Team 5
ENGL-210
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Problem Statement - Final Draft
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Lack of Arable Land in Qatar

Problem

Considering the continually expanding population and rising need for affordable and readily available nourishment, large-scale, self-sufficient agricultural lands are essential to the State of Qatar. Qatar is a peninsula comprising low-lying, flat deserts that are too saline for flora to flourish and too shallow for agriculture to thrive, which limits agricultural production. Nevertheless, Qatar has sought to develop its agricultural sector through supporting local efforts to carry out investment projects in this sector, enabling Qatar to fulfill its goal set in the Qatar National Vision, which is to achieve self-sufficiency vegetation by the year 2030 (Qatar, n.d.). Despite Qatar's current ability to feed its population through food imports, the importance of self-sufficiency has made itself clear after the blockade that Qatar faced in 2017, where Saudi Arabia, the United Arab Emirates (UAE), Bahrain, and Egypt established a trade embargo on Qatar. Imports rose exponentially, costing both government and people. Before the blockade, only 30% of dairy products and 20% of green fodder were locally sourced. However, as of 2019, the country has increased its self-sufficiency to reach nearly 75% in dairy products, 20% in red meat, 25% in eggs, 55% in green fodder, and more than 100% in fresh poultry. Nevertheless, only 25% of vegetables and agricultural crops are obtained from local farms, indicating progress yet to be made (Qatar's Agriculture Sector – USQBC Portal, n.d.). As such, considering the lack of arable land causing insufficient local food production to sustain the population, our team aims to address the issue by developing engineering solutions than make use of the barren landmass for fertile agricultural land.

Purpose

The purpose of this research is to assess the scarcity of arable land in Qatar to promote the development of agricultural practices that increase sustainable agricultural production and food security, as current agricultural production, on its own, is insufficient to sustain population growth(Qatar's Agriculture Sector – USQBC Portal, n.d.). This will be achieved by looking at the different approaches that both Qatar and other countries have employed. Qatar's food security has been threatened during the blockade, causing the state to establish much more local Qatari forms to work towards food self-sufficiency, despite the climate working against them. The number of greenhouse farms from 2017 to 2018 has increased from 471 to 919 (Qatar's Agriculture Sector – USQBC Portal, n.d.), but the total of active farms cover only 360 square kilometers (Qatar, n.d.). This objective aligns with the Qatar National Vision's need for agricultural growth, sustainable production, and sustaining the population using local means, in addition to the second goal of the Sustainable Development Goals, which is the elimination of hunger.

Scope

Arable land is valuable, especially in countries with desert climate. In addition to dry, barren land, Qatar is also surrounded by seawater that is too salty to accommodate vegetation. The fluctuation of climatic factors and lack of rain only further the issue, as does the decline in the proportion of workers in agriculture and the need for more turnout in this field (Environment and Agriculture, n.d.). The social and economic impact of unstable food production and high imports have been demonstrated by imported food being more expensive than the locally sourced, affecting those with low incomes, and the sudden imposed costs following the blockade. As for environmental impact, current and future solutions must not negatively impact the environment or deplete its resources, as some previous approaches have done.

Objectives

The objective is to create and present an effective, professional technical report that clarifies the problem and offers adequate, sustainable solutions, achieved by:

- Developing a comprehensive understanding of the problem of lack of arable land causing insufficient local food production through researching both primary and secondary sources.
- Collecting information about and critically assessing previous and current solutions to determine the ideal approach.
- Understanding users' needs and design constraints to guide solution development.
- Discovering the best possible solution that can be applied in Qatar to ameliorate the problem sustainably and without negative environmental, social, or economic impact.
- Presenting compiled statistics and evidence in a technical report and orally to endorse our problem statement and following recommendations.

Previous and Current Research

Qatar is a country with an area of 11,627 square kilometers, but only 1.83% of its land is fertile (Trading Economics, 2023), due to the desert climate, salty bodies of water, recent urbanization, and more. As such, it has relied heavily on imports from neighboring countries, mainly Saudi Arabia, to supplement its population's food requirements, but the blockade in 2017 has created a market gap and economic drop that highlighted how critical local food production is and the need to develop it further.

Effect of Qatar's Blockade on its Self-Sufficiency

On June 5, 2017, an air, land and sea blockade was imposed on Qatar by Saudi Arabia, the United Arab Emirates (UAE), Bahrain and Egypt on the basis that Qatar supported terrorism, maintained relations with Iran, and criticized the United States foreign policy (Al Jazeera, 2020).

Prior to blockade, Qatar was an independent country with a strong economy due to its exporting of natural gas, and combined with its smaller population, this allowed it to become one of the world's richest countries. Nevertheless, in regard to food, local production was severely lacking and 90% of food was imported (Al Jazeera, 2020), which was supported by the economy.

This all changed during the blockade, as the border with Saudi Arabia was closed, as were the shipping lanes between Dubai and Doha. Merchants were unable to get food and goods through trading, and thus unable to provide food for the population. The termination of imports from Saudi Arabia, the UAE, and Bahrain have led Qatar to establish new trade lines with Turkey and Iran, which didn't come cheap. It had also simultaneously invested in local agricultural projects to promote self-sufficiency following the event, with public-private partnerships between the government and local farms and companies amounting to $20 billion dollars, encouraging them to produce vegetables and dairy (Oxford Business Group, 2022).

Qatar used to receive 400 tons of dairy products daily from Saudi Arabia. To make up for the loss, Qatar imported thousands of cows from Europe and the United States for $8 million (Bloomberg, 2017) to develop its now biggest local farm, Baladna. Baladna then expanded its repertoire of products beyond dairy to provide fresh fruits and vegetables, to an extent. Local efforts have been able to stock supermarket shelves all across the country with rice and oil (Ibrahim, 2020), but more was required in regard to vegetation.

Another notable farm has been Agrico Agriculture Company, located 58 kilometers away from Doha and covering an area of 120 hectares, taking advantage of the large, empty landscapes in Qatar. It delivers fresh vegetables, fruits and sea products to 1400 supermarkets and restaurants, which it provides all year through a combination of traditional greenhouse farming and new hydroponic greenhouses (Agrico, 2022), the latter of which helps conserve natural resources. Agrico is planning to expand to another 100 hectares of farmlands by 2024 (Dizon, 2020). Today, 90% of organic agricultural products found in supermarkets are supplied by Agrico. It produces around 3000 tons of vegetable and fruits per year, in addition to helping the development

of other local farms (Dizon, 2020). It has also advanced so far as to create a hydroponics farm in Oman under its operation (Aguilar, 2021).

Nasser Al-Khalaf, the managing director of the Agrico Agriculture Company, has stated that Qatar has a major role transformation post blockade because of modern technology. Qatar has made great strides since 2017, boosting the local production of fruits and vegetables from 10% to 30%, ranking 13th worldwide in the global food security index, and setting goals to achieve certain self-sufficiency according to the product by 2023 (Fig.1). Nevertheless, these developments have resulted from a loss of $43 billion dollars incurred during the blockade (Ibrahim, 2020), leading Qatar to expand and diversify local production for more food, agriculture, and transportation independence, by running a fiscal surplus and reinvesting in technological developments to support its goals (Kagan, 2020).

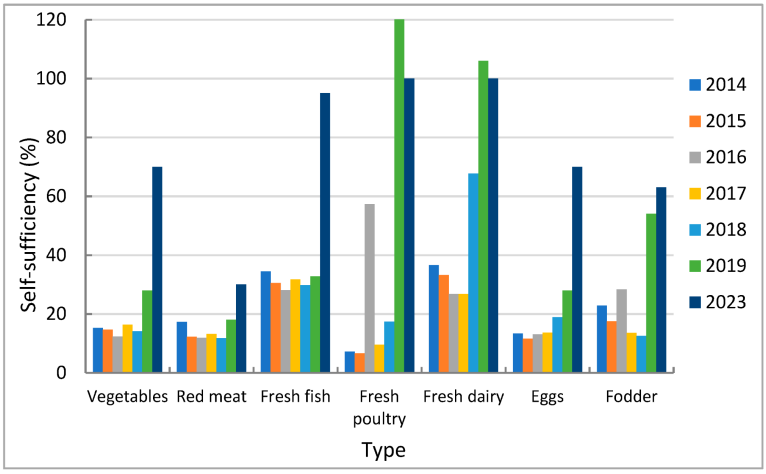

Fig.1 *Qatar's self-sufficiency regarding different food products from 2014 to 2019, compared to its 2023 goal (Karanisa et al., 2021)*

Comparison between Saudi Arabia and Qatar

In the 1980's, the Saudi government directed the economy to focus on the cultivation of land to become entirely self-sufficient, foodwise (Metz H, 1992). Nevertheless, similarly to Qatar, the majority of land in Saudia Arabia is an arid desert, and less than 2% of it was utilized (Bradbury, 2020). The country has opted to work on lands along the coast, deeming them close to a large water source, but seawater is too salty to support plantlife, poisoning the crops. Treating the water was done through desalination, or removing mineral salts from seawater, with approximately 9 million cubic meters of Saudi Arabia's water being desalinated each day (Salloum & Abdelaziz, 2022). Even though desalination proves to be an abundant and reliable source of water for agriculture, it discharges brine (saturated salty water) into the ocean, which harms marine life and contributes to greenhouse gas emissions (Flanagan, 2020). Brine also affects the chemical and physical properties of the soil, where it can cause it to swell and disperse (Meehan et al., 2017). Moreover, the process' high cost has affected the Saudi economy and energy resources. To address the problem, the government implemented diffusers to disperse the brine, but the pollution was only mitigated by 1% (Woollacott et al., 2022). What little fertile land available after its salinization deteriorated due to shifting sand dunes, and with no rivers or lakes to be found in Saudi Arabia, the only other local source of water is rainfall, which is very rare.

Similarly, Qatar faces the issues associated with a lack of fertile land and water scarcity. Only 1.64% of land in Qatar is readily available for farming, close to Saudi Arabia's 1.67% (Fig.2). However, Qatar is a smaller country than Saudi Arabia, and it faces short periods of heavy rainfalls followed longer ones by extreme drought. Qatar has turned to its aquifers for its water source, using 69 million cubic meters each year, but relies on desalination for 98% of its potable water (Qatar Foundation, 2021), with its Ras Abu Fontas plant considered one of the largest osmosis plants globally. Nevertheless, it did suffer the environmental hazards associated with desalination, similarly to Saudi Arabia (Qatar

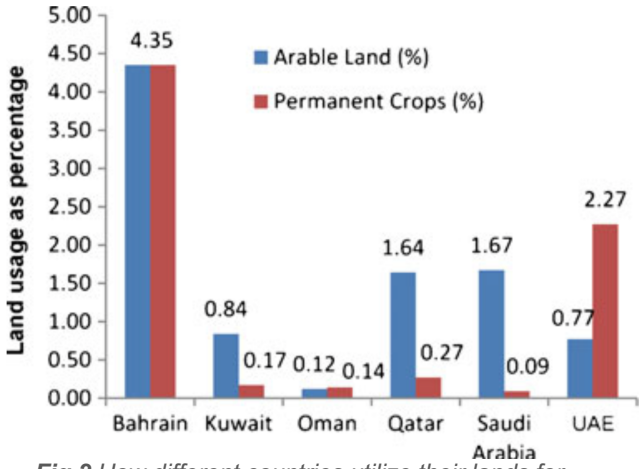

Fig.2 *How different countries utilize their lands for agriculture (Zurayk et al., 2011)*

Agriculture Market Analysis, n.d.). However, the country did not resolve the environmental issues, rather reducing the impact using diffusers (Khan & Al-Ghouti, 2021).

Previous and Current Solutions

Solutions to ameliorate the loss of arable land seem to center around two main foci; the protection and maintenance of land currently being purposed for agriculture, and the development of new strategies and technologies to make full use of any and all available resources. Historically, the former approach was preferred due to its accessibility, with previous solutions including but not limited to:

1. **Importing Food**

Due to the limited agricultural production of food in Qatar, the nation is heavily reliant on other countries for food, with approximately 90% of its food being imported (Miniaoui et al., 2018). Depending on the availability and quality of products, common partners the United States, India, and Turkey, and even neighbouring GCC countries, prior to 2017 (*Qatar Food Products Imports by Country 2020 | WITS Data*, 2020). Nevertheless, Qatar has been working towards food security and self-sufficiency, as events such as the blockade in 2017 have demonstrated how fragile the balance can be (*Qatar – Opportunities in Food/Farming Sector*, n.d.).

2. **Greenhouse Farming**

Greenhouses offer farmers more control over the environment where produce is grown, allowing crops to be grown year-round and regardless of weather conditions or climate. In 2020, Qatar's Ministry of Municipality and Environment announced plans to establish a greenhouse complex with advanced climate control systems and irrigation technology ("QU TO DEVELOP QATAR'S FIRST SOLAR AGRICULTURE GREENHOUSE IN COLLABORATION WITH DEPARTMENT OF AGRICULTURAL RESEARCH AT MME," 2020). While the funds to construct the project are available, the energy and water consumption costs are too high, contributing to greenhouse gas emissions and further depletion of limited freshwater resources. Moreover, larger conglomerates and corporations with more advanced technology can exploit their size and overshadow smaller-scale farms, monopolizing the market and weakening the economy instead of diversifying it.

3. **Remote Agricultural Projects**

Some countries which suffer the same lack of arable land that Qatar does have opted to invest in buying farmland in other countries with larger expanses of fertile land, such as South Korea investing in Cambodia, Singapore in Australia in the past (Evershed, 2015), and the United Arab Emirates in Sudan and Ethiopia (Bakr, 2010). Qatar itself has more recently followed the same trend, with the 'Qatar Livestock Company' establishing itself along the Nile River in Sudan in 2012, and the 'Qatar Turkey Agricultural Investment Company' being set up in 2018 in multiple provinces in Turkey. Investing in farmland differs from food import due to the country owning the land itself, giving it greater control over the supply and distribution and long-term food security. However, issues with unsustainable farming practices and exporting methods arise, in addition to their added cost.

Nevertheless, the growing global population and their need for sustenance have emphasized the significance of approaches which allow for agricultural self-development and food security, which currently comprise of initiatives such as:

4. **Aquifer Alternatives - Irrigation Technology**

In the past, Qatar used to rely on its limited amount of aquifers as a source of fresh water for the irrigation of growing crops, but has since over-extracted the available groundwater; depleted most of that resource and contaminating it with seawater (*World Water Day: Qatar's Groundwater Challenges*, 2022). As such, Qatar has been investing in more efficient irrigation technology that consumes much less water (Pérez, 2022), this includes subsurface layouts that deliver the water directly to each plant, such as drip or bubbler irrigation, and sensors and drones to monitor soil moisture and crop health, delivering the exact amount of water required, allowing for dry land to be nurtured into fertile farmland sustainably.

5. **Aquifer Alternatives - Desalination**

Another approach Qatar has taken follows the footsteps of Saudi Arabia, which is the desalination of seawater. Besides the Ras Abo Fontas desalination plant, Qatar is planning on expanding its reservoirs from 15 to 40, in order to hold a reserve supply up to 4 billion gallons of water (Qatar Foundation, 2021). This is based on the novel desalination technique known as multi-effect desalination (MED), which although has its advantages in terms of reliability, low maintenance costs, and low energy consumption, cannot be scaled down without extreme complexity or operate at high temperatures (Warsinger et al., 2015). Nevertheless, desalination is able it provide an abundant water supply needed to quench the dry land just enough to support agriculture, in addition to greenhouses

6. **Hydroponics**

More recently, Qatar has shifted its focus to hydroponics and similar technologies, as outlined in the 'Qatar National Agricultural Strategy 2018 -2022'. Hydroponics is the practice of growing crops in soilless environments, where the brunt of the work of delivering nutrients to produce falls on the water, supplemented by efficient irrigation systems. While promising, with both governmental and private entities investing in and establishing currently operating hydroponic farms (Perumal, 2023), it comes at the expense of accessibility and cost, with the technology being expensive to set up with a high energy consumptions rate. Nevertheless, other countries that have implemented hydroponics earlier are benefitting from increased production. For example, the world's biggest hydroponic farm in Dubai produces over one million kilograms of leafy greens annually ("Sheikh Mohammed Tours Dubai's Largest $40 Million Vertical Hydroponic Farm," 2022). While there are around 10 hydroponic farms in Qatar, most are still in their early production stages and much is yet to be seen.

User Needs

The lack of arable land has affected most, if not all, people residing in Qatar. In order to guide the solution finding process, we first identified the different levels at which stakeholders are affected by the problem and how they are being impacted:

- **Primary**: farmers are affected by the lack of arable land due to the challenge that lies in finding suitable land for cultivation, which limits their ability to grow crops and meet the demand for locally grown produce (Osabuomen J. I**,** 2011). Moreover, technologies which mitigate the problem are usually expensive and inaccessible to local farms, discouraging and preventing them from contributing to the goal of agricultural self-sufficiency.
- **Secondary**: companies and industries are affected because limited arable land leads to a shortage of local produce, forcing them to resort to importing, which is expensive, or local products of lower quality, at the expense of abiding by quality and health standards. Moreover, monopolies may arise due to technology facilitating architecture, causing both the market and economy to become more fragile.
- **Tertiary**: consumers of produce, which comprise of everyone living in Qatar, find themselves affected by the narrower range of fruits, vegetables, and other food products in the market for customers to buy, caused by the limited diversity of crops due to a lack of fertile land. Also, considering most vegetation in Qatar is imported, this leads to higher prices that can place a strain on households over a while, even if financially comfortable, and more so in the case of those with low-income, which are a sizeable portion of the population considering 60% of Qatar's population are migrant workers employed in low-income occupations (Fargues et al., 2019).

As such, user needs according to previous and current research and solutions can be generalized to be:

- **Arable Land:** farms in Qatar require fertile land to grow produce locally,
- **Abundant Water Source:** agriculture cannot survive without fresh water.
- **Shelter:** plants need to be protected from harsh environmental conditions such as high temperatures and dust storms which could damage (reducing the quality or yield) or kill crops.
- **Diversity of Crops:** both sellers and consumers of vegetables and fruits need to have access to a variety of produce, the former for better diversification and the latter for better nutrition.

- **Sustainable Agriculture Practices:** in consideration of the environmental pillar in the Qatar National Vision, any approaches must be sustainable and not leave harmful impact on the surrounding environment.

Design Constraints

Despite high ambitions and clear requirements, solutions are limited by several design constraints that must be met in order to appeal to stakeholders and environmental, social, and economic principles, the first of which is soil quality in Qatar. Considering that what available soil exists is lacking in quality, farmers need expensive fertilizers for crop growth (Shikha, 2021).

In the case of adopting an approach which does not use soil, such as hydroponic farming or the like, then it must be affordable. Usually, the cost of most large-scale sustainable farming practices is quite high, with examples including investing in renewable energy systems or utilizing advanced technologies for water management. However, these practices can also provide long-term benefits such as improved soil health, increased crop yields, and reduced production costs in the next 3 to 5 years (Tahat, 2020). Developing affordable products or processes is necessary to make them accessible, encouraging more local farmers to grow crops with better yields.

Agriculture cannot survive without water, despite it being a scarce resource in Qatar. The demand for water is already high due to the growing population, rapid urbanization, and expanding industries, which leads to higher water prices (Darwish, 2012) and depletion of its resources. With the limited amount of fresh ground water available, much of Qatar's water supply comes from desalination plants that convert seawater into desalinated seawater (Tahir, 2020) or importing. Nevertheless, the cost of production and maintenance of desalination plants and importing is expensive (Xevgenos, 2014), and neither approach is sustainable due to the former's negative environmental impact and the latter's instability. As such, there is a need for affordable, accessible, sustainable solutions which utilize the very minimum amount of water required for agriculture.

References

Agrico. (2022). Agrico, from http://agrico.qa/

Aguilar, J. (2021, May 18). Qatar vegetable production reaches 60,000 tonnes this year, says agriculturist. Gulf Times. https://www.gulf-times.com/story/691713/Qatar-vegetable-production-reaches-60-000-tonnes-t

AL, H. A. M.; TOK, M. E.; GAGOSHIDZE, T. Rethinking Soft Power in the Post-Blockade Times: The Case of Qatar. DOMES: Digest of Middle East Studies, [s. l.], v. 28, n. 2, p. 329–350, 2019. DOI 10.1111/dome.12188, from https://search-ebscohost-com.srv-proxy1.library.tamu.edu/login.aspx?direct=true&db=asn&AN=139476638&site=ehost-live&scope=site.

Al Jazeera. (2020, June 5). Qatar blockade: Five things to know about the Gulf crisis. GCC News, from https://www.aljazeera.com/news/2020/6/5/qatar-blockade-five-things-to-know-about-the-gulf-c risis

Bakr, A. (2010, November 24). UAE firm focuses on developing farmland abroad. U.S. Retrieved March 16, 2023, from https://www.reuters.com/article/idUKLDE6AN1VB20101124

Bassuk . (2017, September 12). Irma's salt water surge may damage crops, native plants. Media Relations Office. Retrieved March 14, 2023, from https://news.cornell.edu/media-relations/tip-sheets/irmas-salt-water-surge-may-damage-crops-native-plants

Bloomberg. (2016, January). 4000 cows to be flown to Qatar to ensure fresh milk supply. Gulf Times. https://www.gulf-times.com/story/553094/4000-cows-to-be-flown-to-qatar-to-ensure-fresh-milk-supply

Contributor, G. (2022b, June 28). Taking the heat: Can Qatar survive climate change? Geographical. https://geographical.co.uk/climate-change/climate-and-qatar#:~:text=Qatar%20is%20not%20just%20vulnerable,risk%20from%20sea%2Dlevel%20rise.

Darwish. (2012, June 8). *Qatar water challenges*. Taylor and Francis Online. Retrieved March 24, 2023, from https://www.tandfonline.com/doi/abs/10.1080/19443994.2012.693582

Dizon, L. (2020, November 25). Agrico to develop new farmlands. The Peninsula Qatar. https://thepeninsulaqatar.com/article/25/11/2020/Agrico-to-develop-new-farmlands

Environment and Agriculture. (n.d.). https://hukoomi.gov.qa. https://hukoomi.gov.qa/en/topics/environment-and-agriculture

Evershed, N. (2015, February 11). How much of Australia's farmland is owned by foreign companies? The Guardian. http://www.theguardian.com/australia-news/datablog/2015/feb/12/how-much-of-australias-farmland-is-owned-by-foreign-companies

Fargues, Shah, & Brouwer. (2019, January). *Working and living conditions of low-income migrant workers in the hospitality and construction sectors in Qatar : a survey among migrant workers through focus*

group discussions. European University Institute. Retrieved March 25, 2023, from https://cadmus.eui.eu/handle/1814/65987

Flanagan, B. (2020, July 21). Saudi Arabia's giant 'solar dome' desalination plant | WIRED Middle East. WIRED Middle East. https://wired.me/science/environment/desalination-solar-dome-saudi-arabia-neom/

Food and Agricultural organization of the United Nations (2021). The Conservation of Lands in Asia and the Pacific. CLASP. https://www.fao.org/3/v9909e/v9909e00.htm#Contents

Harrington, K. (2016, September 2). How Desalination Created Modern Qatar. AIChE. https://www.aiche.org/chenected/2015/12/how-desalination-created-modern-qatar

Ibrahim, A. (2020, June 5). Beating the blockade: How Qatar prevailed over a siege. GCC News | Al Jazeera. https://www.aljazeera.com/news/2020/6/5/beating-the-blockade-how-qatar-prevailed-over-a-siege

Kagan, J. (2020, November 21). What Is a Budget Surplus? What's the Impact, and Pros & Cons? Investopedia. https://www.investopedia.com/terms/b/budget-surplus.asp#:~:text=Key%20Takeaways,occurs%20when%20spending%20exceeds%20revenues

Karanisa, T., Amato, A. C. M., Richer, R., Majid, S. A., Skelhorn, C., & Sayadi, S. (2021). Agricultural Production in Qatar's Hot Arid Climate. Sustainability, 13(7), 4059. https://doi.org/10.3390/su13074059

Khan, M., & Al-Ghouti, M. A. (2021). DPSIR framework and sustainable approaches of brine management from seawater desalination plants in Qatar. Journal of Cleaner Production, 319, 128485. https://doi.org/10.1016/j.jclepro.2021.128485

Meehan, M., Sedivec, K., DeSutter, T., Augustin, C., & Daigh, A. (2017, July). Environmental Impacts of Brine (Produced Water) — Publications. https://www.ag.ndsu.edu/publications/environment-natural-resources/environmental-impacts-of-brine-produced-water#:~:text=The%20salts%20in%20brine%20alter,toxic%20to%20many%20biological%20species.

Metz, H. (1992). ed Saudi Arabia: A country Study. Washington: GPO for the Library of Congress https://countrystudies.us/saudi-arabia/

Miniaoui, H., Irungu, P., & Kaitibie, S. (2018, May 31). Contemporary issues in Qatar’s food security. Contemporary Issues in Qatar&Rsquo;S Food Security. https://qspace.qu.edu.qa/handle/10576/11481

Natural Disaster Data Book 2021 (An Analytical Overview) - World. (2022b, December 11). ReliefWeb. https://reliefweb.int/report/world/natural-disaster-data-book-2021-analytical-overview#:~:text=In%202021%2C%20the%20total%20of,highest%20amounts%20of%20economic%20losses.

Osabuomen J. I (2011, March 2). Analysis of the effect of arable crop production practices among farmers on environmental degradation. Scholars Research Library . Retrieved March 16, 2023, from

https://www.scholarsresearchlibrary.com/articles/analysis-of-the-effect-of-arable-crop-production-practices-among-farmers-on-environmental-degradation-in-edo-state-niger.pdf

Oxford Business Group. (2022c, November 15). Qatar's economy thrives despite blockade - Qatar 2019 https://oxfordbusinessgroup.com/reports/qatar/2019-report/economy/right-to-be-optimistic-economic-strength-and-potential-have-been-reaffirmed-by-the-short-lived-impact-of-the-blockade

Patel, Shikha (2021, August). Backyard Urban Agriculture in Qatar: Challenges & Recommendations. QSpace Qatar University. Retrieved March 24, 2023, from https://qspace.qu.edu.qa/handle/10576/30946

Pérez. (2022, May 6). Qatar turns to smart irrigation technology - H2O Global News. H2O Global News. Retrieved March 16, 2023, from https://h2oglobalnews.com/qatar-turns-to-smart-irrigation-technology-amid-climate-threat/

Perumal, S. V. (2023, February 27). Qatar a promising candidate for transformation of agritech industry: Invest Qatar. Gulf Times. https://www.gulf-times.com/article/656376/business/qatar-a-promising-candidate-for-transformation-of-agritech-industry-invest-qatar

Qatar Agriculture Market Analysis - Industry Report - Trends, Size & Share. (n.d.-b). https://www.mordorintelligence.com/industry-reports/agriculture-in-qatar-industry#:~:text=Qatar%20meets%20most%20of%20its,to%20adopt%20advanced%20farming%20techniques.

Qatar's Agriculture Sector – USQBC Portal. (n.d.). Qatar's Agriculture Sector – USQBC Portal. https://portal.usqbc.org/qatar-sector/agriculture/

Qatar Food Products Imports by country 2020 | WITS Data. (2020, January 1). Qatar Food Products Imports by Country 2020 | WITS Data. https://wits.worldbank.org/CountryProfile/en/Country/QAT/Year/LTST/TradeFlow/Import/Partner/by-country/Product/16-24_FoodProd

Qatar Foundation. (2021). Qatar's Fight for Future Water Security. Qatar Advertorial. https://www.science.org/do/10.1126/resource.2442131/full/Qatar_advertorial.pdf

Qatar, I. I. (n.d.). Agriculture | Qatar's investment Portal – Invest In Qatar. Agriculture | Qatar's Investment Portal – Invest in Qatar. https://invest.gov.qa/agriculture/

Qatar – Opportunities in Food/Farming Sector. (n.d.). International Trade Administration | Trade.gov. https://www.trade.gov/market-intelligence/qatar-opportunities-foodfarming-sector

QU TO DEVELOP QATAR'S FIRST SOLAR AGRICULTURE GREENHOUSE IN COLLABORATION WITH DEPARTMENT OF AGRICULTURAL RESEARCH AT MME. (2020, September 20). Qatar University. Retrieved March 16, 2023, from https://www.qu.edu.qa/newsroom/Research/QU-to-develop-Qatar's-first-solar-agriculture-greenhouse-in-collaboration-with-Department-of-Agricultural-Research-at-MME

Ritchie, H. (2021, February 9). Forests and Deforestation. Our World in Data. https://ourworldindata.org/deforestation#:~:text=Globally%20we%20deforest%20around%20ten,deforestation%20occurs%20in%20the%20tropics.

Roscoe, A. (2015, February 3). Saudi Arabia plans nine desalination plants by 2020 | MEED.

https://www.meed.com/saudi-arabia-plans-nine-desalination-plants-by-2020/

Salloum, J., & Abdelaziz, D. (2022, September 12). Saudi Arabia produces 20% of global desalinated water, official says. Arab News.
https://www.arabnews.com/node/2160906/business-economy

Sheikh Mohammed tours Dubai's largest $40 million vertical hydroponic farm. (2022, September 13). Arabian Business. Retrieved March 16, 2023, from https://www.arabianbusiness.com/culture-society/sheikh-mohammed-tours-dubais-largest-40-million-vertical-hydroponic-farm

Tahat. (2020, June 15). *Soil Health and Sustainable Agriculture*. MDPI. Retrieved March 25, 2023, from https://www.mdpi.com/2071-1050/12/12/4859

Tahir, F., Baloch, A.A.B., Ali, H. (2020, October 16). Resilience of Desalination Plants for Sustainable Water Supply in Middle East. In: Khaiter, P., Erechtchoukova, M. (eds) Sustainability Perspectives: Science, Policy and Practice. Strategies for Sustainability. Springer, Cham. Retrieved March 24, 2023, from https://doi.org/10.1007/978-3-030-19550-2_15

The Impact of Natural Hazards and Disaster on Agriculture and Food Security and Nutrition. (2015, May). Food and Agricultural Organization of the United Nations. https://www.fao.org/3/i4434e/i4434e.pdf

The Peninsula Newspaper. (2020, November 25). Agrico to develop new farmlands. The Peninsula Qatar. https://thepeninsulaqatar.com/article/25/11/2020/Agrico-to-develop-new-farmlands

Trading Economics. (2023). *Qatar - Arable Land (% Of Land Area) - 2023 Data 2024 Forecast 1961-2020 Historical*. https://tradingeconomics.com/qatar/arable-land-percent-of-land-area-wb-data.html

Warsinger, Mistry, Nayar, Chung, & Lienhard V. (2015, October 30). Entropy Generation of Desalination Powered by Variable Temperature Waste Heat. *MDPI*, *17*(11). https://doi.org/10.3390/e17117530

World Bank Climate Change Knowledge Portal. (n.d.-b). https://climateknowledgeportal.worldbank.org/country/qatar/vulnerability#:~:text=Historically%2C%20only%20about%200.01%25%20of,increased%20rainfall%20unpredictability%20and%20intensity

World Water Day: Qatar's Groundwater Challenges. (2022, March 22). World Water Day: Qatar's Groundwater Challenges. https://www.hbku.edu.qa/en/news/QEERI-SUST-WWDQGC

Woollacott, J., Alsufyani, W. A., Calvin, K., Morrison, L. J., De Hernández, A. B., Rakic, S., Alomran, M., Alsukait, R., Herbst, C. H., & Albalawi, S. (2022b). Effective options for addressing air quality– related environmental public health burdens in Saudi Arabia. Heliyon, 8(9), e10335.
https://doi.org/10.1016/j.heliyon.2022.e10335

Xevgenos. (2014, December 1). *An overview on desalination & sustainability: renewable energy-driven desalination and brine management*. Taylor and Francis Online. Retrieved March 24, 2023, from https://www.tandfonline.com/doi/full/10.1080/19443994.2014.984927?scroll=top&needAccess=true&role=tab

Zurayk, R., Chaaban, J., & Sabra, A. (2011, January 13). Ensuring that potential Gulf farmland investments in developing countries are pro-poor and sustainable. *Food Security*, *3*(S1), 129–137. https://doi.org/10.1007/s12571-010-0107-y