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# Aquaculture and Food Security in the GCC

*Investing in the right technology*

## Table of Context



## Introduction

The Arabian Peninsula's incredible amount of natural resources has made the countries of the Gulf Cooperation Council (GCC)[1] enormously wealthy. Indeed, since the early 1950s, Saudi Arabia, Qatar, Kuwait, the United Arab Emirates and Oman have experienced an incredible influx of oil and gas revenues that significantly contributed to the development of their economies. Today, despite these countries claiming several records – such as Qatar's highest GDP per capital in the world– significant problems exist in terms of food security, water and energy diversification. This is a consequence of the fact that the region ranges between two extremes. On the one hand, it is one of the world's richest areas in terms of energy natural resources. For instance, Saudi Arabia with its 264.5 billions of barrels contains the largest reserves of oil and boasts one of the highest production capacities in the world.[i] Similarly, Qatar has the third largest reserves of natural gas while more broadly; the Arabian Gulf holds approximately 60% of the proven reserves of hydrocarbons.[ii]

On the other hand, the Arabian Peninsula is among one the most arid regions in the world. The majority of its territory is desert with average annual rainfalls of 100 mm. The only exception is on the Saudi Red Sea coast and on the Gulf of Oman eastern shore where rainfall reaches 500 mm per year.[iii] The aridity of this area is combined with a growing demand for water of a constantly growing population. In fact, the GCC has one of the highest growth rates in the world –approximately 3% annually– and leaving standards that demand

[1] The paper will not discuss Bahrain as its economy, demography and geography differ from all the other countries.

always more significant amounts of water. The aridity of the region combined with the lack of water resources make the GCC countries highly dependent on trade for food. In fact, only 1.8% of the GCC land is suitable for agriculture activities. The contribution of agriculture to the GCC's GDP ranges from 0.1% in Qatar to 2% in Saudi Arabia.[iv] Thus, it should not be a surprise that Qatar imports approximately 93% of its food, followed by the UAE with approximately 82% of food imports. Saudi Arabia is less dependent on food imports with a percentage as high as 68%.[v]

In order to bridge the gap between these opposite realities, the GCC can take important steps so as to exploit the revenues from oil and gas in a way that can contribute to enhance food security producing more local food and thus, reducing food imports. This can be done by investing in the right aquaculture technologies. Indeed, aquaculture will respond to the seafood consumption needs of the GCC's society and can as well contribute to diversify and enhance these countries' economies and energy resources.

This paper will discuss the development of aquaculture in the GCC region. It will analyze the current projects in these countries and the prospective of this field in the region. The last part of the paper will propose policy recommendations on which are the best technologies for the countries of the Arabian Gulf and to enhance the development of aquaculture in the region. However, in order to do so, it is firstly important to understand what aquaculture consists off, the various practices of aquaculture and the specific conditions necessary to develop these practices. Thus, the paper will firstly provide a general introduction of aquaculture so as to develop more deeply into aquaculture in the Arabian Gulf.

## Aquaculture

*"Aquaculture is the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms which are exploitable by the public as a common property resources, with or without appropriate licenses, are the harvest of fisheries."*[vi]

Historically, aquaculture has played a significant role in ensuring access to people to cheap protein, particularly in those areas where malnutrition exists. Furthermore, aquaculture employs a significant amount of people which creates higher income and profits than other agricultural activities.[vii] It has been proven that in the rural areas where aquaculture has been implemented, it has enhanced the region's economy and overall standard of living. The benefits of aquaculture come from various aspects of this practice. Most importantly, aquaculture has the advantage of being a flexible activity in the sense that it can be implemented on a large, small scale, in saline environments, and onshore or offshore.[viii] The significant increase in aquaculture production in the past 50 years is a clear demonstration that globally aquaculture is constantly a more welcomed practice. In fact, while in 1970 aquaculture's contribution to the food fish supply was 4%, in 2008 it reached more than 47%.[ix] Aquaculture has grown in the last 40 years at a constant rate of 6.6%.[x]

There are different ways of classifying aquaculture activities. Broadly speaking, aquaculture can be divided into four main categories: extensive aquaculture, semi-intensive aquaculture, highly intensive aquaculture and hyper-intensive aquaculture. The difference

between these four aquaculture practices relies on the degree of human intervention into the production system.[xi] For instance, while in extensive aquaculture feeding activities are completely absent and the fish stocked feed from a natural food chain; in the hyper-intensive fishing farm the availability of natural food is lacking and is replaced by commercial feeds. Based on these four categories it is possible to divide aquaculture into four other production systems: Open Systems, Semi-Closed Systems, Closed Systems and Hybrid Systems. [xii]

The Open System method mainly relies on the natural environment. Generally, for finfish the open method consists of using a cage or a net pen in a natural habitat so as to fence a portion of the water. The way in which a cage aquaculture system works is by placing the desired species cultured, in a constricted area so as to avoid interactions with other animals. The basic needs for the specie to grow are provided by water movements. Indeed, generally cage systems should be installed in areas where there is high water density circulation. Thus, the water body plays a significant role in the success of cage culture. One of the advantages of cage culture is that it can be practiced by both small and large-scale farmers. Thus, it can have positive effects on different socio-economic levels of the economy, and it has a very low initial cost of investment. [xiii]

In semi-closed aquaculture systems there is less of a reliance on the natural environment and a higher human intervention. The natural environment still provides the necessary temperature –thanks to basic ecological services–, the necessary level of oxygen and waste removal. The production units are all man-built and mainly consist of raceways and ponds. Raceways can be described as artificial reservoirs with a proportional water flow to sustain the growth of the fish cultured. Generally, in a raceway aquaculture system, feed is not provided by the water inflow, but by farmers.[xiv]

Ponds are the oldest and most widespread aquaculture system in the world. They are considered to be a technology particularly relevant for arid regions due to the fact that they use less water than other systems. Craig Tucker and John Hargreaves define ponds as

"small, confined bodies of standing water. […] The phrase "of standing water" implies a long hydraulic residence time, which is the key functional attribute of a pond as an aquaculture system. An aquaculture pond can be defined more fully as an aquatic animal culture system where, by virtue of a long hydraulic residence time, suitable water quality for animal production is controlled primarily by natural, physical, chemical and biological processes that occur within the water body."

Some of the advantages of the pond system are, the use of solar energy to regulate the ponds temperature, and the fact that the waste produced by animals is treated in the pond itself. These two elements help significantly reduce production costs. However, differently from other aquaculture systems, ponds have a lower density of the cultured specie.[xv]

In closed systems the natural environment plays an even lesser role to the point where human intervention is needed in every single stage of the aquaculture process. There is clearly a higher responsibility on the aquaculture farmer who becomes in charge of the creation of a natural habitat for the cultured animal. A type of closed system method is the Recirculating Aquaculture Systems (RAS). This type of aquaculture procedure has the advantage of constantly reusing the same water as it is continuously cleaned of the fish's waste and enriched with air or oxygen.[xvi] Water is reused by pumping it through units dedicated to water-treatment. Examples of these units can be bio filters or gas reactors, which are separated from the unit that holds the animal cultured.[xvii] Similar to ponds, the technology used by RAS is extremely suitable for arid regions of the world. It is estimated that RAS uses between 1% to 10% of the amount of water used by other types of aquaculture systems. Moreover, there are no limits in regards to the size of RAS. This is because there is a total

control of the waste streams. And, there are potentially no negative effects on the environment. Thus, RAS is also considered to be an environmentally friendly practice.[xviii] Another of one the advantages of RAS is that they allow for the production of large quantity of fish in a relatively small amount of water. It is important to notice that RAS are a relatively new technology –the first time that it was implemented was in 1990s–, thus there is still a lot that can be done and researched to further improve this system.[xix]

Hybrid aquaculture methods are a way to combine the open, semi-closed and closed systems bringing together the positive aspects of each of this method. For instance, aquaponic are a system that utilizes the closed-system methodology of recirculating water but instead of adding nitrogenous to remove waste it replaces it with saleable plant products. [xx] Incorporating saleable pants within the aquaculture farm allows a 97% reduction of nitrate accumulation compared to common RAS system.[xxi] Thus, the plants used in the aquaponic systems have a purpose of eliminating waste within the aquaculture facility. For instance, compared to the RAS system, the use of plants help to reduce the costs that derive for from biofilters. This reduction in costs can significantly increase the profitability of the recirculating aquaculture system particularly, considering the high initial costs of investment.

For the purpose of this paper, a special attention should be dedicated to the cultivation of algae through aquaculture. Indeed, algae have a special relevance for the Arabian Peninsula as they can be used towards the production of biofuels. Algae can be considered as a way to diversify the GCC's countries energy resources. Generally speaking, in order for algae to grow, the farm should provide carbon dioxide, sunlight and water –at a pH that ranges from 7 to 9. These elements can be provided more efficiently in two ways: ponds and photo bioreactors. The way in which ponds work has been previously described in this paper. In the cultivation of algae the use of solar energy does not only regulate the water temperature but it also provide the necessary sunlight for the photosynthetic process of the plant. Moreover, carbon dioxide is provided by the direct contact of the plant with the air as the ponds system is a semi-closed production system. The advantages of using this method are that production is relatively easier and more cost effective. However, there are some disadvantages that can complicate the cultivation process. Indeed, bad weather conditions can reduce the amount of sunlight received by the algae as well as water contamination with bacteria or other organisms that can negatively affect the cultivation.[xxii]

Compared to ponds, a photo bioreactor system is more complicated and costly to cultivate algae. This method is a closed method where everything needed for growing algae – water, carbon dioxide and sunlight– is provided by the farmer. The process consists in a flow of algae through various units of the system. The first unit is called, feeding vessels from which algae, water, $CO_2$ and other nutrients flows into the second unit, the photo bioreactor. The photo bioreactor has control over all the parameters of the environment created and it provides lights to the algae at various intervals –this is in order to reproduce a photoperiod. Once the flow is completed in the photo bioreactor the algae moves back to the vessel where a cell density sensor assesses whether they are ready to be harvested or not. The algae that are ready for harvesting are collected by the farmer while the others go back to the feeding vessel and restart the process. Clearly, producing algae through a photo bioreactor system produces a strictly controlled environment enhancing productivity and increasing efficiency. Indeed, contamination from bacteria and other organisms is limited and a constant, optimal temperature for growth is provided. However, the costs of producing a photo bioreactor system are particularly high. Moreover, some studies suggested that the higher productivity in a photo bioreactor system compared to ponds is not enough to compensate for the higher costs of production.[xxiii]

To sum up, open and semi-open production systems are cheaper and easier to run than other systems, they significantly rely on the environment and have the advantage of

benefiting both small-scale and large-scale farmers. However, they need a high density of water circulation and the production quantity produced is lower than with closed or hybrid systems.

Closed and hybrid systems are more complex production techniques that require professionally trained workers. Their advantages consist in the significant reduction in the use of water and land, and in the production of high volume of the cultivated specie. Yet, the initial investment and the cost of production are considerably high.

## Aquaculture for Food Security in the Arabian Peninsula

Particularly after the 2011 Arab Spring, the price of food considerably increased in the Middle East. This, combined with the extremely high percentage of food imports and a constantly growing population in the Arabian Gulf – the population is expected to increase by 40% by 2030– led the GCC countries to undertake important steps so as to enhance food security. The significant investment in aquaculture is without a doubt the most important action taken by the GCC countries. In 2014 discussions were held so as to open a fund for financing aquaculture projects in the Arabian Gulf. The same year, $80 million were allocated for the construction of the largest aquaculture facility in the region. These investments and the increasing interest of GCC countries in aquaculture reflects the region's ambitions to both consume more locally produced food and to react to the decreasing number of fish stock. In fact, in the Arabian Gulf pollution and overfishing provoked an 88% reduction in fish availability from 1975 to 2011.[xxiv] Moreover, all of the GCC countries, a part from Oman, consume more seafood than the one naturally available in their waters.[xxv] For instance, the UAE consumes 28.6 Kg of seafood per capita per year– one of the highest amounts in the world.[xxvi] Thus, it makes perfect sense for the Gulf Monarchies to invest in aquaculture as a response to the high demand of seafood in the region. In addition, there are several other benefits for the GCC countries that would derive from the development of fish farming. Indeed, it is important to consider that aquaculture can have a long-term positive effect on the wild stocks as they will suffer less from fishing, allowing them to grow in number as well as the possibility to recycle the water used. This minimizes the impact on the environment. This part of the paper will analyze the current projects occurring in the GCC in order to conclude with policy recommendations on the best aquaculture practices for the Arabian Gulf countries.

## Current Aquaculture Projects in the Gulf

The country in the GCC that has recently put major efforts in developing aquaculture as part of its food security program is Oman. The Omani government has recently encouraged aquaculture as it has recognized the importance of fisheries in the Omani economy. In fact, fisheries accounts for approximately 34% of the Omani agricultural production and seafood consumption in the country is one of the highest in the world –28.7 Kg per year.[xxvii]

In 2004, the Omani government identified the most suitable areas for developing fishing farms. As previously explained, choosing the appropriate area for cultivation is an extremely important aspect of aquaculture particularly for open systems; the geographical location combined with the availability of water resources are key elements for a successful aquaculture field. Moreover, the Omani government has closely worked with (FAO) so as to explore the most relevant strategies for aquaculture development since 2007.[xxviii] The

successful of this work has been evident in the increasing number of small-scale fish farmers in the country who benefited particularly, from the transfer of technology and research in the country. For instance, saline-tolerant tilapia –specie of fish– has significantly attracted the interest of small-scale farmers as well as that of private investors due to the easy of cultivation.[xxix]

Oman's ambitions to enhance aquaculture production managed to attract the interests of several foreign investors. In 2014, a Thai company pledged to invest 70% of a $100 million project to produce 3000 tons of shrimps per year. Similarly, The Lim Shrimp Organization –a Singaporean company– has partnered with local Omani banks so as to develop a $100 million project to produce 4000 tons of shrimps and 1000 tons of sea cucumber.[xxx]

The UAE is another leading GCC country in aquaculture. Aquaculture has started in the UAE with the foundation of the Marine Environment Research Department (MERD) since 1984.[xxxi] However, it began to play a significant role when Asmak was established in 1999. Asmak is a public company that aims at increasing the local farmed fish production through hatchery, research and development, marketing and distribution. Most of the aquaculture infrastructures in the UAE are located in Abu Dhabi. This is because about 66% of the Emirati territorial waters concentrate in that province. In 2013 Abu Dhabi pledged to invest $27 million to build a salmon culture farm with a production capacity of around 4000 tons per year.[xxxii] The same year, Abu Dhabi announced the opening of Emirates Aqua Technologies' Caviar Factory, a 56,000 square meters fish farm –the largest and the most technologically advanced aqua-farm in the world–[xxxiii] mainly dedicated to the production of caviar.[xxxiv] The Emirates Aqua Technologies' Caviar Factory is part of the Emirates AquaTech Park that uses a closed system aquaculture methodology, mainly recirculating systems. In 2014, the fishing farm produced its first sturgeon eggs entirely hatched in the UAE.[xxxv] By the end of 2014, 9 aquaculture farms were established in the United Arab Emirates. It is important to remark that aquaculture has brought positive aspects to the U.A.E. economy among which obtaining food security through the availability of fresh fish is one.[xxxvi]

Despite the efforts made by Oman and the UAE, aquaculture in both these countries is still at an initial stage. The country in the GCC where aquaculture is the most developed is Saudi Arabia. Aquaculture started in the Saudi Kingdom in the early 1980s and by 2011, 30% of the fisheries production in the country was from aquaculture. In 2009, Saudi Arabia invested significantly to expand a hatchery, farms and production facilities in the city of Jeddah. This project aimed at producing 50 tons of prawns a day so as to increase the exports of the National Prawn Company (NPC) owner of the farm. In that year, the NPC exported to more than 30 countries a total amount of 13,000 tones of shrimps a year. With this further expansion the NPC produces a total of 45,000 tones of shrimps per year both for domestic consumption and exports.[xxxvii] NPC's fishing farm does not focus only on shrimp's production. In fact, in 2013 the company managed to produce a biological sea cucumber cycle in harvest conditions and expected to collect approximately 90 tons of sea cucumbers. The production of sea cucumbers is significant not only as it is a product mainly dedicated to international markets –sea cucumbers are not a popular nourishment in Saudi Arabia– but also because of its positive environmental effects. Indeed, sea cucumbers have a purifying effect on the sand as they feed from organic residues present in it.

Moreover, considering that Saudi Arabia, especially the western region near the Red Sea coast has all the necessary favorable environmental requirements for algae to grow, [xxxviii] in 2013, the NPC announced that it will start the production of algae in a partnership with the German chemical producer company BASF. This partnership is signficiant as the production of algae will contribute to enhance food security in the al-Saud Kingdom. In fact, while NPC

has put considerable efforts in researching on algae development, BASF has significant experience and access to technologies for treating algae biomass in products that will be used as beverages or dietary supplements.[xxxix] Furthermore, algae do not only play a role in increasing food security but also in terms of diversifying Saudi Arabia's energy resources. Indeed, with the right technology, Algae's biomass can be used to produce biofuels such as biodiesel, alkanes and alcohols.[xl] This is in clear line with the Saudi Arabia Biorefinery from Algae (SABA) project sponsored by King Abdulaziz City for Science & Technology in 2014 which aims at producing competitive priced biofuels from micro-Algae.[xli] Being a completely innovative area for the Saudi Kingdom the research conducted for this project and the technical assistance is provided by the Portuguese Centre of Marine Science (CCMAR) as well as the Institute of Biotechnology and Bioengineering (IBB).[xlii]

Furthermore, since 2010 Saudi Arabia has been working closely with FAO so as to gain the organization experience and its technical assistance. Formally, the al-Saud Kingdom and FAO signed a $66.7 deal where FAO will provide technical assistance for developing 17 projects in the Saudi Kingdom. The investments in aquaculture in Saudi Arabia have already brought some concrete and important results for the country. In fact, the National Aquaculture Group (NAQUA) –the new name of the NPC– received the Global Good Agricultural Practices (G.A.P) Certification last march. This is extremely important, as NAQUA has become the first company in the MENA region to receive such an important certificate.[xliii]

As previously emphasized, open and semi-open aquaculture technologies need specific sites that have access to freshwater with appropriate soils to be practiced. Saudi Arabia has a clear advantage compared to the other Gulf States both because of its larger size and because of the Red Sea on its Western Coast, naturally conducive for fish farming.[xliv]

## Investing in Aquaculture in the GCC

As this paper strongly emphasized, aquaculture is an important vehicle to obtain food security. However, in order to do so, different aquaculture techniques exist and a successful strategy requires to deeply understand the needs of every different project while investing in the right technology. The Food and Agriculture Organization has established fundamental guidelines that help making the right decision when investing in aquaculture. Firstly, it is important to realize what the ultimate goals are for establishing fish farming. At a country level, this translates into making aquaculture a sustainable and developed industry in the GCC economies and to assess who the ultimate beneficiaries of this field are. Broadly speaking, there is a gap between the private and the public sector on the reasons why an aquaculture project should be established. While the private sector tends to be more concerned about generating high profits, the public sector should be more interested in the overall benefits that aquaculture brings to the economy. On the practical level, this translates into establishing highly complicated production systems that produce significant amounts of seafood for both internal consumption and exports –recirculating aquaculture systems or aquaponic systems– or less technologically advanced aquaculture projects –ponds or cages– that can support the country at different socio-economic levels.[xlv]

Another important element to take into consideration when deciding which aquaculture system to invest in is the availability of technology. Despite being extremely wealthy, Gulf countries still need to partner with foreign companies or organizations in order to transfer the required technology and to acquire the necessary expertize to develop the aquaculture projects.

Environmental damages should be another aspect for the Gulf countries to ponder when deciding the most appropriate aquaculture system. The Gulf States should pay particular attention to this considering the reduction of fish stock in their seas as well as the limited availability of water resources.

In order to assess the priorities of the Gulf countries while deciding in which aquaculture technology to invest, it is important to make a distinction between the GCC countries themselves as different dynamics exist within the different states. Thus, it is beneficial for the purpose of this paper to divide the GCC countries into two groups. One group is constituted by Saudi Arabia and Oman while the second group comprises Qatar, the UAE and Kuwait. Indeed, despite these two groups of countries share the need to diversify from an economy heavily dependent on oil and gas exports and are clearly concerned with enhancing food security, there are other aspects that distinguish them importantly. Saudi Arabia and Oman –that we will call Group 1– have more diverse socio-economic dimensions than Group 2– Qatar, the United Arab Emirates and Kuwait. Saudi Arabia and Oman have different economies compared to that of the other Gulf States. For instance, we can see the relative performance of these two countries to the other GCC countries looking at their GDP per capital. Oman GDP per capital is of $19,309 while Saudi Arabia has a GDP per capital of $24,161. These numbers are considerably lower than the Qatari GDP per capital which is about $97,518.6 or the UAE's one with $44,204.3 and the Kuwaiti one – $48,926.5.[xlvi] Moreover, it is important to point out that a recent report from the International Monetary Fund (IMF) stated that Saudi Arabia and Oman will not be able to maintain financially the current public expenditure for longer then five years. Indeed, their financial assets are estimated to run out if there are no cuts in spending. Finally, Oman's Eastern Coast and Saudi Arabia Red Sea Coast are naturally favorable for open and semi-open aquaculture systems.

Differently, Qatar, the UAE and Kuwait have economies financially more stable that can support substantial public spending for a significant amount of years.[xlvii] The issues that are more pressuring to these three countries regard the scarcity of water resources and the development of their private sector.[xlviii] Indeed, Group 2 countries have a significant problem with their private sector. For instance, Qatar have approximately 1% of their nationals employed in it.[xlix l] Developing the private sector generally, results in capital-intensive projects that generate high returns to their economies. Moreover, in order to develop the private sector these countries have substantially invested in higher education so as to incentive their citizens to apply for more skills-oriented jobs. In fact, the UAE, Qatar and Kuwait together host an incredible number of foreign universities and sponsors actively R&D. For instance, Qatar has eight foreign universities which has actively integrated with the 2004 built Science and Technology Park (S&TP); a hub for scientific research and technological progress.[li]

Then, it is logical that the policies that these two groups pursue or should pursue differ.

## Group 1: Saudi Arabia and Oman

As earlier mentioned, the first action to undertake is establishing priorities. The substantial amount of food imports underlines that enhancing food security through aquaculture must continue to be a main concern for Saudi Arabia and Oman. The fact that Saudi Arabia and Oman have naturally favorable coastal areas for aquaculture –the Saudi Red Sea and Oman Eastern shore– should be a strong incentive for both countries to promote open or semi-closed cultivation systems. These aquaculture technologies will concretely sustain the already existing amount of local fish farmers in the countries enhancing the overall welfare of the economy. The absence of a mature market for cultured seafood makes

subsidize an essential way to encourage locals to participate in aquaculture activities.[lii] The fact that cages and open ponds systems are relatively inexpensive compared to closed or hybrid aquaculture technologies substantially breaks down the costs of subsidizes to both governments. Furthermore, it is important to take into consideration that these techniques require a lower level of expertize than RAS or aquaponic and are easier to learn. Thus, they are more accessible to the Saudi and the Omani nationals.

The use of ponds has also another significant advantage for Saudi Arabia. Indeed, the recent cooperation of the National Aquaculture Group with BASF gives hopes on the future use of algae as a way to produce biofuels as well as dietary supplements. Despite the fact that this technology is still in its initial stages in the country, using ponds to culture algae should still be taken into consideration as a future investment by the Saudi Kingdom. Indeed, ponds allow for the simultaneous cultivation of seafood and algae reducing costs through economy of scope.[2] Moreover, ponds are significantly cheaper than photobioreactors and thus, a lower amount of subsidies is needed to support the development of this technology. Saudi Arabia must support ponds algae aquaculture in light of its energy diversification ambitions. Furthermore, establishing a market for algae will attract the interests of foreign companies and strengthening the development of this technology making it more self-sustaining in the future.

Finally, the fact that Saudi Arabia and Oman have coastal areas favorable to aquaculture significantly reduces the environmental consequences that could derive from the use of open aquaculture systems such as cages or raceways. Instead, developing open and semi-open aquaculture systems will potentially create a shift from fish captured to shift cultured increasing the number of available fish in the Arabian Sea and the Red Sea, thus, helping the natural environment.

## Group 2: Qatar, UAE and Kuwait

Food security is a serious concern for Qatar, the UAE and Kuwait who have extremely high percentage of food imports. Thus, promoting aquaculture systems is a rational and foresight strategy for these countries to enhance the availability of seafood particularly, considering their high seafood consumption.

The small size of these countries combined with the absence of an established small-scale fish-farming sector should bring them to invest in recirculating aquaculture systems. As earlier discussed, these technologies require a substantially lower amount of water and land for cultivation, Group 2 countries' most scarce resources. Establishing RAS facilities could have a potential positive effect when it comes to this. Indeed, RAS facilities require a significant number of trained and skilled workers that can potentially be fulfilled by GCC's nationals. Training Group 2 nationals in the use and establishment of RAS aquaculture technologies can be easily done thanks to their already existing substantial investment in higher education as well as in R&D. The partnership of these countries with foreign universities can further facilitate the learning process. The enhancement of the private sector through aquaculture will also derive as a consequence of the large potential that cultivating seafood can have in these countries. Indeed, RAS have extremely high production capacity and the cultivated specie will not only find a domestic market but an international market as well. For instance, this has been evident in the UAE investments in Aquatech and the fact that the country has become one of the major caviar producers in the world. The potential

[2] "An economic theory stating that the average total cost of production decreases as a result of increasing the number of different goods produced." From Investopedia last accessed December 15, 2015 http://www.investopedia.com/terms/e/economiesofscope.asp

market for aquaculture will substantially contribute to repay for the high initial investment costs and help reduce in the future the currently necessary subsidizes for the industry to develop.

## Conclusion

Aquaculture is an important field of agriculture that allows people to access cheap protein, increase their income and enhance society's standard of living. The various aquaculture technologies make this field extremely flexible and capable of responding to the different needs of different socio-economic levels of the society. The different aquaculture techniques consist in open, semi-closed, closed and hybrid systems. Open and semi-open production systems are cheaper and easier to run than other systems, significantly rely on the environment and have the advantage of benefiting both small-scale and large-scale farmers. However, they need a high density of water circulation and the production quantity produced is lower than with closed or hybrid systems.

Closed and hybrid systems are more complex production techniques that require professionally trained workers. Their advantages consists in the significant reduction in the use of water and land, and in the production of high volume of the cultivated specie. Yet, the initial investment and the cost of production are considerably high.

Choosing the right aquaculture technology is essential in order for this field to be self-sustainable in the long term and concretely contribute to food security. Consequently, the Arabian Peninsula's countries should have in mind their own strengths and weaknesses in order to assess the best investment decision. Saudi Arabia and Oman have been among the countries that have invested the most in aquaculture. Their main aim has been to increase locally produced food, reduce the extremely high percentage of food imports and thus, contribute to food security. As these both countries have naturally favorable coastal areas for the production of aquaculture, they must favor open and semi-closed aquaculture systems. Not only, these technologies are relatively inexpensive compared to closed and hybrids systems but will also benefit low-income fishing farmers and will eventually attract new nationals into the field. Moreover, the cost to the government of subsidizing these technologies will be significantly lower than subsidizing more complicated aquaculture systems; such as the closed systems or the hybrid systems. Conversely, Qatar, Kuwait and the UAE should invest in recirculating aquaculture systems. This is mainly because RAS technology can positively cope with the small size of these countries, the lack of freshwater resources and their willingness to expand their private sector.

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