. The Qatar National Vision 2030 also looks at the agricultural sector with the aim of enhancing the sector's economic contribution and applying the most recent scientific developments in vegetable growing to the State of Qatar to raise the quality of the sector's output in an environmentally friendly and cutting-edge way that will ultimately enhance food security and the general economy. However, in recent years, soilless growing methods that enable year-round crop production, like hydroponics and indoor vertical farming, have been applied in modern greenhouse farming to significantly increase domestic food output. Furthermore, these techniques are applicable to urban food production practices that inherently overcome the limitation and competition from urban land-take and the need for ecological conservation and habitat restoration. Urban farming takes advantage of Qatar's low-density suburbs and benefits from the availability of large quantities of recycled water, efficient use of space, and sustainable use of resources.

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