SCOPE OF FARM ON WHEELS TECHNOLOGY FOR VERTICAL FARMING IN INDIA

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ABSTRACT

Increasing population, industrialization, and urbanization along with limited availability of natural resources have put stress on land resources for Indian agriculture. This issue can be addressed by the concept of vertical farming to grow agricultural products in structured vertical stacked layers or floors. Many types of research have been carried out for exploring the use of techniques of hydroponics, aeroponics, and aquaponics in conjunction with advanced controls. Use innovative practices in vertical farming such as solar energy, roof-top turbines, storage batteries, RWH techniques, IoT; etc. has added new dimensions of research and practices. It can be explored. However, no studies currently exist that qualify the validity of such studies for mobile farming. The purpose of this paper, therefore, is to review the existing developments in the field of vertical farming in India and to identify the concept of "Farm on Wheel" (FoW). The study also explores the advantages and disadvantages of various vertical farming methods and identifies FoW farming as a flexible, simple, and modular solution to supply farm products at door-steps.

KEYWORDS: Vertical Farming, Hydroponics, Aeroponics and Aquaponics, Farm on Wheels

1. INTRODUCTION

Growing population with limited conventional natural resources has put stress on limited lands for farming and agricultural production in India. Agriculture plays a key role in the Indian economy too. Land parcels have become expensive due to increasing urbanization and industrialization. Indian agriculture with horizontal farming involves many challenges and issues related to the requirement of huge land area, more consumption of water through conventional farming practices, excessive use of pesticides and fertilizers, flooding & drought, waterlogging and soil erosion, soil degradation, etc. However, there is an enormous scope of production potential in Indian agriculture by involving technical changes through organized research in this field. Well-designed and planned Vertical Farms are a form of controlled environment agriculture (CEA) for the growing of fruits, vegetables, biofuels, drugs, and vaccines **(Despommier D., 2014)**. Vertical Farming (VF) is structured in vertically stacked layers, vertically inclined surfaces, and/or integrated with other structures such as skyscrapers, used warehouses, or even in the shipping container and facilitates year-round cultivation.

Various organizations have researched the field of Vertical Farming in India. A vertical garden structure is developed recently by ICAR-Indian Institute of Horticultural Research, Bengaluru. This structure is user-friendly for urban and peri-urban societies to grow varieties of daily vegetables, medicinal and flower crops. The system is found to be used to meet the nutritional requirement of the family and thereby resulting in better health of society **(Rathinakumari A. C. et al., 2019)**. Central Research Institute for Jute and Allied Fibres, Barrackpore (West Bengal) explored the use of

Integrated Vertical Farming System (IVFS) to grow fodder for rearing animals and vegetables of daily use **(Singh A. K. and Das D., 2018)**.

The efforts are made to review the literature through various sources for the concept and feasibility of vertical farming and to draw conclusions regarding the future scope of technological enhancement in this field.

2. VERTICAL FARMING CLASSIFICATION

Classification according to processes used in the vertical farming system:

a) Hydroponics (Harris, 1992).
b) Aeroponics (Lakhiar, 2018).
c) Aquaponics (Lennard, 2019)

Hydroponics, Aeroponics, and Aquaponics are recent techniques used for VF. Various Indian researchers have been already worked and been also looking for the feasibility of these technologies in conjunction with other advanced controls.

2.1 Hydroponics

In the Hydroponics method, the plants are cultivated in nutrient-enriched water and so here water is considered as an accountable wholesome factor for plant growth. **Harris (1977)** defined this method as "The science of growing plants using a mixture of essential plant nutrients dissolved in water and the medium other than soil." However, **Jensen (1997)** considered hydroponics as a technology for growing plants in an environment of water containing fertilizers with or without the use of mechanical support of an artificial medium like sand, gravel, etc. Word "Hydro" stands for water and "Ponos" for labour and hence in the hydroponics system the role of labor is played by water as an element.

In this method, the plant root is surrounded or circulated and submerged by a nutrient-enriched solution. The process is controlled with the essential chemical composition of plant nutrients dissolved in water. Without land, the artificial application of plant nutrients supplies all necessary elements that are usually acquired by plant roots through the root zone. In a limited space the maximum healthy yield can be achieved by maintaining an optimized microclimatic condition. The process of growing plants immersed in nutrient solution often involves inert medium sand, gravel, or any such material to support the environment mechanically. Figure 1 shows the general setup of the hydroponic system.

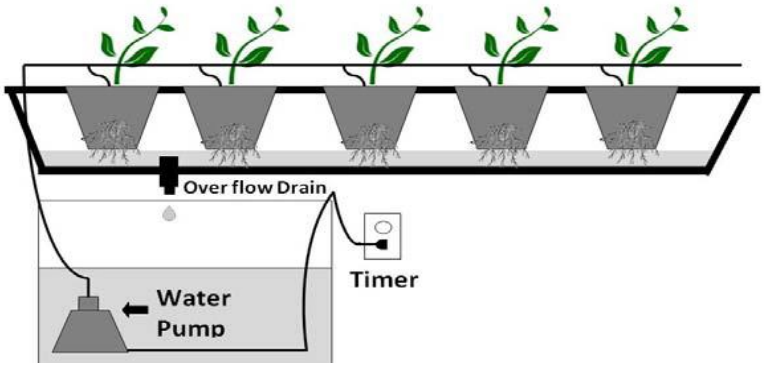

Fig.1 *General Hydroponics Setup*
Source: *Hydroponic graphic. Illustration: NCAT*

2.1.1 Advantages of Hydroponics

- Healthy yield of crops with the composition of nutrient solution, electrical conductivity, DO, and pH levels
- Reduced use of harmful fertilizer and pesticides and thereby abolition of soil-borne diseases
- Decrease the use of fertilizers and pesticides.
- Limited space and limited water usage and so most suitable for urban areas

However, recently many researchers in India have explored the benefits of using Internet of Things (IoT) concepts in hydroponics systems to optimize the micro-climate for plant growth **(Mehra M. et al., 2018; Tembe S. et al., 2018; Pant T. et al. 2018; Bhuvaneswari P. et al., 2020; Murthy B. N. S. et al., 2016).**

2.2 AEROPONICS

Aeroponics is a type of technique in which a streamlined interaction is created for developing yields and plants in an air medium without the utilization of soil or a total medium by splashing the plant's foundations with an atomized or showered, supplement rich water arrangement.

Aeroponics is a cultivating procedure including plant development in an encased chamber by air circulation of roots through a miniature shower of watery supplement fog. This system consists of an aquaculture framework where plant establishes are suspended in air and discontinuously drenched with a supplement-rich, mineral-based arrangement. Figure 2 shows the general setup of the aeroponic system.

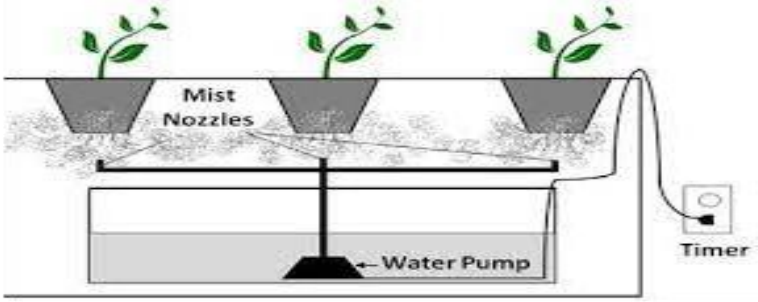

Fig. 2 *General Aeroponic Setup*
Source: *Aeroponic graphic. Illustration: NCAT*

2.2.1 Advantages of Aeroponics

- Aeroponics is more invaluable than the ordinary strategies of engendering for example lesser existence prerequisite.
- All year crop creation in a controlled climate (regardless of season), restricted water utilization because of reusing measure, totally natural cultivating as no need of manures and pesticides, sound (more supplement accessibility) and sickness free plants items, huge scope clonal creation for business and protection purposes, simple admittance to root framework lessening work cost in the event of root crops.

- A high-level type of aquaculture, Aeroponics is the way toward developing plants with just water and supplements. This creative strategy brings about quicker development, better plants, and greater yields all while utilizing fewer assets.

The use of Aeroponics in agriculture was proposed by researchers to establish the optimal, accurate and economical irrigation control **(Mithunesh P. et al., 2015, Suvarna G. et al., 2020, Sudharsan S. et al., 2019).**

2.3 AQUAPONICS

Investigating a record from FAO report, they discuss soil-less societies as a method of developing farming harvests without the utilization of soil. Rather than soil, different dormant developing media, additionally called substrates, are utilized. These media give plant backing and dampness maintenance. Water system frameworks are incorporated inside these media, consequently acquainting a supplement arrangement with the plants' root zones. This arrangement gives the entirety of the significant supplements for plant development. The most widely recognized strategy for soil-less culture is tank-farming, which incorporates developing plants either on a substrate or in a watery medium with uncovered roots.

Aquaponics is another word termed Hydroponics. It is being identified with the mix of both tank-farming (plant outlining) and fish cultivating with reuse of water. It can likewise be referred has organic cultivating as it doesn't contain any synthetic compost rather than that it utilizes the microorganisms and fish waste as manure through the water. Smelling salts in fish squander are separated by microbes and changed over into nitrites and afterward nitrates to be utilized as manure for the plants.

Aquaponics is a change of tank-farming coordinating recycled hydroponics (fish cultivating) with aqua-farming. Fish is filled in indoor lakes creating supplement-rich water arrangement through excreta which is the supplement wellspring of plants in vertical cultivating. The plants thus channel and clean wastewater which is reused in the lake. Figure 3 shows the general setup of the aquaponic system.

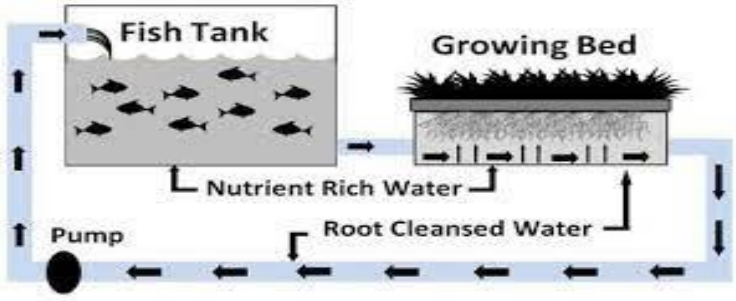

Fig.3 *General Aquaponic Setup*
Source: *Aquaponic graphic. Illustration: NCAT*

2.3.1 Advantages of Aquaponics

- Water-saving since water is re-utilized through natural filtration and distribution
- Eliminates the requirements of manufactured composts

- Efficient and financially savvy since the by-product of one organic frameworks fills in as supplements for other framework
- Provides natural fluid manures that guarantee sound development of the plants
- Cleaning water for the fish environment

As indicated by the National Ocean Service, as the interest in fish has expanded, innovation has made it conceivable to develop food in beachfront marine waters and the untamed sea. Advances in Aquaponics for farming are explored as a cost-effective and sustainable solution by various researchers **(Menon R. et al., 2013; Chavan J. et al., 2020; Surnar S. R. et al., 2017).**

Vertical farming further can be classified based on the types of structures that house the system **(Reja *et al*. 2019):**

- ***Building-based vertical farms:*** This type of vertical farming is often done in abandoned buildings, warehouses, etc. e.g. Chicago's 'The Plant' vertical farm.
- ***Shipping container vertical farm:*** Several shipping companies reject the shipping container after use which is sometimes used for vertical farming. They are furnished with LED lights, drip irrigation systems, and vertically stacked shelves for growing a variety of crops. These containers have computer-controlled growth management systems that allow users to monitor all systems remotely from a smartphone or computer e.g. Freight Farms, Crop Box, Growtainers, etc.
- ***Rooftop farming:*** These practices are performed from very old times for example ziggurats of ancient Mesopotamia and the Hanging Gardens of Babylon. It is simply the growing of fruits and vegetables on the rooftop. The rooftop garden is a rising trend that aims to scale up urban agriculture. The common vegetables that can be grown in rooftop gardens are carrot, radish, bean, beet, cherry tomato, and various herbs. The rooftop garden makes a distinction between a vertical garden and a vertical farm. Though both grow plants vertically the former does not always produce fruits.

3. ADVANTAGES & CHALLENGES AND FUTURE SCOPE

Many researchers have addressed various economic, environmental, and social advantages and consequent challenges for Vertical farming techniques at the global and national level **(Benke K. and Tomkins B., 2017; Kalantari F., 2018; Sonawane M. S., 2018; Sarkar A. and Majumdar M., 2015, Khalil H.I. and Wahhab K. A., 2020; Agrawal H. P. and Sinha R., 2017, Al-Kodmany K., 2018, Aswath C. et al., 2016).** A few of them are summarized herewith:

3.1 ADVANTAGES OF VERTICAL FARMING:

- More yield per unit area of land
- Crop production throughout the year
- Improve productivity against climate change and no weather-related crop failure
- Effective use of water for food production and abolishing the farm runoff
- Recycling of water and organic waste
- Reduces use of fertilizers and pesticides and thereby produces healthy organic food free from contamination
- Reduction in use of fossil fuels and conventional sources of energy using green technology like solar panels, roof-top wind turbines, and storage batteries

- Production of Energy through the generation of methane from compost
- It requires less heat than greenhouse **(Bambara J. and Athienitis A., 2015)**
- Increase in profit due to reduced use of fertilizers, herbicides, or pesticides and even due to no soil preparation required in case of hydroponics and aquaponics
- Start-ups and Employment opportunities in various fields
- Reuse of unused properties/ Shelters close to consumers
- Restore ecosystem functions and services by returning farmland to nature
- Bringing morality and understanding for conserving nature

3.2 CHALLENGES IN VERTICAL FARMING

- High start-up costs and huge investments for Land and building infrastructure in urban areas
- High operation cost due to use of energy
- Vertical farming may be suitable for growing an only limited number of species of green leafy vegetables, fruits, herbs, pharmaceutical plants
- Less acceptance to new farming technology and so alterations to traditional farming practices
- Different crops require different climatological conditions and environmental requirements and so there is a limitation to maintain such variations in a single vertical farm.
- Availability of solar radiation may not be uniform at different levels of VF.
- Cost may increase due to the requirement of skilled labours and workforce, energy management, and operation & maintenance. It is very complex and expensive to make changes and modifications in the design of the infrastructure of VF as per the requirements of the crops. However, natural process like cross-pollination is to be managed manually rather than insect pollination which may increase the additional cost of labour. Maintenance of equipment used for maintaining radiations, humidity, and other microenvironments may cost additionally.
- Cost of transporting and storing the crop yields may increase the additional requirements of infrastructure.

3.3 FUTURE SCOPE AND THRUST IN INDIA

- It is essential to integrate VF technologies with conventional and local farming practices.
- Towns, CBDs, and smart cities can be planned and designed to integrate portable Vertical Farms to supply food at a local level.
- A portable, cost-effective, and user-friendly design of Vertical Farms on Wheels can be explored and in conjunction with advanced green technologies to increase the adaptability and reduce the initial cost of investments.
- Use of local solar power to compensate energy demands, Rain Water Harvesting (RWH) and recycling of used water to address water demands, and provision of natural micro-environment at all levels of Vertical Farms are major concerns.
- The concept of “Farm on Wheels” shall be explored to boost start-ups and to supply farm products at door-steps
- Return of Investment (ROI) for various types of crops and varying levels and sizes of vertical farms can be assessed.

4. FARM On WHEELS (FoW)

Very few researchers have noticed the usefulness and scope of FoW technologies **(Horton R. P., 2017, Seo S., 2018, http://www.truckfarm.org/)**. Few case studies are represented and described herewith. Figure 4 represents a mobile solar-powered urban farm designed by The Seoul, Korea Branch of the Beijing-based the People's Industrial Design Office. The farm consists of hydroponic vessels interconnected by tubes mounted on a metal base and supported by a pair of bicycles. The energy the demand of irrigation pump is supplied through arrays of solar panels installed on the steel frame.

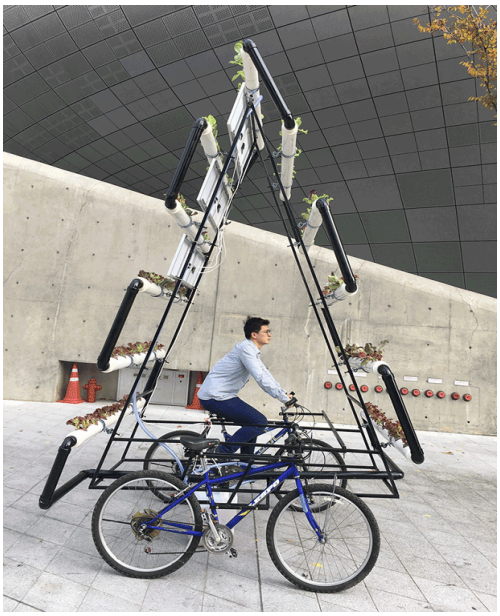

Fig. 4 *Solar-Powered Shared Bike Farm*
Source: *https://www.urbangardensweb.com/*

Moving Farms can be devised to combine production, processing, and distribution. However, these farms can move the residential areas and can provide service at door-step. Seo S., a transportation designer (2018) proposed a moving farm design to serve the significant diet supply of Shanghai. Figure 5 represents the suggested design of moving farm.

Fig. 5 *Moving Farm: Urban Vertical Farm for Shanghai in 2030*
Source: *www.michelinchallengedesign.com (2018: Mobility/Utility/Flexibility)*

Sparks R. E. et al. (2018) designed the mobile, flexible, modular, simple, and efficient Modified Hydroponic Shipping Containers (MHSC) and tested for Nutrient Film Technique (NFT) hydroponics system. With such innovative practice, authors noticed more than 50% reductions in energy consumptions with increased crop production efficiency. Figure 6 shows experimental setup showing use of NFT for crop production.

Fig. 6 *NFT prototype production system at harvesting stage*
Source: *Sparks R. E. and Stwalley R. M. 2018*

Arka Vertical Garden Structure designed by IIHR is represented in Figure 5. Aforementioned this structure can grow varieties of crops at a reasonable cost. This structure is user-friendly, portable, and mobile. However, such a structure can fulfill the daily vegetable requirements and even accommodates in a small space. Figure 7 represents the Arka vertical garden structure designed by IIHR.

Fig. 7 *Arka vertical garden structure*
Source:*https://www.iihr.res.in/arka-vertical-garden-structure*

4.1 ADVANTAGES OF FARM ON WHEELS

- The FoW has the potential to reduce the transport costs and CO_2 emissions and it reduces the spoilage of crops that occurs over a long distance.
- No need of constructing any building and other infrastructure and so no high initial investments
- Multiple crops at multiple levels using any method of vertical farming
- Qualitative supply of vegetable salads, fresh juices, and Ayurveda drinks (popular name: Kaadha) at door-steps
- A cost-effective Farm on Wheel can be integrated with Solar Source for energy and equipped with water conservation and recycling techniques for its optimum use.

- Use of limited levels with the customized area can be flexibly moved and revolved to get required sunlight and wind conditions.
- Easy to fabricate and no skilled force is required.
- Increases employability and promotes start-ups
- It can be mounted on a battery-operated vehicle with the installation of a solar panel at the rooftop.
- Suitable for any topography

5. CONCLUSION

Vertical farming is a relatively new phenomenon in India. Acceptance and adaption of this farming system at the regional level is a need of the hour to meet the growing food demand. This future demand can be addressed by constructing Vertical Farms in an open urban space. Various conventional methods used for Vertical farms have their pros and cons. However, the use of advanced technologies and innovations can be experimented with and embedded with conventional methods to optimize the use of both energy and resources and thereby increase the ROI.

Farm on Wheels is a method of farming that constitutes all key advantages of vertical farming with limited levels of farming. It offers flexibility to serve the farm and farm products at the door-steps of the customer. With little initial investment, this concept is good potential for start-up and self-sustainability. With the reduced cost of transportation, it can nurture environmental benefits to future cities.

State and Central Governments, Urban Planners, Policymakers, and entrepreneurs can associate together to promote and build such land conserving and citizen-centric sustainable Vertical Farming environments in India.

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