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Article

Eco-farming policies and sustainable food security in Qatar: The role of hydroponics

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Abstract: This article explores how hydroponics can help the State of Qatar implement sustainable agricultural policy in the face of the nation's climatic and environmental problems, including a lack of arable land and water. Because it uses nutrient solutions to grow plants without soil, hydroponics is a cutting-edge substitute for conventional agriculture. It reduces water consumption and increases production efficiency. The article discusses how Qatar is adopting hydroponics within the framework of its National Vision 2023, which seeks to achieve food security by promoting innovation and sustainability in the agricultural sector. It also focuses on the environmental and economic benefits of hydroponics, such as reducing dependence on food imports and improving the use of natural resources by analysing available data. The article reviews the challenges of applying hydroponics in the State of Qatar, including the high initial cost and lack of public awareness. The article concludes that the demand for hydroponics in Qatar is rising due to a number of causes. Given Qatar's harsh climate, hydroponics is a cutting-edge and environmentally friendly farming technique that enables year-round growing. Hydroponics is an effective method for growing crops, including fruits and vegetables, on a small amount of arable land and water.

Keywords: hydroponics; sustainable farming; food security; Qatar; agricultural technology; water consumption; farming policies; environmental innovation

1. Introduction

The problem of providing food has become one of the most important problems facing the world today, as it has become a source of concern and fear for various political and economic circles. Today, food security is a fundamental goal sought by all peoples and nations, and agriculture is the first activity through which food is provided. The agricultural sector is one of the fields that any country is concerned with, in an effort to achieve self-sufficiency and food security [1]. Specialists in agricultural economics are working hard to study and achieve food security through successful and advanced agriculture, and to achieve sufficient agricultural and animal wealth to meet the needs of society, which increases the national product and gross national income and reduces the burden of imports on the country [2]. The ongoing population growth in the Arab world and the need to increase food production at the same rate to close the food gap—which is being attempted to be closed through imports of food commodities and the ensuing trade balance deficit—make the food issue in the region crucial [3,4].

The idea that the ease of importing agricultural products, regardless of the availability of transportation and purchasing options and the range of offers from nations worldwide, makes up for agricultural development and local self-sufficiency is a grave mistake [5].

This is because agricultural development is one of the components of building self-sufficient economic power. Especially since building self-sufficient economic power is an essential element for achieving stability and progress. Indeed, economic independence is considered an important foundation of political independence. From this point of view, agricultural development is considered the foundation of any other development, whether industrial or commercial [6].

Periodically, the debate about food security in the State of Qatar is renewed, as it lives in climatic conditions that are not very different from the rest of its neighbours [7]. Water resources are scarce and temperatures are high in most seasons of the year [8]. The lack of natural resources makes agricultural production challenging and costly, particularly for some crops that need to be produced in large quantities including wheat. because the climate in the State of Qatar, is not suitable throughout the year to produce enough fruits and vegetables to meet the needs of the population and achieve self-sufficiency [9]. Therefore, this region has become almost entirely dependent on food imports; which makes it more vulnerable to fluctuations in the global commodities market, and more affected by them. Accordingly, this article seeks to demonstrate the importance of achieving self-sufficiency in agricultural products locally and enhancing food security within the State of Qatar by increasing productivity through activating the hydroponic method [10].

Since the State of Qatar imports over 90% of its food needs, the growing food gap in the country is the major problem. The annual bulletin published by the Ministry of Development Planning and Statistics for the year 2015 states that the resulting imbalance in the country's trade balance was 9967 million Qatari riyals. In contrast to its exports of 571 million Qatari riyals, the nation imported over 10,538 million Qatari riyals worth of food and live animals [9].

The severity of this problem increases in light of the limited geographical area of Qatar, and the limited percentage of arable land out of its total area. In light of the fluctuation in the prices of imported foodstuffs, and the continued increase in its population [10]. The agricultural sector in Qatar faces many challenges, including, but not limited to, high temperatures and humidity, increasing water salinity, limited arable land area, poor soil condition and quality, harsh and unfavourable climatic conditions, limited groundwater sources, and the lack of lakes, rivers and surface sources [11].

In order to solve current issues, close the food gap, and improve self-sufficiency and food security in the State of Qatar, it is imperative to look for strategic solutions and advanced agricultural methods including hydroponics. Thus, the main problem of the study is as follows: What role may hydroponics play in the sustainable agricultural and food security of the State of Qatar? This issue raises a number of research problems, including: Is agricultural self-sufficiency a fundamental requirement for the State of Qatar? Which significant challenges still stand in the way of the State of Qatar achieving food sufficiency? Could the State of Qatar strategically employ hydroponics to become self-sufficient? What part does hydroponics play in increasing productivity? In order to address these issues, the article highlights that implementing hydroponics will aid in the creation of sustainable agricultural policies, which will enable the State of Qatar to achieve self-sufficiency and solve a number of issues pertaining to crop productivity.

2. Materials and methods

This article relies on a comprehensive methodology that combines the case study approach and the descriptive analytical approach to understand the role of hydroponic technologies in achieving sustainable agricultural policies in the State of Qatar. The case study approach is suitable for this study because Qatar represents a unique case within the Arabian Gulf region, facing environmental and climatic challenges that require innovative agricultural solutions [7]. The use of the case study approach allows for an in-depth analysis of the application of hydroponic agriculture in the context of Qatari agricultural and development policies, which helps in understanding the factors affecting the success of this experiment. With regard to the descriptive analytical approach, this approach will be used to analyse data and information related to hydroponic agriculture technologies and their sustainability in Qatar. This approach is based on describing Qatari agricultural policies, analysing their effects, and evaluating their effectiveness in achieving environmental and economic goals. Functional analysis is used to provide a comprehensive picture of the status of hydroponic agriculture in Qatar, including influential variables such as water resources, government policies, and technical innovation. The analysis relies on extrapolating the relationships between these variables in order to understand the factors, which affect the success of hydroponics and its ability to achieve sustainability.

The content analysis method will also be used to analyse public policy documents and strategies issued by Qatari government agencies, which are an essential part of the information sources for this study. Among the most prominent documents analysed in this article are the National Food Security Strategy in the State of Qatar and the documents of the Qatar National Vision 2030, as well as the reports of the Ministry of Municipality and Environment on sustainable agricultural development in Qatar [12]. These documents are analysed using the qualitative content analysis method to determine the policies and procedures that enhance the use of hydroponic technology and the extent of its integration with national goals such as preserving natural resources, reducing water consumption, and increasing local production. In terms of tools for collecting scientific material, the study used the method of personal interviews with the elite in order to collect primary material that helps in answering some questions that were not answered in the literature reviewed related to the research topic.

In addition to analysing the documents, the method of personal interviews with the elite was relied upon in order to collect direct and realistic information from stakeholders within Qatar. Interviews were conducted with a group of key players in the field of hydroponics. That included agricultural experts, government officials, farmers and investors in the agricultural sector. This approach aims to collect multiple insights and observations on the application of hydroponics in Qatar and understand the challenges it faces and the opportunities through which the sustainability of the agricultural sector can be enhanced. These interviews were carefully designed to ensure solutions to ensure comprehensive information covering the technical, environmental and economic aspects of the application of hydroponic technologies. Participants were selected based on their direct experience in dealing with hydroponics and related political decisions, which allows for an in-depth analysis of the factors

influencing the widespread adoption of these technologies. Hence, this dual methodology that combines document analysis and personal interviews seeks to provide an integrated vision on the role of hydroponics in Qatar and how to apply it in a way that can contribute to achieving agricultural sustainability and food security. In addition, this methodology helps in evaluating Qatari agricultural policies and providing recommendations to improve the effectiveness of these policies in line with national goals.

The data and information gathered from the mentioned sources focused on the current scenario of hydroponics in Qatar. That included gathering information about the current agricultural production and land use in Qatar. The collected date also underlined the challenges facing the state of Qatar in advancing the hydroponics. Hydroponics systems such as the flood system, the Nutrient Film Technique (NFT) tube system and the aeroponics system and related information have also been gathered from the previous body of research and the statistical reports issued by government institutions such as Statistics Authority in Qatar and Ministry of Development Planning and Statistics. For data triangulation purposes, the study has also depended on reports published by non-state stakeholders such as independent research centres. During the interviews, the focal point was the evaluation of the level of success of hydroponics in the studied farms as well as the crops the better suited the hydroponics. Some of the data collected have been presented in graphs and tables to summarise and contextualise the main issues covered in this paper.

3. Hydroponics and food security: A literature review

This article addresses the issue of sustainable farming policies and food security and self-sufficiency in the State of Qatar through studying the impact of using hydroponic technology.

3.1. Hydroponics: Definition, techniques and benefits

By reviewing the literature related to this topic, three main categories can be identified in relation to the treatment of the topic under study [6]. At the conceptual level, it can be noted that hydroponics is a modern technology that is gaining increasing popularity all over the world, especially in light of the challenges facing traditional agriculture such as water shortages, soil degradation, and climate change [7]. Hydroponics is known as an agricultural system that relies on growing plants without using soil, as plants are grown in an aquatic environment rich in nutrients instead of soil [13]. This technology uses nutrient solutions that contain all the nutrients necessary for plant growth. Hydroponics can be used in closed environments such as greenhouses, open systems that use fresh water or treated seawater. In this regard, hydroponics provides one popular soilless agri-production method for growing greenhouse crops. One of the agricultural industries that is expanding quickly is hydroponics, which may be a viable alternative for sustainable farming. Because of the world's population increasing more quickly than ever before, hydroponics—a promising technique for producing vegetables in cities without soil—has emerged. The development of hydroponics systems worldwide, even in agro climatic zones, is made possible by regulated conditions, nutritional substrate, and sturdy support [14].

Hydroponics has many benefits such as reducing water consumption by up to 90% compared to traditional agriculture, increasing productivity and the ability to control the environment surrounding plants, which leads to improving the quality of crops (see **Table 1**).

Table 1. Characteristics of traditional soil-based farming and soilless farming [14].

Category	Traditional Soil-Based Farming	Soilless Farming
Production	-Yield: Depends on soil conditions and treatments.	-Yield: Extremely high with dense crop cultivation.
	-Good Manufacturing Practices: Depends on the soil and managing skills.	-Good Manufacturing Practices: Depends on the supply of nutrients to plants.
	-Sanitation: Low-quality water poses a contamination risk.	-Sanitation: Contamination risk is less.
Nutrient	-Distribution: Varies with the quality of soil.	-Distribution: Nutrition supply is ensured at the root zone. Monitoring and additional handling skill are required.
	-Utilization Efficiency: Good.	-Utilization Efficiency: No leaching, ensuring uniform nutrient distribution.
Water Use	-Efficiency: Susceptible to soil conditions.	-Efficiency: Supply of water is controlled via sensors.
	-Salinity: Build-up of salt.	-Salinity: Salt flushing increases water requirements.
Management	-Labour and Equipment: Needed for ploughing and harvesting.	-Labour and Equipment: Skilled individuals and costly equipment are needed.

Hydroponics also contributes to reducing the need for pesticides and chemical fertilizers, making it an environmentally friendly technology. There are several systems for hydroponics including firstly, the flood system, which depends on collecting water in a basin and then draining it, which provides the crops with nutrients and water. It is preferable that the pH of the nutrient solution be between 5.8 and 6.5, as a decrease in the pH level to the acidic level leads to damage to the roots of plants, while an increase in the pH to the basic side leads to the precipitation of many elements in the solution in the form of insoluble salts that the plant does not benefit from. Therefore, it is preferable to use some devices available in the market to measure the nutrient solution. Phosphoric acid can be added when the pH rises above 6.5 to reach the required degree of the nutrient solution. Potassium hydroxide can also be added when the pH drops below 5.8 to raise the acidity level to the required degree. Secondly, the Nutrient Film Technique (NFT) tube system, where the plant is grown in table tubes, where a nutrient solution is pumped continuously. An extremely shallow stream of water with all the dissolved nutrients needed for plant growth is recirculated past the exposed roots of plants in a watertight gully. The foundation of a well-designed NFT system is the use of the appropriate channel length, flow rate, and slope. Enough water, oxygen, and nutrients are available to the plant roots. Because too much or too little of one causes an imbalance of one or both of the others, there was a conflict in the supply of these requirements in previous production methods. Thirdly, the aeroponics system depends on spraying the nutrient solution on the roots of plants suspended in the air. In other words, a nutrient solution or nutrient solution aerosol is periodically misted or sprayed over the plant roots that are suspended in the air [15]. The farmer must choose the most appropriate system according to the available resources, the type of crops to be grown, and the local environment [7,16,2,8].

The application of hydroponics requires the provision of advanced technology

such as climate control systems and lighting in addition to modern irrigation techniques. Therefore, farmers must invest in appropriate equipment such as pumps, vertical farms, and sensor systems that help monitor environmental and climatic conditions [17]. In that sense, hydroponic systems can also be set up vertically, which saves space and allows for several layers of growing in a smaller area. Hydroponics reduces the chance of soil-borne illnesses and pests by avoiding soil, which promotes stronger and healthier plant growth [18]. The application of hydroponics also requires special expertise and a deep understanding of the technologies used. Therefore, it is important to provide training and qualification programs for farmers on how to manage hydroponic systems in addition to teaching them how to deal with potential challenges such as diseases and pests that may affect crops. Countries also need to develop sustainable agricultural policies that support the use of hydroponics. Consequently, these policies must include providing financial support to farmers and stimulating research and development in this field.

In addition, it is essential to provide the necessary facilities for distributing agricultural products in the markets. Governments should also cooperate with universities and research institutions to develop new technologies and promote innovation in the field of hydroponics. Strategies must involve increasing community understanding of the advantages of hydroponics in addition to the previously mentioned elements to guarantee its success. In this situation, producers and consumers can be introduced to hydroponics through workshops and seminars, which helps to raise demand for agricultural products made this manner [19]. From this perspective, hydroponics can be viewed as a single technology that meets food security needs and helps develop more sustainable agricultural policies in countries that adopt it. Hydroponics also helps countries that adopt it to face current environmental challenges by choosing the appropriate system, providing technology and resources, training farmers, and developing supportive policies. By providing these elements, multiple benefits can be achieved from adopting hydroponics technologies, which enhances the productivity of the agricultural sector and contributes to the development and implementation of sustainable and environmentally friendly agricultural policies. Investing in this technology will not only contribute to improving agricultural productivity, but will also contribute to preserving the environment and achieving sustainable development.

3.2. Conceptualising food security

Opinions and theories differed regarding the definition of food security [6]. In a broad sense, the concept reflects the country's ability to secure food for its population and ensure the provision of their basic nutritional needs. In this context, the study of the Food and Agriculture Organization of the United Nations (FAO) highlights the definition that indicates the necessity of the availability of sufficient and safe food to meet the health needs of individuals [20,21]. The organization defines food security as the ability to obtain sufficient and safe food that meets the nutritional needs of all individuals, which contributes to a healthy and active life [22]. On the other hand, the World Bank defines food security as the possibility of obtaining sufficient food for all individuals at all times, stressing the importance of ensuring the availability of food in

times of crisis. In this context, food security emerges as a basic element of sustainable development, making it a major focus of research and study. The concept of food security was addressed from two main perspectives: absolute food security and relative food security [23].

Absolute food security refers to the country's ability to produce food equivalent to or exceeding local demand, while relative food security expresses the country's ability to meet the food needs of its individuals, partially or completely. The analysis reveals that, in spite of their comprehensiveness, the adopted definitions leave out some crucial elements, such as fluctuations in food prices around the world and supply-chain crises. This emphasises the pressing need to broaden the concept to encompass food access sources and the impact of global factors. Nonetheless, the idea of self-sufficiency is regarded as a crucial component of food security since it refers to a society's capacity to become entirely self-sufficient in meeting all of its food demands locally [23]. This definition is accurate and specific, as it indicates the importance of achieving a balance between local production and demand [24].

3.3. Hydroponics and food security in the Arab region

Focusing on the Arab region, it can be noted that a number of studies have pointed to many of the challenges facing Arab countries in the field of using modern technologies such as hydroponics [5,3]. These studies have pointed to the weakness of the agricultural sector and the lack of use of modern technology, which has led to the exacerbation of the food deficit in many Arab countries. Some studies have analysed the reasons behind these challenges, explaining that agricultural research suffers from significant backwardness, which negatively affects agricultural productivity and increases the inefficiency of water resource exploitation. These studies have also indicated the existence of a crisis in the field of agricultural development, which has been reflected in the ability of many Arab countries to achieve food security [25]. At this point we can identify three key elements that have contributed to the worsening of this issue. The first reason is the economic imbalance, which indicates a persistent gap between the population's actual requirements and the resources that are available. The second aspect is funding and investment in agriculture, as research shows that investments in this industry are declining relative to other industries. The third element is the crisis in scientific research and technology, as the agriculture industry faces numerous practical challenges due to its dependence on outdated methods. Research also highlights the difficulties in attaining food security, particularly in the Gulf Cooperation Council nations. A reference was made to the insufficiency of food commodities and the high food gap in the countries studied in the Arabian Gulf region [10]. It is important to take into account that the increase in population due to migration and rapid population growth represents a major challenge to food security in the countries of the region [4]. Therefore, the importance of food security was highlighted, not only as a production issue, but also because it is closely linked to social, economic and political factors.

In terms of developing the agricultural sector and improving agricultural policies in the Arab region, some studies have emphasized the need to use modern agricultural technologies, especially hydroponics technology [10,26]. Modern agricultural

methods, including hydroponics, have been presented as innovative solutions to enhance agricultural productivity, achieve food security, and increase the effectiveness of sustainable agricultural policies in the countries of the Arab region. Some reports issued by official bodies have highlighted the effectiveness of soilless agricultural production systems, which represent the essence of the idea of hydroponics in improving the efficiency of water use [27]. In this context, some countries in the region have achieved tangible successes in raising productivity, especially in the Gulf countries, by using hydroponics. From here, hydroponics can be considered an effective way to improve the use of water and agricultural resources, especially in areas that suffer from water scarcity. Some studies have also addressed the application of hydroponics at the household level with the aim of confronting the problems of poverty and water shortages.

These studies have emphasized the positive impact of using hydroponics technologies on food security in the countries that have adopted it [28]. The results of these studies concluded that the use of hydroponics could contribute significantly to improving the economic conditions of families and enhancing food security by providing the arm with sustainable agricultural production throughout the year. Some studies also clarified the economic schedule for hydroponics projects in some cities in Arab countries, indicating the importance of this technology as a strategic alternative to the challenges of the agricultural sector [22]. Some studies presented practical experiences that Arab countries can benefit from; as they emphasized the high efficiency of hydroponics technologies and the role, they play in increasing the effectiveness of using agricultural resources and reducing the costs of agricultural production [29]. Despite the great importance of the previous literature, some issues deserve to be addressed according to a critical vision. It is noted from the previous presentation that most studies focus on describing the challenges without providing clear strategies to deal with them. The link between food security, self-sufficiency and sustainable agriculture policies shows the necessity of having integrated strategies that take into account geographical diversity and available resources [24].

Moreover, many studies lack a link between the practical and theoretical aspects. For example, studies that focus on the use of hydroponics do not provide clear models on how to apply this technology in different local contexts. It is necessary for future studies to rely on practical models and field data so that they can provide tangible and applicable recommendations to those in charge of the agricultural sector in the countries of the Arab region. There is also a need to expand the scope of research to include the effects of external factors on the sustainability of agricultural policies and food security in Arab countries. These variables include climate change and global food prices. Researchers must take into account how these factors affect the productive capacity of the agricultural sector in Arab countries and how modern technologies can be used to mitigate these effects. Based on the above, it is necessary for studies on the subject of the sustainability of agricultural policies in the countries of the Arab region to provide sustainable solutions that rely on technological innovation, such as hydroponics. These studies must also focus on the local contexts of each country in the region, which is what this article will do through focusing on the Qatari case and the agricultural sector in the State of Qatar. This study will be an attempt to explore the role of hydroponics as an effective tool to enhance food security and self-

sufficiency in the State of Qatar, which contributes to the development of sustainable agricultural policies.

4. Case study analysis: Discussion and results

This part of the paper focuses on analysing the status of hydroponics in the State of Qatar with the aim of identifying the most important challenges that may face the use of this modern method in agriculture. This section begins by reviewing the status of the agricultural sector in general in the State of Qatar, and then focuses mainly on hydroponics as one of the sustainable agricultural methods that is expected to have a significant impact on the future of the agricultural sector and food security in the country.

4.1. Agriculture and food security sector in the state of Qatar

The Rome Declaration on World Food Security and the World Food Summit Plan of Action in 1996 have mentioned that food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. The four pillars of food security approved by the Rome Summit Declaration in 2009 are [20]:

1) Food availability (availability of sufficient quantities of food from local production or imports during a specified period).
2) Access and utilization opportunities (the ability of an individual or household to obtain and use it).
3) Food quality and safety (the diversity of the diet, the type of protein and its safety).
4) Food stability (stability of food supplies and adequate storage capabilities).

To measure the dimensions of food security in developing countries, there are a number of indicators related to food production, income, food expenditure and its share of total expenditure, calories consumed, nutritional status of the individual, etc. The choice of any of them depends on the availability of data or the condition to be measured (individual, household or aggregate level). At the aggregate level, food security can be measured through the following indicators:

a. The percentage of total food exports/imports.
b. The per capita share of food production.
c. The percentage of household spending on food of their total spending.
d. Food consumption (measured in daily calories per person) (difficult to measure due to the lack of data in the State of Qatar).

The first indicator, which is the ratio of total food exports/imports, measures the country's ability to finance its food imports from its total export revenues, i.e., access to international food supply. This indicator grew by about (36.6%) in the State of Qatar. Thus, the State of Qatar is included in the group of countries with high food security. The second indicator, which is the per capita share of food production, declined in the State of Qatar due to the decline in food production from (469) thousand tons to (387) thousand tons. Thus, the State of Qatar is included in the group of countries with above-average food security. The third indicator, which is the percentage of household spending on food out of their total spending, reached about

(12%) in the State of Qatar, which indicates the smallness of what the family spends on food compared to other goods and services, and the increase in income. The higher the percentage (greater than 95%), the more vulnerable the family becomes to food deprivation [30,31]. The State of Qatar is therefore pushed to be among the nations with the highest levels of food security by the following factors: sustained food supply security; rising national income; low household food expenditures relative to other goods and services; and expansion of foreign food investments through the Hassad Food and Mawashi firms.

One of the most important concepts of food security is that related to the degree of self-sufficiency in food, as our measurement of the true size of food security depends on the ability of local agricultural resources to cover the food needs of individuals. The self-sufficiency rate of food commodities in the State of Qatar reached 12.2%, with an annual growth rate of 3%, according to population food security statistics [24]. It is noticeable that the index of self-sufficiency rates of food commodities in the State of Qatar fluctuated over the years [11]. The size of the food gap, which represents the difference between what the country produces itself and what it needs for consumption of food, is also expressed as the deficit in local production to cover the consumption needs of food commodities, which is secured by imports from abroad.

A review of reports and statistics indicates that what is available for consumption from all major food commodity groups exceeds production, and the largest proportion of it is covered by imports, with the exception of the dates and palm trees group, the local production of which exceeded the quantity of imports (see **Table 2**).

Table 2. Quantity index number of agricultural production 2017–2021 [11].

Product	2021	2020	2019	2018	2017
Cereals	194	88	67	135	20
Vegetables	209	229	207	165	167
Fruits and Dates	139	125	134	136	218
Fruits	142	36	34	31	150
Dates	139	129	138	140	214
Green Fodder	200	205	152	198	414
General index Number	198	202	157	190	339

(See **Figure 1**) Added to this, the total local production from all food groups amounted to 260,103 tons, compared to imports, which amounted to 2,216,257 tons, thus the food deficit amounted to 1,956,154 tons. The food gap is taking an increasing trend, as the food deficit in 2014 amounted to 1,685,039 tons, an increase of 271,115 tons in 2015; this is due to the increase in the quantity of imports for the grains and vegetables group [32]. The main deficit is in the grains group, which includes rice, wheat and wheat products, where imports amounted to 492,519 tons, compared to production of only 1,691 tons and a self-sufficiency rate of 0.35%. We note a decline in local production, which amounted to 2540 tons. Fruits are the second largest group in terms of deficit, where local production amounted to 762 tons of fruit, compared to imports of 159,731 tons, with a self-sufficiency rate of 2.39%.

As for the vegetables group, local production increased in 2015 to become 58,077 tons, where production was equal to 51,594 tons, and in return, the quantity of imports increased more, reaching 363,553 tons. The dairy group accounted for the highest percentage of local production, with a total of 90,803 tons, compared to imports of a larger percentage, which amounted to 158,854 tons. The self-sufficiency rate for the dairy group amounted to 36.56%, which is a higher percentage than the rest of the food groups [4].

Figure 1. Agricultural supply (tons) of cereals, fruits, dates, and vegetables in Qatar from 2010 to 2020 [33].

The rest of the food groups have remained stable. The fish group is considered the second highest group in terms of self-sufficiency, as local production amounted to 16,213 tons, compared to imports of double that, which represented 32,505 tons, with a self-sufficiency rate of 34.45%. Local egg production amounted to 4,338 tons, compared to imports of 28,271 tons, and self-sufficiency amounted to 13.34%. As for the meat group, local production of red meat amounted to 7395 tons, compared to imports of 55,372 tons, with a self-sufficiency rate of 8.87%. As for chicken and poultry meat, 8006 tons are produced, compared to imports of 103,715 tons [31]. While self-sufficiency rates are non-existent in each of the following food groups: legumes and oilseeds group, sugar and sugars group, oils and fats group over the years. Thus, it is clear that the State of Qatar imports about 90% of food commodities [4].

The above analysis shows that both imports have taken an increasing trend at a rate lower than the growth of exports. This is due to the fact that the demand for imports is still of great importance to meet the needs of consumers of various crops and agricultural products. Total exports were zero for some food groups such as: rice, wheat products, fruits, vegetables, dairy products, and eggs. While in the remaining food groups, exports constituted a much lower percentage than imports. Consequently, we have the problem of a trade balance deficit, and the deficit amounted to (9967) million Qatari riyals. The trade balance deficit occurs when the value of imports is greater than the value of exports, as Qatar's imports of food and live animals amounted to about (10,538) million Qatari riyals, compared to its exports of (571) million Qatari

riyals [31].

The food deficit in a number of countries has many repercussions that do not only make it an economic concern, but its dimensions extend to affecting national sovereignty and security [10]. This is because the food deficit has very costly economic repercussions, and such a matter causes the depletion and waste of financial resources, and exhausts national economies. In addition to harming development as a whole, as it disrupts the growth, process that was achieved thanks to oil revenues. Instead of spending on new industries and development operations, spending will be directed towards bridging the food gap. As for the political level, the food deficit in today's world means political dependency and submission to the interests of parties that control the threads of the international political game. This is evident in the relationship between food and political dependency. In today's world, food has a political price, and there are many examples of the use of food as a means of political pressure for several countries, perhaps the most prominent of which is "oil for food". With the rise in oil prices, the threat of political bartering and the use of food as a political commodity begins. A set of factors and determinants control the quantities of agricultural production and the size of the food gap in Arab countries, represented by the small area of cultivated land, scarcity of water resources, low irrigation efficiency, and small area of irrigated land. In terms of problems and obstacles that prevent the achievement of the desired agricultural development [34].

4.2. Challenges of the agricultural Sector in Qatar: The potentials of hydroponics

The reported official statistics indicate the agricultural sector in the State of Qatar in Qatar faces a number of challenges. chief among those challenges is the shortage of irrigation water and its poor quality (the scarcity of fresh water sources), and water is considered the biggest and main challenge for the State of Qatar, as the State of Qatar, like other Gulf Cooperation Council countries, is located in a water-stressed region [11]. This is due to the limited groundwater sources and the lack of lakes, rivers and surface sources on the one hand, and the weak efficiency of water use and the small water supplies on the other hand. The State of Qatar falls within the desert climate, where it receives little rainfall that is difficult to predict and regular, due to its low density and annual variation in place and time, and therefore it cannot be relied upon for irrigation and agriculture.

The State of Qatar is considered one of the countries with the lowest natural fresh water resources in the world (see **Figure 2**). The annual groundwater recharge rate does not exceed 65.5 million m^3 and rainwater 63.3 million m^3. It is clear that the safe limit for annual water extraction should not exceed 47.5 million m^3. Most of the groundwater withdrawals are for agricultural purposes (85% of the total groundwater extracted) [11]. This percentage is increasing because of the continued use of traditional surface irrigation methods and the failure to adopt modern agricultural methods and irrigation systems, the continued over-pumping of water in the absence of strict control, and the low cost of using groundwater. This is in addition to the dominance of green fodder production, as the area planted with fodder constituted 54% of the cultivated land area. Fodder cultivation drains the largest amount of

groundwater. The agricultural sector in the State of Qatar consumed 35% of the total water resources used in the economic sectors, i.e., about 296.3 million m^3 and about 92% of the groundwater uses in it. The State of Qatar is considered one of the countries exposed to water scarcity. Accordingly, the State of Qatar is now looking to increase the efficiency of water use in agriculture, and reduce lost and unmeasured water by renewing water networks [11].

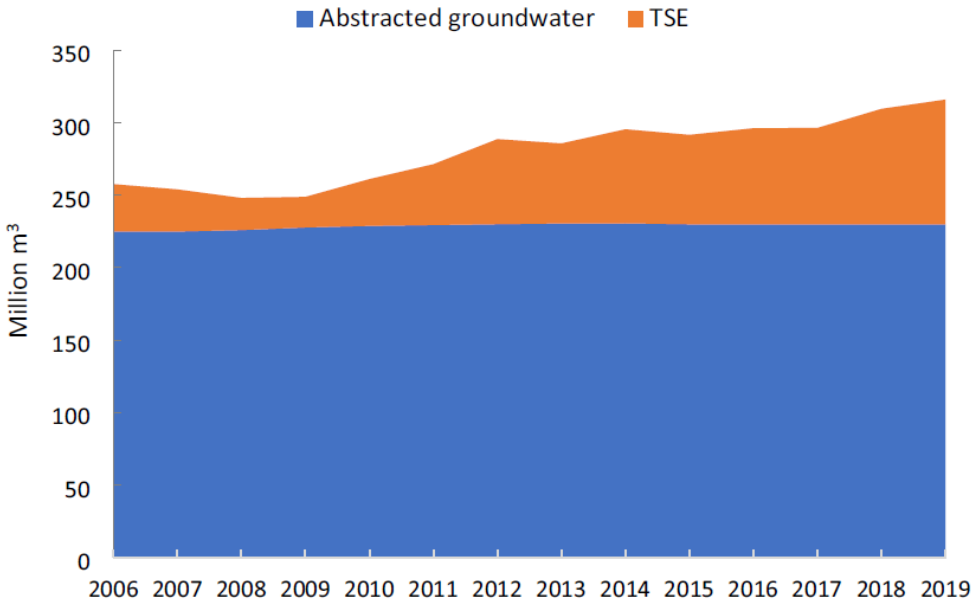

Figure 2. Agricultural water sources for Qatar (million m3) from 2006 to 2019. TSE: Treated Sewage Efuen [33].

The limited area of arable land and the poor condition and quality of the soil represent another major challenge for the agricultural sector in the State of Qatar (see **Figure 3**).

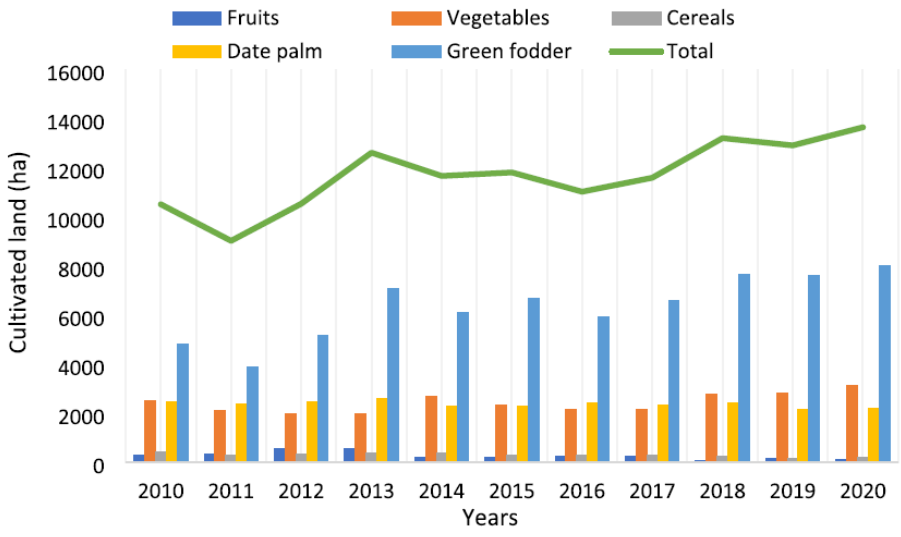

Figure 3. Land utilization of crops (ha) in Qatar from 2010 to 2020 [33].

The area of arable land amounts to 65 thousand hectares, which constitutes about

5% of the total area of the country, of which 11,571 hectares is the area of actual cultivated land and 53,429 hectares is the area of arable land. The number of active farms reached 910 farms out of 1290 farms, with an annual growth rate of 2%. The area of arable land in productive farms amounted to 21,979 hectares, which constitutes 0.02% of the country's area (See **Table 3**).

Table 3. Cultivated land area (ha), number of registered farms, number of active farms and food self-sufficiency index [7].

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Cultivated land area (ha)	10506	9020	10532	12610	11663	11571	11021	11590	13203	12907
Number of registered farms	1275	1281	1318	1340	1282	1290	1307	1310	-	-
Number of active farms	822	831	833	839	872	910	902	916	-	-
Food self-sufficiency (%)	10.7	10.3	11	15.3	13.5	12.7	10.7	11.5	-	-

Moreover, harsh and unfavourable climatic conditions add to the complications faced by farmers in Qatar. The climate of Qatar is defined by a hot summer that lasts from May to October and reaches highs of 34 ℃ to 37.2 ℃ between 2010 and 2020, while the winter season lasts from December to the end of February and is often mild. Summer temperatures rise to more than 40 ℃ and the evaporation rate is high, with an annual average of 2200 mm per year, in addition to high humidity. Additionally, low rainfall and high humidity are seen; between 2010 and 2020, the average annual rainfall was 71.4 mm, while the average annual relative humidity was 51.4%. (See **Figures 4** and **5**).

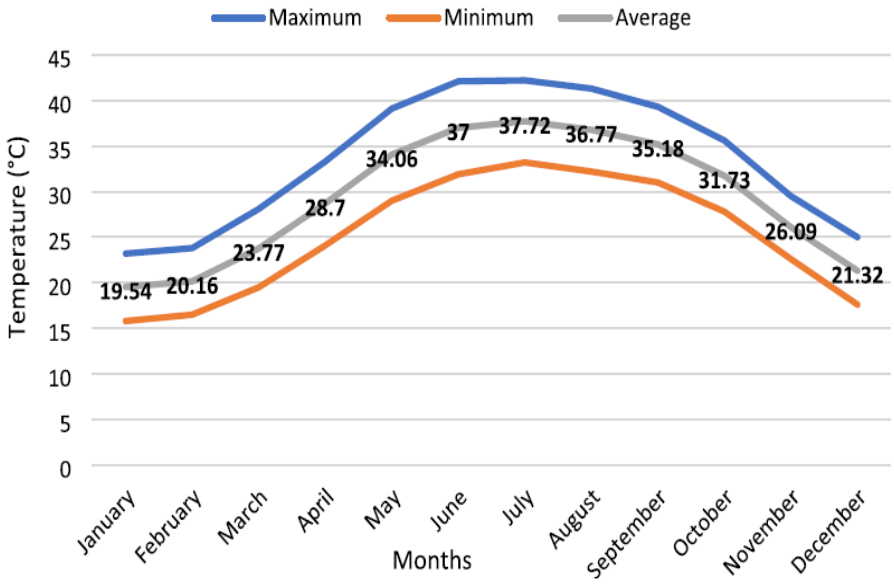

Figure 4. Temperature (℃) per month in Qatar from 2010 to 2020 [33].

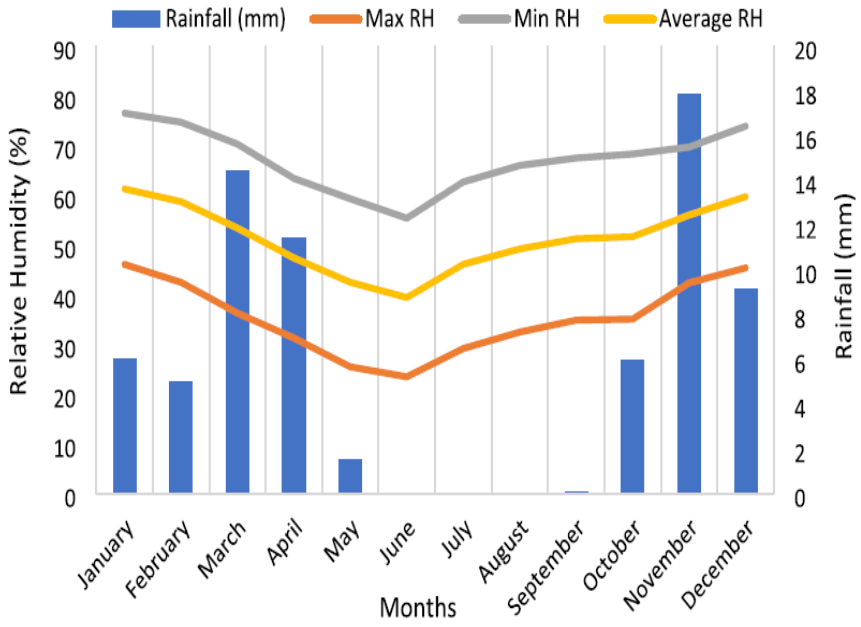

Figure 5. Relative humidity (%) and rainfall (mm) per month in Qatar from 2010 to 2020 [33].

Another challenge is the weak interest of Qatari investors in investing in the agricultural sector, and inefficient marketing operations in addition to the lack of technical personnel and national capabilities and low agricultural skills among the majority of expatriate workers. Finally, the high population growth rates upsurge problems with agricultural holdings [4].

Agricultural development expertise, whether for developed or developing countries, indicate that the rates of growth and development achieved in the agricultural sector are linked to the degree of modernization and agricultural technical development. The use of modern agricultural technology is the way to increase and raise the production capacity of available agricultural materials as well as reduce the risks arising from unfavourable climatic conditions [34]. Hydroponics is a technology that aims to save water used in agriculture and maintain agricultural production in terms of quantity and quality, increase production and obtain better quality production [27].

Hydroponics has a number of characteristics that make it a strategic alternative for achieving sustainability in agricultural policies. The first of these characteristics is the efficiency of water use in irrigation due to the low loss of steam or drainage in the soil with recycling of water use. This increases the efficiency of water use to the maximum possible extent. As soilless agricultural systems allow the reuse of the nutrient solution, this is considered one of the relative advantages of these systems in areas where the quantities of water needed for agriculture are small and suffer from water scarcity, such as the State of Qatar [26]. The results of experiments and studies have shown the superiority of hydroponic technology in many aspects. It produces abundant production and helps save a large amount of irrigation water, reaching 70%–90% of the water consumed. This also in turn reduces the cost of production inputs, which leads to an increase in the financial return for the farmer. Since water is an important source in the production process, the economic calculation of any

technology must be based on productivity per $m^3$of water [29]. The second advantage of hydroponics is agricultural intensification and increasing the number of plants per unit area. Which leads to increased crop production, early harvest and the possibility of increasing the number of planting seasons per year. This leads to a higher crop yield as productivity per unit area increases with vertical farming [35]. In contrast to 1000 plants in the same space utilising the horizontal technique, 8,000 plants can be cultivated in a greenhouse (360 m^2). Another benefit of hydroponics is its high productivity efficiency since food and water are available close to the roots, which slows down root growth and speeds up vegetative and fruit growth. For example, lettuce germination takes 25 to 30 days in hydroponics, while it takes 60 to 70 days in traditional farming [36].

Hydroponics is the most suitable technology in arid areas, such as the State of Qatar. Soilless agriculture can be developed in arid lands, in areas prone to salinization, as well as in urban and suburban environments, or in any places where competition for land and water increases, or due to unfavourable climatic conditions, which requires the adoption of intensive production systems. The high productivity from a small area makes the use of soilless agriculture an interesting method for achieving food security [16]. Hydroponics is also one of the most efficient methods that contribute to solving the problem of nutrient deficiency in the soil and reduces fungal diseases, soil salinization, the growth of harmful weeds, and soil diseases and pests. Hydroponics also saves labour because it does not require many agricultural operations such as plowing, weeding, etc. Agricultural products based on hydroponics are characterized by their high quality. This is due to the significant reduction in the use of chemical pesticides and the possibility of protecting crops by methods other than chemicals, thus increasing the quality of crops and protecting the environment [26]. From this standpoint, hydroponics can be considered environmentally friendly since fertilizer waste is recycled while in conventional agriculture fertilizers are discharged into the lower layers of the soil, which leads to groundwater pollution.

From an economic point of view, hydroponics is economically viable. Note that crops produced from soilless agriculture systems are sold at a higher price compared to the product of agriculture in normal soil. This is due to the quality of the crop and its longer survival period in the market after harvest. Especially if the farmer finds marketing points for his products such as hotels or large markets. In addition to all of this, the process of early maturity in soilless agriculture systems compared to normal agriculture helps the farmer increase the number of productive crops in one agricultural season and contributes to increasing his income. As for the construction cost, it is an initial cost so that it can be used for many years, unlike agriculture in normal soil, which requires plowing, cleaning the land, spreading black plastic, and other agricultural operations such as sterilization after each crop, which will increase the cost of production inputs. Soilless farming systems are very economical in terms of water and fertilizer consumption compared to conventional farming, which in turn reduces the cost of production inputs, leading to increased financial returns for the farmer.

Despite the benefits, hydroponics has a number of drawbacks that make this eco-friendly farming technique less practical. The most important of these disadvantages is that any failure in the hydroponic system leads to the rapid death of the plant due to

the lack of soil that acts as an insulator. In addition, the high initial establishment costs compared to traditional agriculture may discourage farmers from adopting hydroponics. The reason for the high initial establishment costs is due to hydroponics relying on advanced technological methods and advanced equipment compared to traditional agriculture, which relies on old agricultural methods that are considered low-cos. In addition to the above, there is the need for skilled and trained management and human resources to manage the system successfully, as any error will lead to a very high cost. These trained human elements are sometimes difficult to provide. The possibility of fungal diseases being transmitted if the system is not monitored and managed efficiently and skilfully is one of the disadvantages associated with hydroponic agriculture techniques.

4.3. Hydroponics in the state of Qatar

The rise in popularity of hydroponics in Qatar's agricultural landscape has fuelled the market for hydroponics. Benefits of this soilless growing technique include accurate nutrition management, space optimisation, and water efficiency. Hydroponics offers a practical way to overcome the limitations of traditional agriculture in an arid setting like Qatar. The sector is seeing investments in cutting-edge hydroponic technologies and systems as Qatar looks for environmentally friendly food production options [37]. The importance of introducing hydroponics in the State of Qatar lies in rationalizing the use of irrigation water due to the low loss in deep seepage, evaporation and transpiration. In addition, hydroponics saves the cost of using chemical fertilizers while increasing productivity and ensuring the quality of the product. Hydroponics also contributes to overcoming the problems that have appeared among farmers in greenhouses as a result of continuous cultivation in the soil. These problems have led to the emergence of many fungal and bacterial diseases, and the emergence of the problem of soil salinization as a result of the excessive use of chemical fertilizers in a random manner. In this context, a new experiment in agriculture has emerged in the State of Qatar, relying on the hydroponics method, as two Qatari farms have succeeded in neutralizing the climate and using the best technologies and methods to enhance the agricultural sector and environmental sustainability in the State of Qatar. The next section is focusing on the experience of two models: the global farm and Agrico farm. The analysis in these two sections is driven by a series of interviews conducted with stakeholders in the farms as well as the hydroponic sector in general. The aim was to evaluate the practice of hydroponics in Qatar based on the experience of the two studied models.

4.3.1. Model (1): The global farm

Founded in 1961, the Global Farm occupies 230 denim acres. As reported by the farm owner, hydroponics began 4 years ago. The aim of using this technology was to find solutions to groundwater and soil problems. The soil fertility decreases with increased production, even if it is supplied with all the necessary elements. The farm also aimed, through its reliance on hydroponics, to save water and pesticides and provide the necessary elements for crop growth. Hydroponics gives an abundance of production and can achieve higher returns in a shorter period. It is possible to save up to 70% of the water consumed in agriculture, with the same production efficiency, in

addition to the possibility of growing multiple types of fruits, vegetables and all leafy crops. The interviewee added that all types of vegetables could be grown using hydroponics. The focus of the global farm is on leafy vegetables such as lettuce 5 types and onions, in addition to cucumbers, tomatoes and peppers of all types and colours. For three years, strawberries have been grown and the experience of growing them was crowned with success. There are also experiments on fruits, all of which were successful, as 22 types of fruits were grown and succeeded.

As for the production quantity, it reached 800 thousand kg and this year it is increasing until it reaches 1.2 million or 1.3 million kg in the entire agricultural season. The trend towards increasing quantities was based on the firm principle that those who do not own their food do not own their decision and freedom, as food is considered the most important pillar in any society. Hydroponics constitutes 80% of the global farm's production offered in the market from production. The interviewee at the global farm explained that the pace of production increased rapidly and significantly by 30% after the blockade, and that the number of vegetable farms in Qatar increased by 42% during that period. There was also horizontal and vertical expansion of production operations, noting that the launch of offers and marketing of the project of distinctive national products increased by a record rate in terms of the number of participating farms. The number of participating farms increased from 15 to 62 farms, in addition to the expansion in increasing quantities in the central market and shopping malls. The global farm contributes to providing a hydroponic system for homes. There is an increasing number of residents in Doha who are starting to take an interest in growing some vegetables such as celery, tomatoes, cherries, lettuce and other products that use the system, especially during the winter [38].

Since some basic materials were produced locally with quality comparable to that of imported goods, there was a trend from the farm to cut costs. Examples of this include cooling ponds and replacing agricultural pillows made of rock wool or steel with others made of iron and bricks locally, which reduced the material cost of the farm. Hydroponics is considered an economically viable agriculture because it rationalizes the consumption of water, fertilizers and pesticides. In addition to the abundance and quality of production, which returns economic benefits to the farm owner if it is marketed in the correct and viable way. For example, an average of 33 kg–37 kg of cucumbers is produced in hydroponics compared to 15kg–20 kg in field agriculture. The benefit of the local product is further enhanced by the fact that, unlike imported goods, which take days or weeks to reach Qatari markets, domestic products are delivered to consumers fresh and undamaged from the farm, sometimes even within hours of being picked.

4.3.2. Model (2): Agrico farm

Agrico Farm is one of the largest farms in the State of Qatar, which was established in 2011 and is distinguished by its diversified production, as it produces 5 tons per day of all varieties. Its area is 120,000 m^2. It is considered the first of its kind in the Arabian Gulf region that uses high-quality systems in agriculture, and it manufactures greenhouse structures. The farm operates in the protected biome system, which uses the desert cooling system to reduce temperatures in the summer to grow vegetables and fruits, which reach up to 20 ºC. Agrico was keen to replace traditional

agriculture with modern ones—hydroponics—which grows its plants in limited areas of land and saves 90% of water consumption.

Agrico project records indicate that its production is free of any chemical materials and is all natural, as approximately 40 types of vegetables of different sizes were grown, and the yield of these vegetables was between 3 to 4 tons of vegetables and a ton of mushrooms per day. The project produces 14 types of local tomatoes at a production rate of half a ton per day, which competes with the quality of European products imported in the Qatari markets. In addition to three varieties of cucumbers at a rate of half a tonne per day, four varieties of zucchini (which are produced year-round at a rate of 500 kg per day), eight varieties of sweet pepper, four varieties of hot pepper and three varieties of mushrooms, the production per square metre is equal to 25 kg–30 kg annually. Greenhouses were developed to produce in vegetable houses with an area of 3600 m^2, which gives the same amount of production as a house with an area of 5000 m. Agricco's crops consume 5% to 10% of water when compared to others. The farm is considered the first to use an organic hydroponic system for fruit cultivation, as papaya is produced in addition to five types and varieties of figs and pomegranates. All of them have a 100% success rate in addition to production outside the seasons, as it depends on cooled greenhouses in agriculture and on hydroponic agriculture, which encourages continued research to increase production throughout the year. Agrico Farm has allocated an entire 5000 square meter reserve for papaya cultivation. This nursery will expand to one million m^2, but the cultivated area so far is only 80,000 m^2. As for the soil used in papaya cultivation, it is manufactured by Agrico. It is supplied with coconut fibres and the soil is mixed to become 100% local. The company is planning to develop another 100 hectares of farmlands in Qatar within the next three years [39].

The previous review of hydroponic farming experiences in Qatar demonstrates the extent of the success of the application of hydroponic technology in the State of Qatar. The results of the analysis of the two case studies of the Global Farm and Agrico Farm indicated that hydroponic farming contributed to providing solutions to address many of the challenges that hindered the agricultural sector in the State of Qatar. The most prominent of these obstacles are environmental challenges in addition to problems related to soil and water [40]. The results also indicated the ability of hydroponic farming to produce various crops of vegetables and fruits even out of season and provide them in most months of the year. Hydroponic farming also helped increase productivity per unit of cultivated area compared to traditional agriculture. Hydroponic farming does not require large spaces and has the ability to expand vertically [35]. The products of the farms studied were characterized by high quality and high competitiveness with imported products due to their freedom from chemicals, pesticides and diseases. Hydroponic farming provides fresh products that are available in the market on the same day after harvest. We conclude from this to confirm the thesis of the study, which stated that activating the use of hydroponic farming contributes to increasing the productivity of agricultural crops within the State of Qatar and the possibility of achieving self-sufficiency.

4.4. Obstacles to hydroponics in the state of Qatar

Notwithstanding the benefits of hydroponics, investors in the agriculture industry and hydroponic system users continue to face a number of obstacles and hurdles. The main obstacle facing the hydroponics market in Qatar is the substantial upfront costs associated with establishing hydroponic systems. Although hydroponics allows for space and water savings, the infrastructure, equipment, and technological requirements might be exorbitant. Hydroponic producers also face continuous difficulties in guaranteeing a steady and reasonably priced supply of nutrients and climate control equipment [37]. Based on the analysis of the interviews materials the following challenges can be underlined:

4.4.1. Climate challenges

High temperatures in the summer are one of the biggest climate challenges facing hydroponics in Qatar. Part of this problem can be addressed, but not completely, through cooled houses. However, humidity poses another challenge, as cooled house technology relies on dry air. Therefore, to address humidity, it is necessary to resort to high-quality technologies, and these technologies are very expensive and economically unfeasible for the Qatari farmer if they are not supported or part of their costs are borne by the state.

4.4.2. Marketing challenges

The national agricultural product faces major marketing challenges because the Qatari market is an open market. According to the laws of the World Trade Organization, it is difficult for the Ministry of Economy to limit the imported quantities of agricultural products. Therefore, competition with foreign products is one of the most important marketing obstacles facing the national product, as there is no protection for the national vegetable product so far. The local agricultural product suffers from unfair competition and dumping in front of the imported product in the absence of legislation to protect it. Many memoranda have been submitted to the government so that Qatari farmers can obtain protection and encourage other investors to enter the agricultural sector. Therefore, ensuring the marketing and absorption of national agricultural products in the local market represents a great encouragement for farmers, especially since the local product is distinguished by its quality and cleanliness because it is picked and put on the market on the same day. In contrast, the imported product may take days to reach the consumer and is subject to long storage periods. In addition, the absence of chemicals and pesticides from the national agricultural product produced using the hydroponic method is one of the factors that encourages its purchase compared to imported products. Another problem in marketing hydroponic products is the entry fees paid to commercial complexes for each ton or type. These fees raise the costs of the local agricultural product and this is reflected in the prices at which these products are sold. Overcoming these obstacles will ensure the marketing of agricultural products at competitive prices and will help diversify hydroponic products from vegetables or fruits. These measures will lead to increased production and these are all factors and achieve self-sufficiency. “Marketing and support will increase production as the matter will become profitable for farm owners and will encourage them to increase and diversify their production.” There is

also a need for legislation and mechanisms to protect the national agricultural product, especially hydroponic products, against dumping and unfair competition. It is also necessary to give hydroponic products priority on the display shelves of consumer complexes. Some consumer societies refuse to take the full quantity from Qatari farm owners and give priority to the imported product because they benefit from it more.

4.4.3. High production costs

The initial cost of establishing a hydroponic project in Qatar is high [37]. Most of the equipment, technologies and seeds are imported from abroad, which increases production costs. Hence, there is a need to direct financial support from the state to bear part of the high production costs to promote hydroponic agriculture in Qatar. It is also necessary to exempt agricultural inputs used in hydroponic agriculture operations from customs duties. "Although customs duties on hydroponic imports are low, they still constitute an economic burden on the Qatari farmer." Hence, state support for farmers will contribute to reducing production costs and thus contribute to achieving financial profit for the investor, encouraging him to continue hydroponic agriculture projects. Government support for these projects will also contribute to maximizing the benefit to the consumer in the form of lower prices because of lower production costs.

4.5. Towards a sustainable hydroponic agriculture in Qatar

The analysis of the interviews materials has indicated that in response to the aforementioned challenges, the Qatari Government have taken serval measures and devised deferent policy tools including:

4.5.1. Distinguished agricultural product program

The Ministry of Municipality and Environment offers a program to support Qatari farmers by providing outlets in shopping malls to market their products in the Qatari market. The Distinguished Product Program aims to market premium Qatari vegetables with the aim of supporting production in local farms and facilitating its marketing. The first phase of the program began by marketing Qatari farm products in Al Meera markets. The second phase of the project was launched after the blockade in Carrefour and Lulu markets. The program provides the advantage of the product entering the markets for free without paying fees, provided that the quality of the products is available in terms of their freedom from infections, their type, their packaging level and safety, in addition to their freedom from chemicals. The number of participating farms reached more than 60 farms. Their price is 30%–40% lower than their imported counterparts.

The Ministry of Economy and Commerce provides support for distinguished Qatari products in terms of pricing. In this context, the Ministry has allowed the display and sale of luxury products above the agreed price through the Distinguished Product Program. Through this initiative, the Ministry aims to support Qatari farmers and encourage them to produce by making their products economically viable to cover the costs of their distinguished production, which relies on high-cost methods and techniques such as hydroponics. The Ministry of Municipality and Environment provides a discount on the prices of seeds, fertilizers and equipment of up to 50% to 75%. Agricultural Loans Project in cooperation with Qatar Development Bank: An agreement was concluded between Qatar Development Bank and the Ministry of

Environment for the bank to finance agricultural activities of all kinds (plant-animal-fish) at an interest rate of only 1% over 8 years. In this context, soft agricultural loans were provided for projects with a capital of less than one million riyals without a feasibility study. If the amount exceeds one million riyals, the project owner must submit a feasibility study for his project in order for the loan to be approved. Currently, several initiatives worth almost a quarter of a billion riyals are being studied to boost the production of agricultural and animal feeds. Requests for funding agricultural projects have also increased, particularly during the 2017 blockade that Qatar experienced. This is an indication of the increasing demand for agricultural projects by investors and the increased awareness of the importance of the agricultural sector in meeting the needs of the local market with Qatari hands.

4.5.2. Agricultural yards

Marketing is considered an important process for any economic activity, especially hydroponic products. From this standpoint, the idea of establishing yards for selling local vegetables emerged from the Ministry of Municipality and Environment. The first yards were opened in 2012, while Al Khor and Al Thakhira yards were opened in 2013, and finally the third yards were opened in 2014. The number of farms participating in the yards reached 88. The agricultural yards are characterized by allowing Qatari farmers to display their products for free, in addition to the quality of the displayed products, which have the same sorting degree, and the presence of periodic and continuous monitoring. During this season, (4785) tons of fresh Qatari vegetables were marketed, and the Ministry of Environment opened yards for farmers to help farmers market their local production directly without intermediaries, which increases the financial return for the farmer. This measure encourages increased agricultural investment in addition to improving the marketing method, which reduces marketing losses from 20% to only 3%. A fixed bracket to support water and electricity for productive farms: Reducing the electricity bracket directed to farmers in Qatar to 0.09 dirhams/kilowatt.

5. Conclusion and policy recommendations

The demand for hydroponics in Qatar is rising due to a number of causes. Given Qatar's harsh climate, hydroponics is a cutting-edge and environmentally friendly farming technique that enables year-round growing. Hydroponics is an effective method for growing crops, including fruits and vegetables, on a small amount of arable land and water. In addition, the Qatari government's encouragement of local food production and food security has resulted in incentives and investments in hydroponic farming. The market for hydroponics has also been supported by growing public awareness of the advantages of locally grown products and the necessity of lowering food imports. The Qatar Hydroponics Market is expected to flourish as the movement towards sustainable food production and urban agriculture gains momentum.

The results achieved so far are very encouraging, especially in the production of vegetables and fruits. Hydroponics has faced the most prominent challenges that hinder the progress of the agricultural sector in the country, such as scarce water resources, low water quality, infertile soil, harsh climatic conditions, poor water management, and limited arable land. So far, despite some farms turning to hydroponic

technology, self-sufficiency in vegetables and fruits has not been achieved due to several factors, the most important of which are:

- Although there are a few hydroponic farms in Qatar, their numbers are insufficient to meet the size of the market in the country, necessitating the expansion of this agricultural practice in the near future.
- As one of the promising production techniques to attain self-sufficiency in the State of Qatar in fruit and vegetable categories, hydroponic agriculture has not yet been formally adopted or expanded in the State of Qatar.
- There is currently no regulation or legislation protecting local products from dumping and unfair competition. Due to the open nature of the Qatari market, the local product confronts unfair competition from imported goods and dumping in local marketplaces, making competition with the imported product the main obstacle. One of the main causes of Qatari investors' hesitancy to participate in the agricultural sector is the absence of legislation protecting local products from dumping. This makes the problem economically unfeasible and unsecured and discourages investment or continuation in the sector.
- Converting farms to hydroponics is a costly matter and requires financial support from the state in terms of production inputs to support farmers, reduce the burden of costs on them, and encourage them to increase production, in addition to technical and supervisory support for the project's progress and continuous monitoring.

6. Recommendations

Based on the key findings of the study, the following policy recommendations can be suggested:

- Because of its small area, the small percentage of arable land in its total area, the fluctuating prices of imported food products, and its ongoing population growth, the State of Qatar must prevent fluctuations in food security. This calls for improved water management, the development of agricultural policies, the regulation of institutional and legislative aspects, the application of improved agricultural technologies, and support for its agricultural investments overseas.
- Since Qatar is one of the nation's experiencing water scarcity, attention should be directed on growing aquaculture in the country as a means of addressing the limited water supplies and their ongoing depletion.
- Farm owners agree that the initial cost is high, but they also agree that the economic return is high. As a result, the state should provide more financial support for production inputs to lower costs, encourage farmers to increase productivity, and provide the market with as much production as possible. Additionally, financial support should be directed towards attracting modern and advanced technologies that can withstand high humidity and heat, particularly during the summer, as this will help to ensure that the local market is continuously supplied with national products.
- The project's progress requires technical and supervisory support in addition to financial support, and it must be continuously monitored for success, productivity, and water usage. Despite the low costs, the necessity to exempt farm

owners from customs charges places a financial strain on Qatari farmers. Expanding the foundation of partnership between the public and private sectors is necessary because the next stage requires a crucial role from the private sector, especially with regard to the speed of implementation and completion of projects with high and distinguished speed and efficiency. Additionally, the public sector must give the private sector more attention so that it can play its true role. Providing this appropriate environment for partnership between the public and private sectors contributes in turn to the growth of the national economy, in addition to achieving commercial results, profits and distinctive services. The private sector must be given appropriate investment opportunities so that it can play a successful, effective and distinctive role.

- Since hydroponics is the way of the future for the State of Qatar because it does not require large areas or a lot of water and produces a lot, it is advised that the matter be handled at the legislative and regulatory level with mechanisms, a strategy, and complete coordination between the various parties. Since there is now no regulation governing and assisting agricultural activities, new and legally binding procedures must be established, beginning with the creation of legislation governing hydroponics and agriculture in general. Legislation must be in place to safeguard domestic goods from unfair competition and dumping by foreign goods. The requirement that local products be prioritised when it comes to being displayed on consumer complex shelves. Because the problem will be profitable for farm owners, protection and support will boost production. Farmers will also think about expanding and diversifying their production in the upcoming years since their products have found a market and are making money to spend on their farms. Consequently, the State of Qatar will become self-sufficient and its food security would be improved.
- In order to progress the agricultural sector, boost productivity, and improve food security in the nation, it is imperative to support scientific research pertaining to the growth of the agricultural sector in the State of Qatar in particular and to work towards promoting technologies that benefit the State of Qatar's environment and climate. This will only be accomplished by offering financial assistance and directing investments towards the establishment of specialisations, paying attention to agricultural education, selecting its curricula, and taking the needs of the Qatari environment into consideration. Forming a civil agricultural association of agricultural labourers and farm owners.
- Promoting a culture of production and independence in society by using the hydroponic system on building roofs and in homes, particularly during the winter, as its efficiency and productivity rise. This leads to increased productivity and the attainment of self-sufficiency in certain fruit and vegetable crops at the family, regional or institutional level.

Conflict of interest: The author declares no conflict of interest.

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