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The Prospects of Sustainable Desert Agriculture to Improve Food Security in Oman

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Abstract

Food security will continue to be one of the important issues occupying policy makers in the Middle East and Oman in particular. Desert countries such as Oman depend significantly on imported food commodities for food security because the desert environment is harsh in such a way that only very little food can be produced locally. As a result, Oman produces only a fraction of the food it consumes, and most of the food, especially grains and red meat is imported. Land and water scarcity are among the leading constraints to agricultural production such that by 2050, Oman is expected to depend solely on imports to meet food security needs. This paper proposes alternative technologies and approaches that can be employed by Oman under desert agriculture to help improve domestic food production and thus food security in the country.

Keywords: Food security, desert agriculture, hydroponics, land and water saving technologies, biosalinity.

1. Introduction

In 2050, there will be about 9.3 billion people sharing the planet (Sahara Forest Project, 2012), and thus the challenge of producing enough food to feed these people will be enormous. We therefore need to critically think of innovative ways to increase our food production capacity for the future. Food production challenges are and will continue to be daunting especially for desert countries such as Oman. Even though these countries have oil and gas deposits and by extension enough financial resources to import the foods they need, it is a fact that oil and gas deposits will not be there in perpetuity—these resources will be depleted sooner or later. The food crisis of 2008/2009 also taught many countries in the Gulf region a lesson that having the financial means to import food does not necessarily mean that they will to obtain it. This is because during the last food crisis, countries such as India and Pakistan imposed an export embargo for rice. It is therefore important to start thinking of innovative ways to produce whatever food locally as much as possible in order to reduce food import burden (Mbaga, 2013).

Desert agriculture, which is the farming of crops that are well suited for arid conditions such as wild plants that are agronomically adapted to the weather in the area, is one potential solution. Desert farming approaches are principally water and land saving and, as a result, have the potential to promote food production in Oman. Experiences from other countries such as Israel and Egypt shows that it is promising and possible. In Egypt, for example, desert farmland is expected to grow about 40% until 2017 (Reuters, 2007).

The objective of this paper is to explore and present the various possibilities that are available to Oman to engage in desert agriculture (economizing on water and land) so as to increase food production locally and reduce food import dependency. It is important to emphasize and make it clear at this point that desert agriculture is not easy and will not completely address food security, as water is not the only limiting factor, but also land. However, with technology we do not need plenty of naturally occurring underground water and vast tracts of fertile land to produce. Desalinated water and the hydroponics technology could be used to reduce water consumption by 40-60%.

This paper is organized into five sections as follows: Section two looks at the current and future prospects of Oman to expand domestic production without employing desert agriculture. Section three highlights prospective land and water saving technologies that could be employed by Oman for desert agriculture to improve food security. Section four presents a case for Oman to invest in desert aquaculture to improve food security. Section five is the conclusion of this paper.

2. Current and Future Prospect for Oman to Expand Domestic Production without Employing Desert Agriculture

The current and future prospects of Oman to expand domestic production without employing desert agriculture are limited by land and water scarcity. With respect to water availability, which is critical to increasing local production, Oman is among the countries that will face water deficits by 2050, as shown in Figure 1 below.

Figure 1 illustrates in green the number of countries in 2050 that will face freshwater surpluses (> 1,300 cubic meter (m^3) per capita per year in water for food availability over current agricultural land). In orange and red are countries facing freshwater deficits (< 1,300 cubic meter per capita per year). According to FAO (2003), developing countries such as Oman will require an average production of 3,000 kcal/capita/day by 2030. Assuming that 20% of this is animal protein, an estimated 1,300 cubic meter per capita per year of freshwater would be needed (Rockström et al., 2007). As indicated in Figure 1, by 2050 Oman will have between 0 and 500 cubic meters per capita per year of freshwater available, which is a serious water deficit since the amount required is 1,300 cubic meter per capita per year (FAO, 2003).

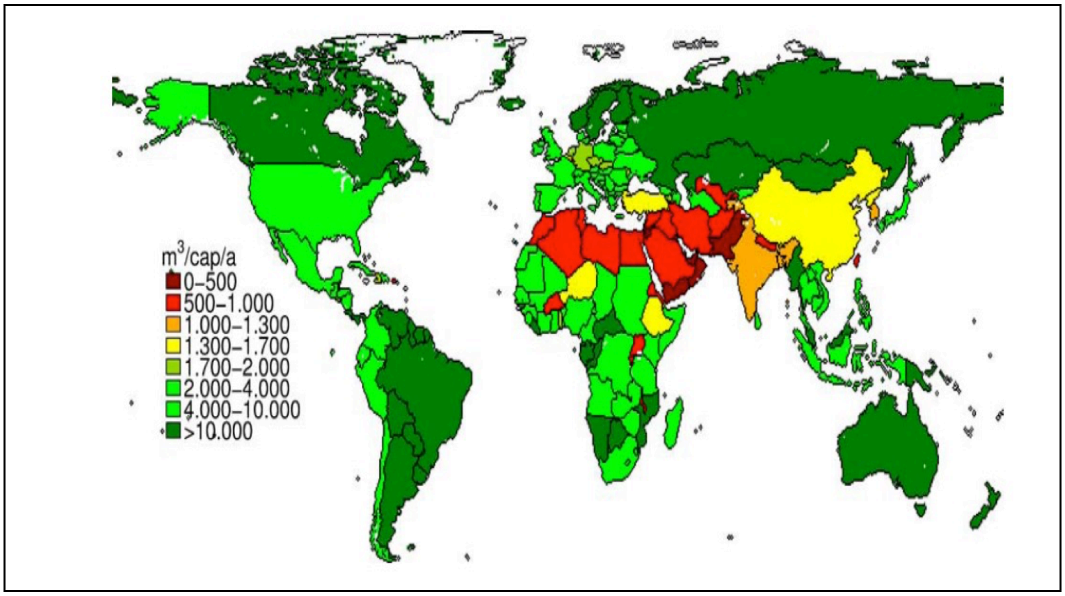

Figure 1: The number of countries in 2050 facing freshwater surpluses and deficits. Source: Falkenmark et al, (2009)

From a water availability perspective therefore, Oman is expected to continue being a food-importing country, as indicated in Figure 2 below, unless innovative strategies are identified and harnessed to increase local production with less water.

Aside from water scarcity, land suitable for agriculture is also scarce in Oman. Arable land in Oman is about 2.2 million hectares (MoA, 2010) which is equivalent to 7% of the total area of Oman (31.4 million hectares). The actual cropped area in the Sultanate was 62,000 hectares or 2.8% of the total arable land[1] and 0.2% of the total area of the country. This indicates that irrigated land in the Sultanate of Oman is below 1%.

In this backdrop, the Oman self-sufficiency ratio for important food groups as of 2008 is presented in Table 1.

Table 1: Oman self-sufficiency ratio for important food groups for 2008

Food groups	**Domestic production**	**Imports**	**Exports**	**Available for consumption**	**Self-sufficiency ratio**
	--------------------------In thousands of tons-----------------------------				
Cereal / grain	4.6	630.6	64.9	570.3	0.8
Vegetables	141.1	163.6	27.6	277.1	50.9
Fruits	327.6	155.0	18.8	463.8	70.6
Red meat	13.0	92.6	2.7	102.9	12.6
Chicken meat	20.9	75.6	9.2	87.3	23.9

[1] Due to irrigation water shortage

Eggs	10.2	13.9	4.5	19.6	52.0
Milk	48.6	112.6	77.2	84.0	57.9

Source: Ministry of Agriculture (MoA), Department of Statistics; Royal Oman Police, Directorate General of Customs

Table 1 show that Oman is less than 1% self-sufficient in grain production. To achieve self-sufficiency from local production, Oman will have to increase local grain production by 99%, which is impossible given that only 2.8% (or 62,000 Ha) of total arable land is cropped. In addition, producing a ton of wheat would require 1,000 tons of water (1,000 cubic meters (m^3)), and a ton of rice would require 3,400 cubic meters (Tony Allan, 2001), which is an amount that Oman does not have. Table 1 also shows that Oman is 12.6% self-sufficient in red meat. To achieve full self-sufficiency from domestic production, Oman needs to increase production by 82%, which is next to impossible given that 16, 000 cubic meters of water are needed to produce a ton of red meat. As highlighted herein in relation to land and water availability in Oman, it is clear that the prospects of Oman achieve self-sufficiency from local production are not good. Land and water availability are the limiting factors. Therefore investing in desert farming seems to be the way forward for Oman. Desert farming or desert agriculture entails among other things the use of a combination of traditional and modern water- and land-saving technologies. Next, this paper attempts to highlight some of these traditional and modern water- and land saving technologies that could be adopted in Oman.

3. Land- and Water-Saving Technologies

For the purpose of this paper, land- and water-saving technologies (both traditional and modern) are those technologies that are geared towards reducing the need for land and water to produce the same amount of food. These are the key technologies that have potential to help Oman increase agricultural output with the same amount of cropped land that, as we saw earlier, currently stands at 0.2% of the total area of the country. These land saving technologies include:

3.1 Promoting Traditional Crops

In order to improve food security, Oman needs to promote traditional crops that are suited to arid conditions. These include traditional crops that have been growing in Oman for many years such as tree crops, including dates and lime, which have both nutritional and export value (FAO, 2008). Oman is also endowed with traditional grain crops like wheat, barley, and chickpea for local consumption.

Dates have been growing in Oman desert oasis for many years and therefore can be said to be very well adapted to arid weather conditions. What is needed is more research to find ways to increase food security and export potential for the benefit of the country (Mbaga et al., 2011). Oman farmers have been growing wheat (locally-adapted varieties) using traditional methods in areas such as the Hajar Mountains in Rustaq for many years. Table 2 and Figure 3 present data on wheat production in Oman between 1961 and 2009.

Table 2: Production Quantity of Wheat in Oman

Year	Amount	Year	Amount	Year	Amount
1961	1,400	**1977**	500	**1993**	1,300
1962	1,400	**1978**	275	**1994**	1,325
1963	1,500	**1979**	150	**1995**	1,350
1964	1,500	**1980**	359	**1996**	1,380
1965	1,500	**1981**	359	**1997**	1,250
1966	1,700	**1982**	1,141	**1998**	770
1967	1,700	**1983**	1,141	**1999**	1,050
1968	1,850	**1984**	1,141	**2000**	1,413
1969	1,850	**1985**	251	**2001**	1,429
1970	2,000	**1986**	289	**2002**	1,421
1971	2,000	**1987**	369	**2003**	1,210
1972	2,000	**1988**	700	**2004**	1,200
1973	3,000	**1989**	900	**2005**	865
1974	3,000	**1990**	1,190	**2006**	775
1975	3,000	**1991**	1,200	**2007**	947
1976	2,000	**1992**	1,250	**2008**	1,070
				2009	1,200

Source: http://data.mongabay.com/commodities/category/1-Pr/1-Crops/15-Wheat/51-Production+Quantity/221-Oman. The table data comes from the FAOSTAT database produced by the Food and Agriculture Organization of the United Nations (FAO). The data is displayed with the express written permission of UN/FAO and was downloaded from FAOSTAT on 07/17/2011.

As indicated in Table 2 and Figure 3, wheat production in Oman reached the highest level ever recorded of 3,000 tonnes between 1973 and 1975. Wheat production has since been going up and down; the most recent data available show that production was around 1,200 tonnes in 2009.

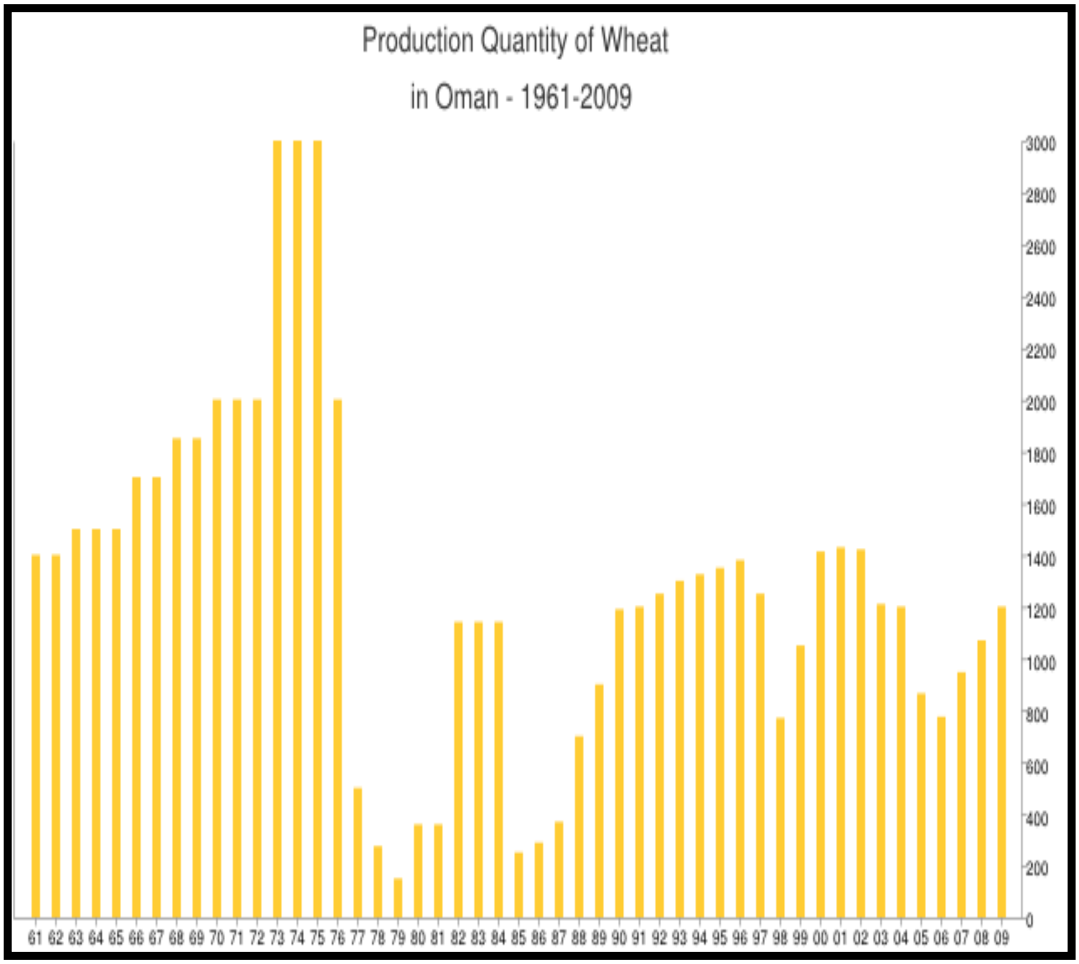

Figure 3: Production Quantity of Wheat in Oman, 1961-2009. Source: FAOSTAT Database produced by the Food and Agriculture Organization of the United Nations (FAO). The data is displayed with the express written permission of UN/FAO and was downloaded from FAOSTAT on 07/17/2011.

Wheat is one of the food commodities that Oman spends a lot of financial resources on for import. The government therefore needs to put more effort towards research and extension in order to increase production and thus reduce the import burden.

3.2 Hydroponic and Greenhouse Farming

Hydroponics is the agricultural technology that utilizes nutrient-laden water rather than soil for plant nourishment (Bridgewood, 2003). Hydroponics, combined with a controlled environment, allows farmers and growers to produce large quantities of high-quality fruits and vegetables year round. In combination with greenhouses and high technology with capital intensive inputs, hydroponics systems can be highly productive, water and land conserving, and environmentally safe. A hydroponics system is therefore both land and water saving.

For a country like Oman, flooding irrigation combined with rapid evaporation from the soil surface has led to salinity problems. Under such conditions, hydroponics offers a way of improving water- and land-use efficiency.

Therefore, the countrywide adoption of hydroponics in combination with greenhouses in Oman would go a long way towards increasing agricultural output with less land and water. The Ministry of Agriculture (MoA) has introduced a hydroponics research on different agricultural crops at the Agriculture Research Center in Rumais. The adoption of hydroponics farming in Oman has already registered some promising success. For example, there is a private farm in Samail, Al-Dakhelia region that in 2008 produced around 20,000 tons of cucumber, which was three times higher than the recorded output from the same area of land for conventional agriculture. However, more needs to be done especially with respect to the possibility of combining hydroponics and greenhouses technologies with solar energy technology. Solar energy is needed during the summer season to run the air conditioning system for cooling purpose.

The hydroponics and greenhouse technologies have been adopted in other countries in the region. In Qatar, a half-hour drive from the centre of Doha, the Qatari capital, you will find the Al Sulaiteen Agricultural and Industrial Complex, a luscious farm set in the middle of a dusty expanse of desert. The farm grows among other things: cherry tomato, cucumbers, capsicums, green beans, and many other fruits and vegetables.

In the United Arab Emirates, a number of hydroponics farms have been set up in recent years, and are now starting to play a more important role in the market. Similarly, Saudi Arabia has seen new agricultural companies emerge.

Emirates Hydroponics Farms, which in 2005 was one of the early entrants to the region's advanced technology farming market, has now started to deliver for free for its customers in Abu Dhabi and the surrounding area. The company sells its produce, such as cucumbers, capsicums, strawberries and lettuces, online and at similar prices to the supermarket.

Emirates Mushrooms is another private hydroponic farm. It is the only fully organic mushroom grower in the market so far, with a farm of 10 specially designed growing rooms that can produce 8,000 kg of mushrooms a week.

Last year, Abu Dhabi announced it was set to launch Baniyas, the largest aquaponics centre in the world, a project that started with lettuces, but that was set to expand to other vegetables. Aquaponics uses water that fish live in, beneath the plants, offering extra nutrients to the lettuces.

It is therefore clear from the discussion above that the opportunities presented by hydroponics and greenhouse technologies to save land while increasing agricultural production are unlimited.

3.3 Seawater Greenhouses

The Seawater Greenhouse Technology is a low-energy means of growing food in desert regions using nearby abundant saltwater. Such greenhouses built near coasts (See Figure 4 below) turn plentiful seawater into fresh water for crops, without expensive desalinization plants.

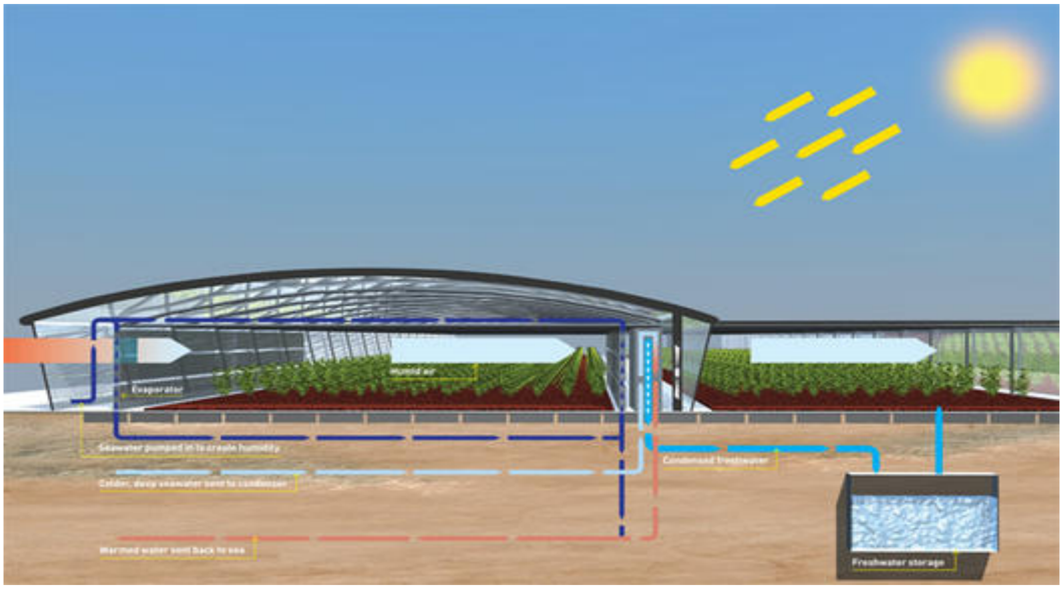

Figure 4: Seawater greenhouse evaporates seawater into humid air for plants and then condenses it into freshwater for watering. Source: http://www.popsci.com/environment/article/2009-07/8-farming-solution-help-stop-world-hunger

Three pilot greenhouses in Tenerife, Canary Islands; Abu Dhabi, United Arab Emirates; and Oman use prevailing winds, fans and simple evaporators to convert seawater into fresh water, and in the process create a humid environment in which just about any plant can grow.

The seawater greenhouses, which cost as little as RO 2 or $5 a square foot to build, get water from the sea, either by gravity or a pump. The water trickles down honeycomb-shaped lattices on the front wall and evaporates, cooling and humidifying the air inside. The air warms as it travels across the greenhouse – hotter air can hold more moisture – before reaching a second evaporator, which supersaturates it. From there, the air moves immediately into a condenser, which pulls out freshwater and sends it to an underground storage tank for watering the plants. This is a very promising technology for Oman insofar as the issue of water scarcity is concerned. More research needs to be directed towards this technology.

3.4 Rainwater Harvesting

No matter how low the rainfall experienced in a given area, rainwater harvesting can go a long way towards relieving water needs (Bruins et al., 1986). In the arid regions of Tunisia for example, considerable investments have been made to capturing the scarce amount of rainwater (100–230 mm/year) for agricultural, domestic, and environmental purposes.

For rainwater-harvesting to be possible, three basic landscape elements must be present: The landscape surface or soil conditions must be able to produce runoff; the landscape surface must include variations in elevation so that runoff water created during rains will flow into and be collected; and the collection areas must have adequately deep soil horizon of a suitable structure to store sufficient runoff.

Harvesting rainwater can be traced back to the 9th and 10th Century (GRDC, 2008). Perrier and Salkini (1991) defined water harvesting as a water-management technique for growing crops in arid (desert) and semi-arid areas where rainfall is inadequate for rainfed production and where irrigation water is lacking. Rainfall is collected from a modified or treated area to maximize runoff for use in a specific site such as a cultivated field, for storage in a cistern or a reservoir, or for aquifer recharge. Water harvesting has been and is being practiced in many countries in the region and beyond, such as in the Edom Mountains in southern Jordan (Oweis, 1996; Nasr, 1999), southern Tunisia (Prinz and Wolfer, 1998), Sudan (UNEP 2000), and Iran (Siadat (1991).

In recent years, Oman has experienced increased rainfall, especially in the interior, Jabal Akhdar, and the Dhofar mountain areas. This presents an opportunity for rainwater harvesting. Water harvesting is one of the desert agriculture strategies, and therefore needs to be researched and exploited for the benefit of agriculture in Oman.

3.5 Investing in Biosalinity Research

Approximately 97.5% of global water resources is salt water (Taha and Ismail, 2011). Investing in biosalinity research therefore makes a lot of sense. Biosalinity is the study and practice of using saline (salty) water for irrigating agricultural crops. In Oman, the water available in abundant quantities is either brackish (0.5-5g/L salt) or saline (30-50g/L salt). With traditional farming practices (e.g., what is happening in Batinah region) saline water results in soil salinization, rendering it unfit for raising most crop plants. The soils of Batinah region have traditionally been very productive, but agricultural practices there have slowly rendered it saline and hence unproductive. Currently, Oman is estimated to have 320 million m^3/year of usable brackish water resources. In addition to this, Oman has around 25,200 hectares of potential land for biosaline agriculture (Taha and Ismail, 2011).

Biosalinity research includes studies of the biochemical and physiological mechanisms of salt tolerance in plants, and breeding and selection for salt tolerance (halotolerance). It also includes the investigation of the use of saline irrigation water to increase desirable traits (such as sugar concentration in a fruit) or to control the ripening process. Furthermore, biosalinity research deals with issue related to the interaction between salinity and soil properties, and the development of naturally salt-tolerant plant species (halophytes) into useful agricultural crops. This kind of research is what we need in Oman, as it will help to provide answers on how we could use the saline water that is abundantly available to us in order to increase agricultural output. Some biosalinity-oriented research has already been done in Oman (see for example, S.A. Al-Rawahy, 2010) but more needs to be done.

3.6 Pink LED Technology—Grow Future Food with Less Water

Figure 5: Pink LED Technology Building with Plants Inside. Source: http://www.greenprophet.com/2012/02/pink-leds-grow-future-food-with-90-less-water/plantlab-purple-future-food/

Pink LED technology is still in the early stages of development but presents hope for the future in particular to desert countries facing water scarcity like Oman. What is Pink LED technology? A Netherlands-based company called PlantLab has devised a method for growing plants indoors using an unearthly pink-purple light made by the combination of red and blue LED lights instead of sunlight. Plants convert light from the sun into energy through the process of photosynthesis, but plants only need some parts of the sun's colour spectrum. Blue and red LEDs (See Figure 5) can provide just the light a plant needs, making the process more efficient while resulting in a stronger, healthier plant.

The usefulness of this technology is that all the water used within the indoor environment is recycled for reuse. As a result, water is efficiently economized. Furthermore, because plants are grown indoors, away from their pests, there is no need for pesticides, further reducing the costs of production.

Therefore, the LEDs technology's climate-controlled indoor farms not only use less energy, water, and space than traditional agriculture, they also reduce the unpredictability of our food supply. Nowhere is this need for carrying out agriculture with less water and land more crucial than in Oman and other desert countries in the region. This Pink LED Technology is therefore worth exploring for Oman.

4. Investing in Desert Aquaculture in Oman

Oman has a very long coastline and active fishery sector with approximately 40,000 fishermen distributed in more than 90 fishing villages along the Omani coast (Al-Jufaili et al., 2010). Fish prices in Oman have, however, been high to the point of rendering this important commodity inaccessible to low-income households. Investing in desert aquaculture in Oman is one possible solution for addressing the problem of fish shortage, and thus fish prices and food security.

Broadly, aquaculture refers to the breeding, raising, and harvesting of plants and animals in all types of water environments, including tanks, ponds, rivers, lakes, and the ocean.

Therefore desert aquaculture can be defined as aquaculture activities practised in desert and arid lands characterized by low precipitation (<250 mm/year), high solar radiation, and high rates of evaporation, and subsurface and surface water.

Aquaculture in desert and arid lands has been growing steadily over the last decade thanks to the modern technologies and alternative energy sources that have allowed water in these places of extreme weather conditions to be exploited more effectively and more efficiently (FAO, 2010).

Developing aquaculture in harsh environmental physical conditions, typical of deserts requires the adoption of production strategies focused on good water management, including the use of water conservation, recycling practices, and protection against strong solar radiations.

Aquaculture can also be integrated with agriculture and, in doing so, reduce the water requirement for the production of quality fish protein and fresh vegetable products relative to both culture systems being operated independently (McMurtry *et al.*, 1997). Furthermore, innovative fish/vegetable co-culture systems could be developed; such systems use the nutrient by-products of fish culture as direct inputs for vegetable production, constantly recycling the same water (e.g. aquaponics).

A large variety of fish species can be cultured in arid (desert) conditions like that of Oman, if the technology used is conductive to species proliferation. In the selection of species to be reared in desert environments, it is recommended that they:

- Tolerate hyper-saline waters
- Have high tolerance to large temperature fluctuations
- Be relatively fast-growing species to face off water-limited conditions typical of these desert environments.

The choice is also influenced by other factors such as the availability of farm inputs, market value and volume, local consumption and preferences, and dietary habits. Currently, the most suitable fish species for water-limited aquaculture systems include the tilapias (*Oreochromis* spp.), the barramundi or Asian sea bass (*Lates calcarifer*), carps and mullets (*Mugil cephalus* and *Liza ramada*), and several catfish species (*Clarias gariepinus* and *Bagrus* spp.).

Other fish species include the small brine shrimp (*Artemia* sp.) and the unicellular green algae (*Dunaliella* sp.). Currently, Australia farms and supplies over 60% of the world's natural ß-carotene extracted from *Dunaliella salina,* which is mainly produced in large saline evaporation ponds in South and Western Australia (Benemann, 2008). The FAO desert aquaculture production statistics shows that in 2009, Egypt produced approximately 600,000 tonnes of fish in brackish water, and Saudi Arabia produced 17,500 tonnes of shrimp. Other countries such as Israel and Algeria are producing substantial amounts of fish in marine and brackish waters.

The reviewed information above suggests that it is worth it for Oman to explore investing in research to establish desert aquaculture. Such an undertaking will go a long way towards solving food security problems, as well as, creating jobs for Oman's people.

5. Conclusion

With land and water scarcity seriously limiting agricultural production in Oman, as well as in other GCC countries, increasing agricultural production through expansion is not feasible. A sustainable marginal increase in agricultural production might be achievable through improvements in land and water productivity. This paper looks at the prospects of desert agriculture to improve food security in Oman. Land- and water-saving approaches and technologies have been proposed. These include: hydroponics and greenhouse farming powered by solar power, traditional crops adapted to Oman's weather and the environment, seawater greenhouses that turns seawater into fresh water for crops, rainwater harvesting to recharge aquifers, investments in biosalinity research, Pink LED technology to grow food with less water and land, and lastly investments in desert aquaculture.

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