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How Far Modern Vertical Farming is Appropriate for Developing Countries Like Oman?: A Review Based Analysis

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ABSTRACT

Purpose: Vertical Farming (VF) is a technique of growing food in vertically stacked layers or vertically inclined surfaces. Theoretically, it has the capability of growing any crops, fruits, or vegetables. The modern techniques of vertical farming through a controlled environment can support the growth and harvest of a crop irrespective of the season and climatic conditions. The newer modern techniques of VF have further reduced the dependency on sunlight, soil, and water. This paper analyses the appropriateness of vertical farming for developing countries like Oman.

Design/Methodology/Approach: This paper is based on secondary data and establishes the arguments in favor and against vertical farming.

Findings: The findings support the need for vertical farming and suggest that it is very appropriate for the urban setups, where it reduces the transportation cost and facilitates the availability of fresh and pesticide-less food products

Research Limitations: The major limitation of this paper is that it only accounts the secondary information, the empirical investigation is missing.

Managerial Implications: This paper implies government policies, allied agencies, and the agricultural sector.

Originality/Value: This paper is an original paper based on secondary data, providing a conceptual model for Oman, on which very limited studies in the given context is available.

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Introduction

Vertical Farming (VF) is a farming technique in vertically stacked layers or vertically inclined surfaces. In theory, it has the capability of growing any crops, fruits, or vegetables. Vertical farming can be done through a variety of ways that be segregated mainly in terms of traditional and modern techniques. The traditional technique involves

employing natural factors like weather, sunlight, water,etc. on the crops grown on vertically stacked layers. Modern techniques however support through a controlled environment can support the growth and harvest of a crop irrespective of the season and climatic conditions. The newer modern techniques of VF have further reduced the dependency on sunlight, soil, and water. In the field of agriculture, this technology is known as controlled-environment agriculture (CEA) as part of indoor farming practices (Khan et al., 2020; Khan et al., 2022). The modern techniques are not dependent on soil, and arable land, they can be practiced in any closed structures like buildings, skyscrapers, warehouses, etc. (Khan et al., 2020). Certain reports and organizations claim that VF through CEA and a few modifications in the VF design require 95% less water and 0% soil (The Guardian, 2016). One such organization that is doing significantly great in the field of VF is Aerofarm which achieves less water and no soil dependency through a water misting system (The Guardian, 2016; Khan et al., 2020). Instead of soil, the crops are grown on reusable plastic cloth and for photosynthesis rows of LED lighting system is used instead of sunlight (Khan et al., 2020). This setup along with the climate control system reduces the growing and harvest time to almost half (Stories, 2016). Also, this system facilitates the growing of any crop at any point in time in a year i.e., summer crops can be grown in winter and vice versa.

Oman is undergoing economic turbulence in light of the global oil demand crisis. The sultanate is striving to diversify its revenue sources and minimize the expenses or outflow of foreign exchange. The food sector is crucial to the economy of Oman, as the geography of the country doesn't support agriculture of many kinds of food items that otherwise has a high demand in the economy. According to (World Bank, 2019; World Bank, 2018) during the year 2018, Oman imported food products worth OMR 0.44 billion (USD 1.16 Billion) against a GDP of USD 79.28 Billion in the same year (World Bank, 2019). According to various forecasting agencies the GDP of Oman is expected to fall to USD 70 Billion and trend around USD 70-72 Billion for the next few years, whereas food consumption is expected to grow at the rate of 4.6% annually (Times of Oman, 2019). On the other hand, Oman has a good infrastructure for electricity generation, ample land area, and a strategic location on the world map. This study proposes the model of vertical farming through the modern farming technique of controlled temperature. In light of all such issues, vertical farming appears to be a logical and feasible solution in contributing to the food sector and facilitating self-reliance. The present study believes that the food crisis brings enormous opportunities for economists, entrepreneurs, and existing business management learners to take proactive measures. The present study takes into account the need and rationale for the adoption of the modern techniques of vertical farming to combat a variety of issues that might get avoided in times to come.

Methodology

This study utilizes secondary data, official reports, and published research work from the field like geography, agriculture, management sciences, and ecology. The study intends to highlight the issues that trigger the need to have innovative practices in the field of agriculture and attempts to establish an area of study that requires further deliberations and discussions.

Need for Innovative Agricultural practices

The increasing food demand is one of the pertinent issues that need to be addressed. The world population is estimated to be around 11.2 billion by 2100 (United Nations, 2019).The food demands are expected to rise by thirty percent by 2050 and fifty percent by 2100 (Khan et al., 2020). The present world population is 7.96 billion as of July 2022 (WorldOmeter, 2022). The increasing food demand has a direct impact on the agricultural sector i.e., more food means more agricultural produce. The present setup of agriculture majorly happens in the rural areas, with the change in lifestyle, migration patterns, and human settlements, it is expected that close to eighty percent of the world population will live in the urban setup by 2050. This means that the agricultural sector to needs to explore the possibilities in the urban areas. The agrarian economies like India also, things are changing at a faster pace, so far, India has been claiming to be a self-sufficient nation in terms of food production. The economy of India which once used to be dominated by the agricultural sector is now dominated by the service sector. The population of the entire subcontinent (combined known as

SAARC nations or south Asian nations is growing at a faster pace than ever (Yaqoob et al., 2022). The rural-to-urban migration is recorded at 20% for females and 39% for males as of 2008 (Kumari et al., 2014). For instance, the urban population of India by 2030 is expected to increase by 163 million whereas the rural population is expected to grow only by 30.9 million (Wilson et al., 2019). The rural areas have the advantage of relatively sufficient arable land and irrigation facilities in addition to the low cost of labor and other benefits. Such is not the case in an urban area.

Another aspect to consider is water scarcity, only 3% of the water available on planet earth is fresh water i.e., the water fit for drinking, bathing, and use in agriculture. Out of this 3% fresh water, only one-third is available to the world population,and the other two-thirds is tucked in the form of ice and glaciers (World Wildlife, 2017). Across the globe one-third of the population faces the scarcity of water for at least one month a year. For instance, India is home to 1.4 billion people as of July 2022 (WorldOmeter, 2022), approximately one-sixth of the global population lives in this country. The water resources it has is only 4% of the world's water resources (Government of India, 1999). The per capita water stress criteria suggests that water availabilityhas gone down from 1,700 m((Damkjaer & Taylor, 2017) to 1,170 m^3 in 2010 and has been continuously depleting (Kheirinejad et al., 2022). India is a tropical country with many perennial rivers and freshwater sources, unlike Oman. Agriculture accounts for 70% of the water consumed in any human activity. Currently, the water crisis is becoming big, infer-ences can be drawn from the fact that in terms of sanitation 2.4 billion people have reported issues.This leads to the issue of serious exposure of peoplelike cholera, typhoid fever, and other water-borne illnesses (World Wildlife, 2017; Khan et al., 2022).Water scarcity has reached to the level that 2.7 billion people suffer from it for a minimum of 1 month a year (World Wildlife, 2017; Khan et al., 2022).

The next issue is the availability of the agricultural land or arable land. Traditional agriculture requires arable land i.e., the land that has the capability of supporting agriculture. (Khan et al., 2022) define it as land that can be ploughed and used to grow crops. The global increase in the urban population has been a major threat to arable land Mansour et al., (2020). The urban population witnessed an increase from 14 percent in 1900 to 54 percent in 2014, and is expected to reach 66 percent by 2050, i.e. one-third of the world population living in the cities. On the other hand, one-third of the global arable lands have been lost in the hands of erosion or pollution in the past 40 years (The Guardian, 2015). The ever-expanding cities, growing population, and food demands have increased the requirement for arable land. Today it has become critical for any country to cover non-arable lands (including forests) with arable land to meet with the increasing demands (Khan et al., 2020; Mansour et al., 2020). Oman isa country on the Arabian Peninsula that has limited arable land concentrated on the coastal line to the Arabian Sea and Gulf of Oman. The urban growth rate in the sultanate has been 418.5 during the year 2008-2018 leading to the loss of arable land available on the coastline and the fertile valleys (Mansour et al., 2020). Similar stories are from other developing nations too that have led to the depletion of their forest covers, or intrusion into the areas that otherwise would have been protected like corals, mangroves, etc. Khan et al., (2022). Other elements to consider in the urban setup is the cost of agriculture and transportation, as the agricultural zones are getting away from the cities due to the expansion of city size and the increase in the cost of land in the surrounding areas. The opportunity cost of the land makes traditional agriculture less profitable. Also, the cost of transportation from an area far from the city makes the food items expensive and contributes to the inflation.

Innovation in Agriculture through Vertical Farming

Traditional Vertical Farming

According to M, Saravanan M & D, S (2018) assessment of VF, one of the essential occupations that supports human life for decades is agriculture. But right now, there is a severe impact on agriculture as a result of the lack of fresh water. Traditional agriculture uses more than 40% of its annual fossil fuel use for transportation. Additionally, excessive population converts agricultural land into apartments and structures. In the next years, only VF will be able to solve all of these problems. With the use of technology, we can efficiently farm in urban areas with few resources and produce enough food to feed the whole population. VF

will soon be the only dependable source of food due to advancing technologies.

Modern Vertical Farming

In the concept of Kale et al., (2020), the area under agriculture has reduced in recent years due to increased global population and urbanization. There is an urgent need to address the conundrum of reducing farmed areas while producing food for an ever-increasing population. As a result, the ground-breaking concept of VF was developed to boost agricultural output while utilizing less area. The farm uses soilless farming techniques such as hydroponics and aeroponics to increase yields faster throughout the season by understanding crop nutritional and temperature requirements. These approaches not only multiply the yield by 3-5 times, but they also produce food with fewer water, pesticides, and fertilizers. They further elaborated that; agricultural farming is a vital part of the Indian economy. Farmers in India have been using modern agricultural systems and techniques for many years now, but these methods are not as effective as they used to be due to increasing food demand. There is a need to shift from traditional practices to more efficient ones so that farmers can remain economically beneficial. New modern techniques, such as molecular breeding and GM technology, are very effective in improving crop yields in less land. They can also help to improve the environmental health of crops by reducing the need for farmland. This century is an important time for biotechnology and information technology revolutions, so using these technologies to improve major crops is a key solution to future food supplies.

Type of Modern Vertical Farming-Hydroponic

The idea of Banerjee & Adenaeuer, (2014), Most widely used method in the arena of vertical farming is hydroponic systems. This is a soilless farming practice where the nutrient-rich water is run through the exposed roots of the plants arranged appropriately. The water once it has run through all the roots, goes back to its tank and re-circulates. This allows the plants to absorb the necessary nutrients and minerals from the water (Banerjee & Adenaeuer, 2014). It is a division of hydro culture. The correct chemical composition and nutrient level have to be maintained as per the need and requirements of the plants. Such nutrients can come from a variety of sources such as manure, fish waste, or artificial chemical composition. As the system requires relatively less labour, and through the artificial photosynthesis the plants can have increased yield, the hydroponic system is getting popular. Also, this system brings the benefit of avoiding toxic pesticides and other agrochemicals (Savvas, 2003).

Type of Modern Vertical Farming-Aeroponic

Aeroponics VF systems are relatively new and often require a heavy investment thus they can be found to be rare in practice. However, the researchers believe it to be one of the most efficient ways of doing VF. As it is based on the mist technology, where the nutrient-based mist is added to the exposed roots of the plants. Plants absorb the necessary nutrients and moisture required for them to grow. The correct composition of the nutrient levels in the mist ensures that the plan gets exactly what it requires and thus, the chances of waste are minimal. On the use of water also, it uses far less water compared to the hydroponic systems (AeroFarms, 2016). This system is one of the most advanced systems of vertical farming in the world and has shown a lot of potential in the arena of agriculture (Stories, 2016; Khan et al., 2020).

Type of Modern Vertical Farming-Aquaponics

Aquaponics systems comprise both aquacultures (i.e., raising and breeding of fish, crayfish, snails, oysters, or prawns in water tanks) and hydroponics units (Lennard & Simon Goddek, 2019). In simple words, the practices of aquaculture e.g., fish, and utilizing the fish tanks' water to feed the plants and crops. Thus, the water recirculates in the system reducing the need for water. This system nullifies the need for any fertilizers or nutrients for the plants as the aquacultures provide necessary nutrients (i.e., their excreta released in the water). On the other hand, the plants absorb the nutrients and minerals from the water and in a way clean the water to be reused

(Lennard & Simon Goddek, 2019; Goddek et al., 2019). If done properly, the Aquaponic system develops its own ecosystem facilitating a less water and soilless agriculture method.

Concerns for Vertical Farming

Profitability is one of the important considerations for the modern practices of VF. The occupancy cost in the prominent cities can make practicing VF very expensive. The major cities in the world where the land rate runs into several thousand USD per square meter in terms of the land acquisition cost, and several hundred to several thousand USD per square meter rental cost make the modern practices of VF an expensive affair. The costs like electricity (as it utilizes CEA) and nutrients are to be artificially introduced to the plants, and the cost escalates (Khan et al., 2020). In the era of issues like Break Even Points and Return on Investments, there is a big challenge in front of the modern practices of VF. There are a few other components of cost like site preparation, construction, capital equipment, working capital, cost of labor, and other administrative costs that need to be considered.

The CEA facility requires and substantial power backup (i.e., electricity) that often requires the VF facility to be dependent on the power backup backed on fossil fuels like diesel gen sets. Also, the modern VF is dependent on artificial lights that consume power in like traditional farming that uses free sunlight. The energy requirements to pump water and air are another form of consideration that invites concerns from the experts in the field (Khan et al., 2020). The contribution to the pollution by these farms also cannot be ignored as the energy production emits greenhouse gases if not generated from sustainable sources like solar energy. Also, these closed enclosures required pumping of Carbon Dioxide (CO_2) to increase the photosynthesis and subsequently increase the yield. There isa high chance that such CO_2 might get leaked into the atmosphere as these facilities are not airtight and require a proper ventilation system.

Conclusion and Recommendations

Employing the modern techniques of VF can substantially support the urban setups where the land is expensive and transporting the food items from the nearby agricultural sector is expensive. The modern VFs can give as much as 36 times the harvest from the same land area as compared to the traditional farming (AeroFarms, 2016). As the urban population is expected to expand, the food demand will rise, arable land will shrink and water scarcity will increase. Considering all these factors, the modern techniques of VF appear to be a feasible solution. VF through modern practices also offers a faster harvest and round-the-year production of any crop that is high in. Soil-and water-poor, poorer, landless areas can greatly benefit from vertical farming that favors feed crops of maize, potatoes, and short-lived crops such as vegetables that can be grown all year round. For the countries like Oman where there is an abundance of non-arable land and lesswater, VF can be a potential solution to combat its food requirements and lower the import of food from other countries. Despite the challenges, it poses tothe planetary health of the world, the fact of increasing food demands, shrinking arable land, reducing the availability of fresh water, and self- sufficiency of the nations. The countries (irrespective of developed or developing) need to make vertical farming projects viable by way of subsiding the land use and land acquisition cost, energy subsidies, and other public benefits. Also, the policymakers need to ensure that the energy use in the VF comes from the sustainable sources like solar energy, hydro energy, or wind energy. For the countries like Oman, having abundant land area, efforts should be made to establish VF centres that can cater to more than one city.

Limitations and Future Scope of the Study

The Modern practices of VF are relatively a less researched area. The present studies establish the relevance ofthe theory; however, the practical implementation and results have not been checked in most of the research. Many government agencies must have supported this idea considering its relevance but in the body of the research, the feasibility check or practical functioning of such systems is not present. Thus, this study also adds to the body of literature and warrants the future researchers to check the implementation of VF through practical projects, prototype development, and real use. Also, the entrepreneurial and agricultural intentions towards to adoption of the modern practices of VF needs to be checked through an empirical investigation.

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