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ENVIRONMENTAL ASSEMENT OF HYDROPONICS IN URBAN SYSTEM FARMING

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Abstract: According to the Food and Agriculture Organization of the United Nations, the world population will reach nine billion people in 2050, of which 75% will live in urban settlements. One of the biggest challenges will be meeting the demand for food, as farmland is being lost to climate change, water scarcity, soil pollution, among other factors. In this context, hydroponics, an agricultural method that dispenses with soil, provides a viable alternative to address this problem. Although hydroponics has proven its effectiveness on a large scale, there are still challenges in implementing this technique on a small scale, specifically in urban and suburban settings. The ability to grow local food without agricultural land occupation is for sure an added value of vertical hydroponics, representing a less environmentally harmful way to supplement the vegetable demand of urban populations.

Index Terms - urban farming; hydroponics, life cycle assessment (LCA)

I. Introduction

Hydroponics sustainability has been touted as one of the leading farming technologies to combat climate change. Its promise is to help reduce water usage, soil erosion, environmental damage, and species extinction caused by overexploitation and intensive farming. The year 2050 harbingers a milestone in human history as, according to estimates from the United Nations for Food and Agriculture Organization (FAO), human population is expected to reach about 9 billion people (1). To satisfy the demand for food, world production will have to raise about 70% from 2007 levels. Additionally, since the world is becoming increasingly urbanized, 75% of the world population is projected to live in urban settlements (2).

Urban farming has been identified as a promising solution to secure food supplies and reducing the emissions of greenhouse gasses, microclimate improvement, improved water management, improved diet-related health, and stress reduction reduce pressure on agricultural land (3, 4,). Smit and Nasr (5) pointed out that urban agriculture could promote the development of a circular economy by closing ecological loops using wastewater and organic solid waste as inputs. However, urban agriculture is not a homogeneous practice, and includes, among the others, small commercial farms, community-supported agriculture, community gardens, rooftop gardens or greenhouses, hydroponic and aquaponics farms and indoor agriculture (6). Mougeot (7) proposed to categorize UA based on types of economic activity, products, location, area used, production system, production scale, and product destination. There are many examples and methods for urban farming, although approaches such as vertical and hydroponic farming have been popular options worldwide (3, 8, 9). The methods for vertical urban farming can be summarized by controlled environments, which are less affected by climate change or other outside factors that might affect the production, typically with the help of LED lighting, a controlled atmosphere and hydroponic systems for nutrient and water management (4,8,9). Many urban environments have unutilized spaces which have led to

the further promotion of such vertical farming methods. Much of the literature available points to the expectations of the systems and the potential technical solutions for these growing systems (10, 11, 12]. However, despite the scientific literature focusing on case studies, application and practice are still scarce (13). Advocates of vertical farming claim that it may increase productivity reduce environmental footprints from production and transportation and offer many advantages to traditional greenhouses and agriculture by controlling the growing conditions in indoor climate-controlled spaces, typically in urban environments (13). However, while there is an increasing body of literature reviewing the potential of urban and vertical farming systems and technical solutions, there is a limited number of studies reviewing their sustainability (8, 14, 15). To grow the food in urban areas itself utilizing less distance and saving the time in bringing the food produced in rural areas to the cities.
The aim of this study was to assess the environmental impacts of vertical hydroponic farming in urbanwas carried out by identifying important parameters in the production system and assessing the sustainability of potential options. Growing food in urban environments has fresher foods available faster and at lower costs.

2. Methods

2.1 Vertical Farming Hydroponics

Hydroponics is the process of farming using water instead of soil as a medium. Nutrients are injected into the water line for all crops to enhance their growth resulting in a better crop yield and output.

A vertical farm is a tall structure, like a tower, with multiple trays, with one on top of the other in the form of shelves going down each side. This helps to save space and is ideal for any indoor farming concept.

Vertical farming could enable food production in an efficient and sustainable manner, save water and energy, enhance the economy, reduce pollution, provide new employment opportunities, restore ecosystems, and provide access to healthy food. In a controlled environment, crops will be less subject to the infestation, the nutrient cycle, crop rotation, polluted water runoff, pesticides and dust (16). Vertical farming provides an opportunity to support the local economy. Abandoned urban buildings can be converted into vertical farms to provide healthy food in neighbor hoods where fresh produce is scarce.

Vertical hydroponic farming uses the trusted principles and techniques of greenhouse production, making it ideal for urban farming in a condensed controlled environment in place of traditional farming methods that need more space. Growing different types of plants without any soil is far away from conventional farming techniques, but it is certainly one of the best ways to solve the space and efficiency problems.

2.2 World scenario

Vertical farming involves growing crops vertically in controlled atmosphere using technology like LED lighting, heating, ventilation and air-conditioning (HVAC) systems, sensors and smart software, Internet of Things (IOT), drones, mobile apps to maintain total control over the environment. Food crops can be cultivated easily in urban areas by planting in vertically stacked layers in order to save space and use minimal energy and water for irrigation.

Sparks and Stwalley, (17) tested the Nutrient film technique hydroponics system was by growing lettuce plants and monitoring energy use throughout the growth period.Various experiments are being done about vertical farming all over world. It has already been introduced in the US and Europe, Spain, Japan and Singapore. Several tech-enabled vertical farms like Aerofarms and Green Sense in the USA, Delicious in The Netherlands, Sharp's strawberry farm in Dubai, Spread, Toshiba and over 100-plus vertical farms in Japan, Packet Greens of Singapore, the EU funded INFARM in Berlin are proven examples of successful vertical farming. INFARM is now operating more than 50 farms across Berlin in supermarket aisles, restaurant kitchens and distribution warehouses. The National Aeronautics and Space Administration (NASA) researchers have seen hydroponics as a suitable method for growing food in outer space. They have been successful in producing vegetables such as onions, lettuce, and radishes. In Columbia, Association for Vertical Farming is working on its sustainability.

3. Vertical farming systems

Vertical Farming systems can be broadly divided into two categories those comprising multiple levels of traditional horizontal growing platforms and grown on a vertical surface. Horizontal growing systems are stacked horizontal systems and multifloor towers, Balconies. Vertical growth surfaces are green walls and cylindrical growth units.

3. 1 Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is a methodology used for the evaluation of the environmental impacts of a product or a service. Its utility in the food sector has been recognized, thanks also to the opportunity of improving the performance of a product by acting on the most burdensome processes.
The functional unit for the assessment is the annual production of plants available to. As the study compared options for production controlled by the producer, the assessment was conducted using a cradle-to-gate perspective, i.e., up until the plants were available to consumers at the retailer, including all upstream processes in the cultivation, infrastructure, production of the pot systems, seeds, soil and fertilizers, packaging materials, etc.
The infrastructure for the vertical farming system includes LED fixtures, steel structural platforms,pumps, tubing, trays, a heater, and a control unit and timers for pumps and lighting (Table 1).

Table 1 Material and energy inputs for vertical hydroponics

Main Category	Process/ Flow	Amount	Unit	Transport (Km)	Life time (Years)
Infrastructure	Steel Structure	242	Kg	100	30
	LEDs	8640	Units	100	15
	Trays (PET)	36	Kg	100	15
	Tubing/Other Plastics	10	Kg	100	5
	Pumps	2	Units	100	10
	Heater and Other Electronics	3	Units	100	10
Raw materials	Pot	240	Kg	100	--
	Seed	6	Kg	100	--
	Growing Medium (Soil)	12,350	Kg	50	-
	Nitrogen (N)	10	Kg	100	-
	Phosphate (P)	12	Kg	100	-
	Potasium (K)	14	Kg	100	-
	Paper	449	Kg	100	-
	Wrapping Paper	38	Kg	100	-
	Label	480	M^2	50	-
	Water	144,890	Liters	-	-
Energy Inputs	Lighting	26490	Kwh	-	-
	Ventilation	490	kwh	-	-
Output	Plants	60,000	plants	-	-
	Distribution	1390	km	-	-

All energy, including electricity for lighting the LED fixtures, ventilation, pumps and heating was included in the assessment. Heating of the space was assumed only to be regulated by the external heating unit (used primarily during cold months). Other heating from the local district heating system used in the building was not allocated to the assessed system as the hydroponic system produces residual heat from the LEDs. It was assumed that the ventilation systems were running 24 h per day and LED fixtures were assumed to run 12 h per day based on consultation with the producer (7). The fertilizer used for the hydroponic system was blended into the water bath and recirculated.In this study, the composition was based upon information from the producers and only the major nutrients were included: nitrogen (N), phosphorus (P) and potassium (K) (29%N, 33% P, and 38% K). It was assumed that there was no fertilizer emissions due to the closed loop system.

4. Large-Scale Vertical Hydroponic Farming

Hydroponic growers can take advantage of their non-conventional farms to grow various types of fruits, leafy greens, microgreens, vegetables, etc. Some types of root vegetables like potatoes, garlic, carrots and onions are not ideal as they are usually grown in the ground. The list of vertical hydroponic crops is long, with more than fifty types of crops that can grow well in vertcical hydroponic farms.

There are also several experiments going on to test and grow other plants in this type of system. This kind of research and development will hopefully help to increase the variety of crops that can be grown in a vertical hydroponic farm across the world and solve the problems of food scarcity and land degradation. It is certainly sustainable and profitable for all commercial growers. Especially great for urban farming.

In most cases, we see that small- or medium-scale farmers, especially urban farmers, resort to vertical hydroponic farming as the best solution. Indeed, these are both ideal for small areas with big aspirations without creating a massive footprint. Some small-scale urban or indoor farms cannot solve our hunger problems alone, we need to enhance operations to larger scale growers for this type of need.

However, with more and more professional farmers resorting to indoor setups with vertical hydroponic growth techniques, there's hope. This is particularly true because of the small amount of space that they take. Additionally, with complete control over all growing conditions, it is possible to get various crops grown all year long with amazing yields.

4.1 Advantages of vertical farming

The major advantage of vertical farming is producing extremely high yields per available land or area. Producing the food throughout the year without the risk of vagariesof nature like floods, heavy rains, uneven rains, hail and snowfall, drought, dry spells, extreme high temperatures, cold waves, epidemics of pest and diseases, etc. It reduces the cost over transporting loads of food grains from rural area to urban areas and reduce the spoilage occurring there in. Fossil fuel consumption in transporting the farm produce to cities from village places is also reduced to a greater extent. Vertical farming uses 70 to 95 % less water compared to traditional farming 90% less or no soil is needed in vertical farming and thereby no pest and disease infestations. Pesticide free or organic food is produced as there is no use of pesticides.

4.2 Disadvantages of vertical farming

Initial huge cost for establishing the vertical farming system is the majorϖ problem. It will include the cost erecting the structures along with its automation like computerized and monitoring systems, remote control systems, programmable LED lighting systems, climate control system, etc. Huge energy cost as growing plant is entirely with artificial lights. The excess nutrients used in vertical farming may interfere and contaminate the main urban water system if not taken care of. LED lighting systems emit heat though small amount will create problem ofmaintaining the temperatures especially in summer months and may overload the air conditioning systems which will again incur high energy cost.

5. VERTICAL FARMING IN INDIA

India is one of the largest producer of vegetables, fruits and many other agricultural commodities. In India, vertical farming has been introduced. ICAR experts are working on the concept of 'vertical farming' in soil-less conditions, in which food crops can be grown even on multi-stored buildings in metro cities like New Delhi, Mumbai, Kolkata, Hyderabad (Urban Kissan), Bangalore and Chennai without using soil or pesticides. Small-scale adaptations of vertical farming have been seen in Noida, West Bengal and in Punjab. Bidhan Chandra Krishi Vishwa vidhalaya in Noida has found initial success in growing brinjal and tomato. Punjab also has succeeded in producing potato tubers through vertical farming (18).

5.1 FUTURE THRUST IN VERTICAL FARMING

Vertical farms were integrated in the cities, they will be able to supply of food for the entire population. Research is need to be assesses the Return of Investment (ROI) of various types and sizes of vertical farms and to investigate the full life-cycle analysis (LCA) and the number of years to reach parity with a traditional farming, advance and further development of local farming techniques to make vertical farm projects.

6. Conclusions

Vertical farming methods have become increasingly popular worldwide as a solution to viably provide urban populations with sustainable food supplies. The ability to grow local food without agricultural land occupation is for sure an added value of vertical hydroponics, representing a less environmentally harmful way to supplement the vegetable demand of urban populations.

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