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The Lack of Arable Land in Qatar

Abstract

This technical report discusses the issue of the lack of fertile land in Qatar due to its low-lying and flat desert climate, which is too harsh for sustainable, large-scale agriculture. Considering that the country heavily relies on external imports to feed the population, this problem threatens Qatar's current and future food security. Three approaches were suggested to address this conundrum: hydroponics, eco-friendly desalination, and sandponics. A decision matrix was constructed based on criteria generated from research conducted on stakeholder needs and design constraints: cost, design accessibility, and environmental sustainability, which determined sandponics to be the optimal solution to be feasibly implemented in Qatar.

Introduction

Qatar is a country with an area of 11,627 square kilometers. However, only 1.83% of its land is fertile (Trading Economics, 2023) due to the desert climate, salty bodies of water, recent urbanization, and more. The State of Qatar's ability to sustain its growing population comes from food imports, which although is an approach that worked well thus far, is fragile due to its dependence on politics and international relations. There is a need for agricultural self-sufficiency in Qatar, as was proven by the blockade the country faced in 2017, where Saudi Arabia, the United Arab Emirates (UAE), Bahrain, and Egypt established a trade embargo on Qatar. The blockade has created a market gap and economic drop. Qatar had relied heavily on imports from neighboring countries, mainly Saudi Arabia, to supplement its population's food requirements. The cost of imports from other nations, factored into the budget increase for local agricultural food production, cost the government and people a loss of 43 billion dollars (Ibrahim, 2020), expanding the problem to a social, economic, and environmental one. To put the issue into perspective, prior to the blockade, Qatar used to receive 400 tons of dairy products daily from Saudi Arabia.

As such, the importance placed on local efforts to develop Qatar's agricultural sector grew exponentially, with huge investment projects and innovative technologies requiring substantial funding. For example, after the blockade, Qatar imported thousands of cows from Europe and the United States for $8 million to develop its now biggest local farm, Baladna (Bloomberg, 2017). The Qatar National Vision, a development plan outlined for the country's growth, aims to achieve self-sufficiency in vegetation by 2030 (Qatar National Vision 2030 - Government Communications Office, n.d.), highlighting how critical local food production is.

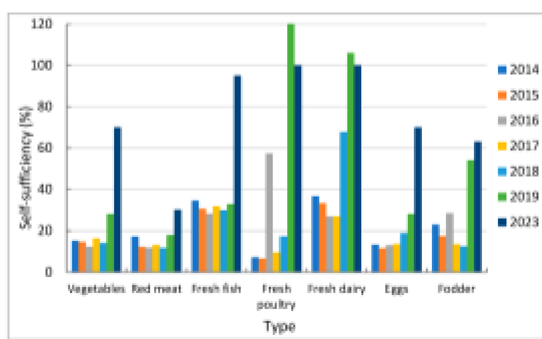

Fig.1 Qatar's self-sufficiency regarding different food products from 2014 to 2019, compared to its 2023 goal (Karanisa et al., 2021)

Nowadays, new farms such as Baladna and Agrico have managed to flourish and thrive, replacing obsolete brands such as Almarai and Nada. The Agrico Agriculture Company provides fresh vegetables, fruits, and sea products to 1400 supermarkets and restaurants through a combination of traditional greenhouse farming and new hydroponic greenhouses (Agrico, 2022). Agrico plans to expand to another 100 hectares of farmlands by

2024 and produce around 3000 tons of vegetables and fruits annually (Dizon, 2020). Nasser Al-Khalaf, the managing director of Agrico, has stated that Qatar has made great strides since 2017, boosting local production of fruits and vegetables from 10% to 30% and setting goals to achieve self-sufficiency by 2023 (Fig.1). However, Qatar still needs to expand and diversify local production for more food, agriculture, and transportation independence, as only 25% of vegetables and crops are obtained from local farms (Qatar's Agriculture Sector – USQBC Portal, n.d.), in order to achieve the dream of complete self-sufficiency. To address the lack of arable land and its impact on Qatar, the team aims to develop engineering solutions that work on transforming the barren landmass into fertile agricultural land.

Methodology

1 - Investigating the Context and Determining the Problem

To identify a current issue in Qatar, our team reviewed the Qatar National Vision of 2030, which is based on four development pillars: economic, social, environmental, and human. We narrowed down our interest to environmental sustainability, which aims to manage environmental resources to ensure the healthy and organic growth of the country. We brainstormed multiple problems, eventually refining them to three, and then constructed a decision matrix based on concerns found within the Qatar National Vision. The decision matrix yielded the lack of arable land as the most compelling issue to address, mainly due to its long-standing status and large impact.

Qatar is a rapidly growing population with an increasing demand for food. As a result, Qatar heavily relies on food imports to meet its domestic demand, with 90% of its food being imported (Hassen, 2020). The main stakeholders identified were companies, industries, and consumers. Farmers struggle to find suitable land for cultivation, limiting their ability to grow crops and contribute to agricultural self-sufficiency. Companies and industries face a shortage of local produce, forcing them to import or settle for lower-quality products. Consumers have a narrower range of fruits, vegetables, and other food products in the market, and prices are higher due to the limited diversity of crops and the need for importing.

2 - Conducting Research and Finding the Possible Approaches

Our next goal was to find possible solutions. Our starting point was to examine the previous and current approaches Qatar has taken to address this issue, in addition to other countries (whether neighboring or otherwise) which struggle from similarly harsh climate conditions. For this part, we relied on secondary research in the form of credible scholarly articles to understand Qatar's environment and assess the efficiency of certain technologies, such as the depletion of aquifers or use of hydroponics. We also referenced press releases by companies and the industry to ascertain their current and future goals and projects, and Qatar's self-published databases for statistics on food imports and agricultural production. The same research methodology carried over when investigating potential solutions that might sufficiently tackle the problem, of which we narrowed down into three approaches.

3 - Constructing the Decision Matrix and Identifying the Optimal Solution

To settle on a final, optimal solution, our team was tasked with constructing a comprehensive decision matrix. Due to our identification of the main stakeholders involved and where their interests lie in the matter, found to be farmers, the industries, and food consumers, we were able to generate our user needs and design constraints in terms of the engineering solution.

The user needs include fertile land to make farming possible, an abundant water source to keep crops quenched, a shelter for crops against the harsh weather, the diversity of crops for consumer nutrition. On the other hand, the design constraints comprise soil quality, affordability, environmental friendliness, and access to water, which is a scarce resource in Qatar.

Our team selected three criterions, summarized in Table 1 along with the focus of each, adequately covering the user needs and design constraints while aligning with principles of sustainable development found in the Qatar National Vision. The cost considers the economic aspect, placing heavy emphasis on not only reducing the cost of imports on the nation as a whole, but also the cost that the solution places on farms, making it affordable enough to sustain in the long run. Design accessibility considers the social aspect, where the solution needs to be simple enough to suit agricultural producers of all sizes, and perhaps even expand to encourage every member of society to participate in growing their own food. Environmental sustainability covers the environmental aspect, where the solution needs to aid Qatar in achieving its goal of food security while maintaining the environment and its resources. We rated each solution independently according to the criteria, then took an average of our scores to determine the final solution, found to be sandponics.

Table 1 *- The criteria to determine the most effective solution.*

Criterion	**Focus**
Cost	Start-up, running, and maintenance costs
Design Accessibility	Scalability of design and availability of materials
Environmental Sustainability	Short-term and long-term impact on the environment

Results

Hydrogel Technology

Hydrogel technology introduces enhanced soil for greenhouse agriculture that can tolerate harsh climate conditions. Although typical compost soil is rich with plant nutrients like potassium, it does not preserve enough water when used in a dry climate. However, the structure of hydrogel, as a polymer, can be used on compost soil to maintain its hydrated state for a longer time and only gradually discharge water, minimizing the loss of water through evaporation and percolation. This results in the ability to grow a larger, more consistent yield of crops with lower amounts of water. Research conducted at Qatar University studied the effectiveness of hydrogel-infused soil, demonstrating a 20% increase in agricultural production using 35% less water for hydrogel-infused soil as compared to untreated soil (Al-Hawari, 2022). Hydrogel agriculture is still in the process of being developed to eventually be implemented in Qatar by Agrico. The technique has been adapted to cucumber and tomatoes thus far, which are the crops most consumed in Qatar (Agrico, n.d.).

Eco-Friendly Desalination

Qatar is characterized by its arid climate, lacking natural water and rainfall, with the 50% of the water demand currently being fulfilled by seawater desalination (*Water Infrastructure in Qatar - Fanack Water*, 2023). However, this is a chemically and energetically intensive process which produces brine, concentrated saltwater that is toxic to the environment (Khan et. al., 2018). An eco-friendly alternative is membrane desalination, a process which utilizes a hydrophobic membrane that separates hot and water streams. The membrane only allows water vapor to enter, which condenses on the other side, now purified (Charcosset, 2009). Pretreatment is needed to remove undesirable salts in seawater to prevent membrane damage, as is post-treatment. The size of the membrane desalination plant is approximately 70% smaller than a normal desalination plant of equal capacity, and given that its design is not affected corrosively by seawater, it requires less maintenance and shutdown operations. Thus, the cost of membrane desalination is less than that of other plants (Zaidi & Rahman, 2018).

Sandponics

Sandponics is an aquaponic-related growing technique for agriculture that uses sand to filter water coming from fish tanks, designed to improve the yield of crops by enabling continuous cropping in a controlled environment. Fish produce ammonia as waste, which is converted to nitrates (essential plant nutrients) by bacteria in the habitat. The water is pumped to a sandbed, where the sand acts as a mechanical filter, biofilter, and medium to grow crops (Periera, 2021). The purified water is then pumped back into the fish tank, to be reused. A sandponics system can be easily sterilized and recycled, and is less expensive compared to soil (Sewilam et al., 2022). The sand has sufficient water retention and a high water absorption power to allow for crop yields comparable to greenhouses (Baba & Ikeguchi, 2015). Nevertheless, the efficiency of sandponics depends on different factors, such as the size and biomass of the fish, along with the amount and nature of the fish food. Also, environmental changes affect the Sandponics system, growth, fish, and plants, like the temperature, type, salinity, and oxygen levels of water (Sewilam et al., 2022).

Analysis

Each of the mentioned solutions can be assessed for the viability of its implementation in Qatar, according to both their inherent characteristics and the generated criteria, the latter of which has been numerically analyzed and tabulated (*Table 2*) after analyzing each approach, all in an effort to determine the most suitable solution to the problem of the lack of arable land in Qatar.

The first proposed solution was the use of hydrogel technology to enhance the water-holding capability of soil, minimizing water loss and keeping plants and vegetation quenched for a much longer time. This reduces the amount of water required for agriculture while contributing towards making agricultural production more efficient and consistent, which addresses the issue with the lack of arable land. Nevertheless, the technology is novel and much of its application has been in laboratories and strictly controlled environments, which does not provide any indications on large-scale use, nor its availability or cost as a commercial product. Moreover, hydrogels are a combination of water and polymers, the latter of which may not necessarily have a sustainable manufacturing process, as many polymers are derived from finite natural resources the world is working towards abandoning, such as petroleum, and their production is typically energy-intensive (El Sayed, 2023). Also, polymers are often non-biodegradable, which calls into question the longevity of hydrogels, and a sustainable course of action for how to discard them after their product life-span has ended (Das, 2011).

On the other hand, eco-friendly desalination addresses one of the largest concerns with the desalination process itself; its high energy consumption. Membrane desalination bypasses the need for a thermal gradient to purify the water, which is where the bulk of energy goes to, as opposed to more traditional desalination techniques, greatly reducing the running costs of the operation. It is also well-established technology in Qatar, with readily available materials and machines (Kayvani Fard et al., 2015), but is difficult to scale down to the extent where it suits small-to-medium sized agricultural producers, despite the actual size of a plant being 70% smaller than typical desalination plants of equal capacity. Furthermore, despite the pre-and-post treatment of water within membrane desalination also being low in their energy consumption, the process does not address a common issue found in all desalination techniques, brine. This greatly diminishes the positive effect of any steps made to make the process more sustainable and eco-friendly.

The last approach to the problem is sandponics, which builds upon current agriculture enhancing techniques used in Qatar, hydroponics and aquaponics, while maintaining an equal production capacity. Sandponics uses low-complexity and low-cost starting materials which can be scaled up, although to the extent of which is unknown, making its large-scale use only a viable possibility. The system is mechanical in its design, requiring only the sporadic use of a water pump to feed the sand bed, and can even revert to complete manual operation, all of which is low in energy consumption. The main challenge of sandponics lies in the agreement of fish and sand, as the former is very sensitive to changes in environmental conditions. The sand must be free of carbonate and clay, and with sufficient percolation ability. While the particle size of sand in Qatar meets the required percolation ability , it must be thoroughly washed and treated to free it of the contaminants (Al-Ansary et al., 2012), a process which many companies in Qatar already do and is thus inexpensive when bought in bulk. Additionally, considering the circularity of sandponics, where the fish provide nutrients for the plants, and excess water is drained from the sandbed into the aquarium with the fish, the design is sustainable in regard to the environment and its longevity.

Table 2 *- Decision matrix determining the optimal solution using the criteria from Table 1*

	Hydrogel Technology	**Eco-Friendly Desalination**	**Sandponics**
Cost	2	3	5
Design Accessibility	2	3	4
Environmental Sustainability	2	2	5
Average	2	2.7	4.7

Discussion of Recommendation

After thorough research and analysis, sandponics has been found to be the optimal solution for the problem of the lack of arable land. Despite a few challenges regarding the set-up of the system, such as the type of fish, quality of sand, and source of water required, most of them can be conquered using resources which are readily available in Qatar. More specifically, goldfish and tilapia, the fish best suited to sandponics, can either be readily available on a smaller scale or bulk-imported (one-time investment) on a larger one. The sand can be obtained from companies such as the Qatar National Cement Company or the Qatar Primary Materials Company. Water can be sourced from treated sewage effluents (TSE's), which are less costly in terms of money and energy than even desalination (Jasim et al., 2016). Any potential obstacle pales in face of the advantages a sandponics system can provide, which includes lower overall costs and energy consumption, the abundance and availability of building materials, the potential scalability of the operation, diversity of crops, and lack of any negative environmental impact or depletion of resources.

One of the keys to Qatar's sustainable development in regard to the environment, economy, and society lies in its ability to maintain its food security despite its lack of fertile land available, but with the potential sandponics holds to transform Qatar's expanses of barren land into fertile ones, our team strongly advocates for the use of sandponics on a large scale as the most effective approach to facilitate this goal.

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