Implementation of Vertical Farming: Review

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Abstract— The development of new type of farming technique is required over the traditional farming technique so as to fulfill the increasing demand for food. Land based cultivation has been able to suffice food demand till now, but with increasing scarcity of land, water and other resources an improvised and efficient way of farming needs to be implemented. With the world population over 7.6 billion as of 2017 and expected to reach 9.5 billion by 2050, there is going to be manifold increase for food production demand. Vertical Farming could well be the answer to this demand. This paper reviews research papers, magazine articles, conference talks, etc. mentioning various needs, advantages, disadvantages, sustainability, acceptability, future trend, etc. while implementing Vertical Farming technique.

Key words: Vertical Farming, Vegetables, Crops, Hydroponics, Light, VF

I. INTRODUCTION

Since the very beginning of human race agriculture has been the only source of food production. With the advancement in technology the farming practice has improved a lot by using cultivating tools, modern machinery, etc. but the farming technique used is the same(refer fig1). Currently, there is approximately 800 million hectares of land which is designated to soil-based farming globally, which constitutes about 38 % of the total global land area. Due to the increasing food demand, there is a need for utilizing more arable land for farming as swell as intensifying farming efforts that would affect global agriculture. A new method that could potentially meet this demand, is by designing and developing vertical farms. In theory, Vertical Farming (VF) is an agricultural technique involving large-scale food production in high-rise buildings that enables fast growth and planned production by controlling environmental conditions and nutrient solutions to crops based on hydroponics, using cutting-edge greenhouse methods and technologies. VF incorporates both disciplines of both engineering and natural sciences, and has multiple applications in both society and the environment.

Recently, producing sustainable food in cities has garnered much interest and attention in many academic and practical fields. At present, these farms are largely growing and produce different types of crops inside cities such as China, Holland, South Korea, Japan, Canada, Italy, U.S, Singapore, United Arab Emirates, and England. Because the plants will be grown indoors by controlled environment agricultural techniques, then changing of seasons will have no effect on the crops. It is obvious the various amount and types of products determined the VF is not just happening, it is prospering at multiple cities with different regional characteristics around the world.

Vertical farms comes in different shapes and sizes they are classified in two major types as:

- Simple two level or wall mounted system.
- Large warehouse to several stories.

All vertical farms use one of these three soil- free systems for providing nutrients to plants:

- Hydroponic
- Aeroponic
- Aquaponic

Majorly Vertical Farming is done by using Hydroponic method. It involves growing plant in nutrient solution that is free of soil. Plants roots are submerged in nutrient solution which is frequently monitored and circulated to ensure the correct chemical composition.

Mainly terrestrial plants are grown with the help of this type of farming. Two main techniques is used sub irrigation and top irrigation .these irrigation is done with the help of reservoirs. Most of the reservoirs are made up of plastic, woods, vegetable solids. The containers should exclude light to prevalent algae growth in nutrient

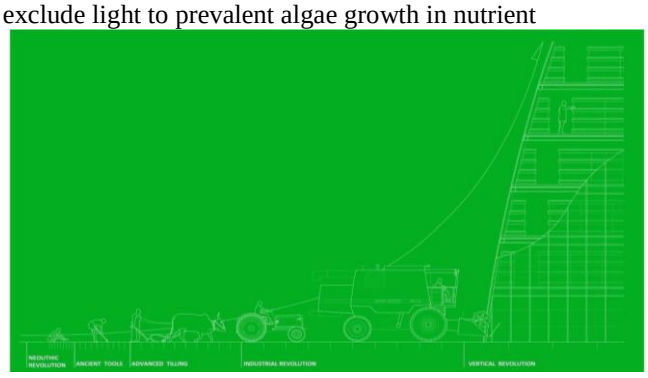

Fig. 1:

II. REVIEWS

Serial No	Name of Researcher, Year of Publication	Paper Title	Methodology Adopted	Conclusion
1	Urban Forestry & Urban Greening, Xiao Ping Songa, Hugh T.W. Tana, Puay Yok Tan 2017	Assessment of light adequacy for vertical farming in a tropical city	Study was to evaluate the spatio-temporal characteristics of PAR for growing leafy vegetables at high-rise vertical spaces, using	Survey of PAR conditions along the façades of public housing apartment buildings with basic linear & L- shaped configurations show that PAR increased gradually with building height, but remains highly influenced by façade orientation and building forms. Chinese

			tropical Singapore as a case-study location. Chinese cabbage and lettuce were grown & correlate with naturally grown ones.	cabbage, and lettuce require moderate amounts of light. The result suggested that building façades that experience a minimum of half-day direct insolation will support the growth of vegetables that mostly fall within the moderate to very high-light DLI categories
2	Canadian Greenhouse Conference, Dr. Martine Dorais, 2003	Use of Supplemental Lighting for Vegetable Crop Production.	The physiological influence of Supplemental Light intensity and photoperiod on seedling production as well as on vegetable crop production was studied.	The photosynthetic yield of HPS Lamps was found to be 34% more than natural lighting. Energy consumption per kg of crop produced and carbon dioxide release into environment reduced on use of HPS Lamps. The intercropping system under supplemental lighting is promising for year round production of vegetables. However for such an energy and capital intensive system to be profitable high yields must be obtained.
3	Journal of Plant Breeding and Crop Science, Ahmad Mohammadi Ghehsareh, Samira Khosravan & Ali Asghar Shahabi, 2011	The effect of different nutrient solutions on some growth indices of greenhouse cucumber in soilless culture	This study was conducted to analyze use of different nutrients on the growth of cucumber. A total of 3 Nutrient solution were tested on identically growing cucumber under a media mixture of Cocopeat and Perlite. Plant height, stem diameter, intensity of leaf color, leaf area index, stiffness of fruit tissue, yield of fruits, dry matter weight were measured in every treatment of nutrient solution. (refer fig 2 for composition of different nutrient solutions).	Comparison of means of cucumber fruit yield showed that there are no significant difference between solutions No 3, 2 and 1. The results showed that No 3 nutrient solution had most effect on the intensity of leaf color, stem diameter, plant height and leaf area index as compared with other nutrient solutions during the growth season. No 2 nutrient solution had most effect on the weight of plant dry matter, weight of fruit dry matter and stiffness of fruit tissue. The height of cucumber plants in treatments had no significant difference. The comparison of stem diameter means showed that No 3 and 2 nutrient solutions had significant difference at 5% level with No 2 solution but it had not any significant difference with No 1 nutrient solution at 5% level. The results showed that stiffness of fruit tissue in No 3 and 1 nutrient solution had not any significant differences but between No 3 and 2 nutrient solutions had significant difference.
4	SSRG International Journal of Agriculture & Environmental Science, M.Jegadeesh, Dr.J.Verapandi, 2014	An Innovative Approach on Vertical Farming Techniques	The paper discusses about the vertical farming structure, where it has to be completely made off with advanced technology such as, hydroponic system, artificial lighting system and efficient farming management in urban areas.	The vertical farming system has various methodologies, it is an eco-friendly process, and we can cultivate variety of crops all year around. Multiple crops can be cultivated in this process and in occurrence of heavy rains crops being in an enclosed building possess no risk or damage. Water can be recycled multiple times and used again as water is passed over hydroponics system and the excess amount of water is collected and recycled. It is a fully eco-friendly technique where new kinds of crops can also be developed easily in vertical farming system and the plants or crops which are grown under vertical farming are free from pesticides and thus are pure, fresh, natural when compared to the land farming system.
5	Sustainable Cities and Society, Malek Al-Chalabi, 2015	Vertical Farming: Skyscraper Sustainability.	Dr. Dickson Despommier's design was used as basis for this research. In this design light is used to cultivate crops inside the	Lighting and water pumping throughout the building are the two main energy demands. The feasibility and plausibility of the vertical farming concept from a socio technical mixed method research perspective was examined. This includes developing multifunctional

			building and water is pumped throughout the building for hydroponic culture. Solar panels are placed on roof and on facades. Therefore using this design energy flow demand and generation was quantified. The purpose of quantifying energy demand was to test whether renewable energy sources would be able to provide such amount of energy.	designs with input from engineers, architects and vertical farming technology providers simultaneously in order to help design future structures that can adapt to the 21st century needs, developing pilot programs where real time data can be collected and analyzed in order to examine where opportunities and barriers exist compared to conventional produce developing a large model that can take more factors into account and conduct a techno economic study that incorporates construction and maintenance costs. Vertical farming does hold potential in right circumstances.

Table 1:

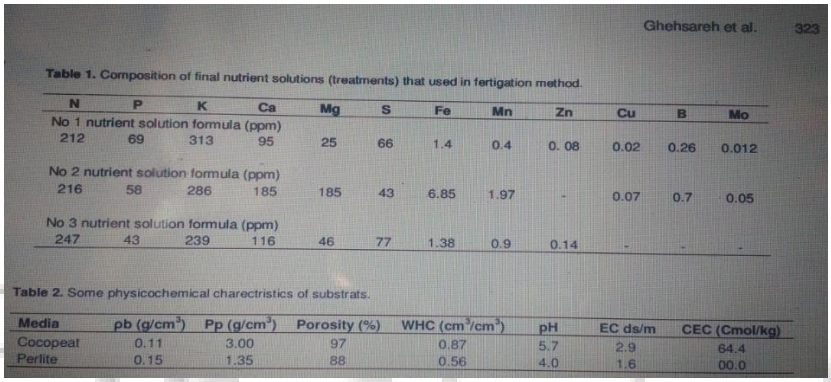

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Table 1. Composition of final nutrient solutions (treatments) that used in fertigation method.

N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B	Mo
No 1 nutrient solution formula (ppm)											
212	69	313	95	25	66	1.4	0.4	0. 08	0.02	0.26	0.012
No 2 nutrient solution formula (ppm)											
216	58	286	185	185	43	6.85	1.97	-	0.07	0.7	0.05
No 3 nutrient solution formula (ppm)											
247	43	239	116	46	77	1.38	0.9	0.14	-	-	-

Table 2. Some physicochemical charectristics of substrats.

Media	ρb (g/cm^3)	Pp (g/cm^3)	Porosity (%)	WHC (cm^3/cm^3)	pH	EC ds/m	CEC (Cmol/kg)
Cocopeat	0.11	3.00	97	0.87	5.7	2.9	64.4
Perlite	0.15	1.35	88	0.56	4.0	1.6	00.0

Fig. 2: Some Effective Vertical Farming around the World.

Sr No	Name	Location	Height	Type of Building	Products	Area	Technology	Year	Website
1	Sky Greens Farms	Singapore	9 m	New	leafy green vegetables	600 m	-Aeroponic system -Low carbon hydraulic water-driven -Natural sun energy	2009	www.skgreens.appsfly.com
2	Republic of South Korea VF	South Korea	3 story	New	leafy green vegetable, wheat, and corn	450 m²	-Renewable resources like geothermal and solar -Automated rack system - LED	2011	www.cityfarmer.info/
3	Green Sense Farms	Shenzhen, china	6 story	New	-Micro Greens -Baby Greens -Herbs -Lettuces	20,000 sq./ft	-Using stacking vertical towers -Using automated computer controls, which provide the precise amount of light, nutrients, water, temperature, and humidity - Minimize waste, and recycle water technique	2016	https://greensensefarms.com

Table 2:

III. CONCLUSION

We can conclude that even a little knowledge and awareness of VF can help food security and viability greatly. New technologies such as aeroponic systems, insulation methods and pest free plant growth has not only transformed the greenhouse industry but has also paved the way for new forms of farming such as rooftop farming. In apartments and

office buildings, creative climate management technologies and natural light management technology helped to save energy and cut down on greenhouse gas distribution (Germer et al., 2011). These have all made local food production in highly populated city areas possible, where more people require more food and their needs cannot be met (Thomaier et al., 2015). VF has got numerous advantages over traditional farming, which includes more efficiency, adaptability, and environmental benefits, which is all made possible through carefully controlled systems of VF. In VF, no waste or pollution is involved, it enjoys high levels of potentiality. All the above-mentioned benefits in a single system seems rather unbelievable, but VF has made it possible. If its use becomes common and widespread across the globe, the fear of starvation will also disappear and detrimental climate change will slow down too. Practically all famous Vertical Farms were situated in cities with more than 150,000 populations. Europe and North America have the biggest part of sustainable food production, while in high-density Asian cities, like Hong Kong Tokyo and Kuala Lumpur, the focus seems to be on improving the sustainable food production inside the city centers.

In addition, VF has provided new opportunities for architecture and urban designing. Urban designers have attested to the importance of making cities green, healthy and safe. By combining food production and architecture, VF helps to produce buildings capable of multiple functions. This is accompanied by many social and ecological advantages (Thomaier et al., 2015).

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