



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 11, November 2022

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.118

9940 572 462

6381 907 438

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Integrated Agriculture and Biophilic Urbanism in Urban Environment

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ABSTRACT: Over the decade, integrating nature and biophilic design has received widespread attention in architecture, especially in response to growing environmental challenges like urban degradation, environmental sustainability, and agricultural production. This has further created a gap in research in which the ideology of biophilic urbanism is merged with variables related to urban agriculture. Hence, this paper is a wake-up call to that effect and therefore aims to bridge the gap in knowledge in building integrated agriculture and vertical farms with an architectural biophilic approach to tackle urban heat island effects in temperate regions. A qualitative approach was adopted in which authoritative i.e., empirical studies and case studies (AeroFarms, Living Tower, Sky Greens FarmOne) were gathered and relevant information was elicited centering on information related to the variables. This process of qualitative analysis gave the researcher insight into models of implementing a biophilic approach to vertical farms and building integrated agriculture in temperate regions to tackle urban heat island effects. Key findings that were discussed included the pros (sustainable agriculture, increased yield, space management) and cons (failure to the soil due to cultivation, irrigation, and additives) of the agricultural innovation, which further shaped the conclusion and recommendations were drawn out in line with the cons and lessons learned which would play positive roles in ensuring that a successful biophilic approach is adopted to develop and build vertical and integrated farms with a goal of tackling urban heat island effects.

KEYWORDS: Biophilic, Integrated Agriculture, Urban Agriculture, Urban Heat Island Effects, Vertical Farms.

I. INTRODUCTION

Vertical farms and integrated farming are a form of urban farms located within an urban environment which have the capacity to supply local grocery stores, farmer's markets, and the community with produce and meats. These forms of innovative farming can help enhance the local soil, reduce greenhouse effects, improve air quality, and further tackle the menace of urban heat island effects. Vertical farming can be further approached with a biophilic initiative to bridge the menace of urban heat island effects on agriculture. The biophilic approach to urbanism has emerged as a way to bring nature more purposefully into cities, not just between buildings and infrastructure, but into and onto them in ways that increase the connectivity between people and nature and derive benefits from natural services and functions [1]. This process, called the 'biophilic effect' [2] relies on an intimate informational connection between humans and nature, and supports the need to introduce natural systems into the design of the built environment. The biophilic design attempts to achieve the benefits of contact between people and nature within the modern built environment [3] by integrating nature, internally and externally, into buildings, built infrastructure, and across the urban space [4]. By adopting the strategies of this design principle, creating habitats for people, as biological organisms, that restore or enhance their physical and mental health, fitness and well-being become viable [3]. In contrast, seven SDGs (Goals 1, 2, 5, 6, 10, 14, and 16) generally only benefit from biophilic design's indirect contributions. Examples include developing urban agriculture to produce food for Goal 1 Zero Hunger which is related to this study that centers on tackling urban heat island effects to develop the agricultural system and building integrated agriculture.

Vertical farming is means of urban food production that grows produce vertically instead of horizontally place. New technology such as hydroponics, aeroponics, and LED lighting has made vertical farming a new business model for people interested in food production in urban areas. The major benefits are the ability to produce more food in a tighter space, especially in urban environments, where space is a premium [4]. The concept of "vertical farming" refers to a

method of growing crops, usually without soil or natural light, in beds stacked vertically inside a controlled-environment building. It often incorporates soilless controlled-environment farming techniques (such as hydroponics, aquaponics, and aeroponics), which aim to optimize plant growth. This idea was first proposed in 1999 by Dickson Despommier, a professor (now emeritus) of parasitology and environmental science at Columbia University and the author of “The Vertical Farm: Feeding the World in the 21st Century”. He argued that traditional farming methods are ruining the planet in his book. Instead, Despommier advocated for building vertically and embracing new farming technology to grow food in glass high-rise buildings [5].

The integration of agricultural systems can provide support in help in slowing or reversing some of the detrimental environmental and economic problems associated with specialized industrial agriculture. Modern agriculture requires intensive inputs and the use of forages and other diverse crops in the crop rotation can reduce intensive inputs, while in some cases increasing crop yield, enhancing nutrient cycling, reducing plant disease, and improving soil quality [6]. These acts are typically the integration of agricultural outputs in an interdependent web providing an ecosystem of self-dependent produce. Integrated agriculture aims to guarantee the smallest environmental impact possible, preserve biodiversity and reduce risks to the health of agricultural workers and consumers, minimizing the use of synthetic chemical substances (such as pesticides and fertilizers). This type of agriculture employs a system of integrated fight that envisages the use of various instruments wisely mixed to fight parasite attacks: these methods value natural resources as well as self-regulation mechanisms of ecosystems and use chemical methods that are accurately balanced.

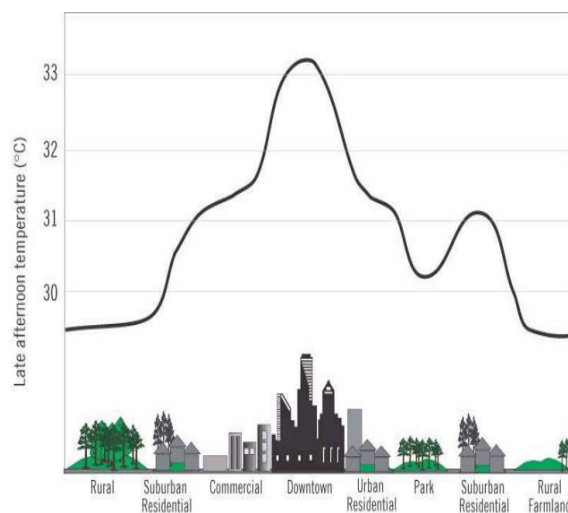


Figure 1: Profile of the Urban Heat Island [8]

The urban heat island effect is a phenomenon that refers to an increase in air temperature in urban centers compared to the rural area [7]. Three types of urban heat islands were recognized [8]. The Boundary Layer Heat Island (BLHI), Canopy Layer Heat Island (CLHI), and Surface Layer Heat Island (SLHI) were identified. The BLHI is the layer above the average height of a building. It begins at the rooftops and extends up to the point where the urban landscape has no influence on the atmosphere. The CLHI is the layer just above the surface to the top of trees and roots. The SLHI is the actual surface temperature that can be measured directly on the surface or indirectly by satellite or aircraft.

Adopting biophilic urbanism to vertical farms and building integrated agriculture will not only tackle urban heat island effects, but will also serve sustainability aspects such as social, economic, and environmental sustainability. Vertical farms have the most significant influence on the ecological aspects as the farm will perform the role of greenery spaces in the urban context, reducing the impact of urban heat island and repairing the surrounding atmosphere by the exchange of the O₂ and CO₂ between the indoor farm and outdoor neighbor. The indoor farm will depend on LED lighting to deliver the crops with the needed amount of daylight. At the same time, an environment with strong sunlight has essential resources to incorporate solar panels to transfer direct sunlight to energy to operate the farm and reduce operating costs.



II. PROBLEM STATEMENT

The proportion of the world's population living in cities is increasing dramatically. It is predicted that by 2030, the worldwide population of urban dwellers will be nearly 5 billion [9], and by 2050 it may reach 9 billion [10]. The increased rate of urbanization has important economic, social, and political implications: A large number of people residing in the cities can approach education and employment easily; they can trust the healthcare industry and can see cultural evolution. But this rapid growth of population is often integrated with communal challenges and also climate change: cities may fail to provide the basic facilities resulting in communal riots leading to inferior and undesirable living conditions. Therefore, in order to deal with the challenges of rapid urbanization, urban agriculture is in demand nowadays [11]. This paper further aims to bridge the gap in knowledge in building integrated agriculture and vertical farms with an architectural biophilic approach to tackle urban heat island effects.

III. REVIEW OF EMPIRICAL AND CASE STUDIES

Vertical farms are a type of Controlled Environment Agriculture (CEA). CEA strategies are far from new, as they emerged in the 1700s. They have traditionally taken the form of greenhouses, which have greatly contributed to the global food supply over the last decades. Vertical farms differ from greenhouses in terms of their height. Indeed, a vertical farm can be simply perceived as a stack of greenhouses on top of each other. Therefore, for the same amount of ground space used, the plant yield is multiplied by the number of floors of the vertical farm. The higher the vertical farm, the more products it yields, albeit with the same footprint. Consequently, they are now capable of producing millions of tons every year [11]. The author also laid out some technological methods used in adopting the vertical farming

1. The first one, hydroponics, consists of growing plants on a neutral and inert substrate (e.g., sand, clay, and rock material), which is regularly irrigated by a liquid fortified with minerals and nutrients that are necessary to sustain plant growth. Hydroponic systems use 60-70% less water than traditional outdoor agriculture. They are widely employed by hundreds of thousands of commercial greenhouses and vertical farms throughout the world.
2. The second process of vertical farming is aeroponics, through which plants are grown without the use of any soil (or soil replacement): their roots, hanging down in the air inside a closed container, are exposed to a fine mist of nutrient-laden water, regularly sprayed through a nozzle. While this is a relatively new method for growing edible plants – it was first developed in 1983 – it is increasingly employed by commercial vertical farms such as Aerofarms and Tower Garden in the US.
3. Finally, a hybrid method, aquaponics, integrates fish production into the hydroponic growing scheme. More precisely, it uses fish waste as a nutrient source for the plants after treatment, operating as a closed-loop ecosystem for indoor farming. However, this system's complexity and high cost hinder its widespread use. The former two methods are the most common forms of CEA.

The author further highlighted the challenges facing the realization of vertical farming which are generally –

- i. First, the question of training and indoor farming skills is very important. Commercial vertical farms operate like any other business, and there are numerous reasons why businesses fail. They require constant oversight of all aspects of the growing environment, as well as employing skilled and experienced staff, who can identify and correct problems in the growing system.
- ii. Commercial viability is definitely a challenge for vertical farms. There is however great hope that it can become sustainable on a large scale. Some have suggested that the energy cost of running a vertical farm makes it difficult to realize a profit. However, as the price of electricity and LED lights become cheaper, the profitability of vertical farms will undoubtedly increase.
- iii. Opposition from city dwellers and politicians to urban agriculture remains common. Many assume that due to the dense, crowded, contaminated environment of cities, these are not appropriate spaces for vegetable growth.

Vertical farming, however, has yet to be realized because it would require significant technological breakthroughs with regard to energy consumption and lighting. A prototype of a five-story farm would cost between \$20 million to \$30 million and most authors assert that most of the financing should come from private sources and clean-tech investors with a good business development strategy in urban farming.



Figure 2: The Living Tower is an urban vertical farm concept associated with a residential and business campus ©SOA Architects [6]

A study [13] conducts a literature review to discuss biophilic design as a theoretical framework to interpret ‘nature’ in architecture. The review identifies and compares the key frameworks of biophilic design and explains their major elements. The benefits were further analyzed (e.g., enhance health, well-being, productivity, biodiversity, and circularity) of biophilic design in achieving sustainability, as framed through the UN Sustainable Development Goals. The results indicate that biophilic design is more complex and richer than the mere application of vegetation in buildings; it broadens the variety by encompassing different types of nature from physical, sensory, metaphorical, morphological, material, and to the spiritual. Moreover, knowledge gaps are identified to motivate future research and critical reflections on biophilic design practices.

The world’s largest indoor vertical farm, AeroFarms, is located in Newark, New Jersey, and grows more than 2 million pounds of greens per year without sunlight, soil, or pesticides. Instead of using a huge quantity of water to grow plants, the Aero Farms system sprays nutrient-rich mist onto the plants. Seeds are sown, germinated, and grown on reusable sheets of cloth and are stretched out over trays stacked vertically. LED lights are used instead of the sun, and the exposure is controlled depending on the maturity of the plant [14]. Rob Laing founded Farm One in the year 2016 in order to grow rare and hard-to-find produce for chefs and restaurants in the middle of New York City. The first farm was set up at the Institute of Culinary Education (ICE) in downtown Manhattan, and the second farm is in Tribeca. It uses hydroponics and LED lights and aims to grow rare produce every year. The company supplies rare herbs, edible flowers and microgreens to some of the best chefs in New York [15].

One of the world’s first commercial vertical farms named Sky Greens was built in Singapore. This vertical farm produces one ton of vegetables every other day. Large varieties of tropical vegetables like Chinese cabbage, spinach and lettuce are grown. Sky Greens uses a hydraulic system called “A Go-Gro,” which consists of 6-m-tall hydraulic water-driven A-shaped towers. Each tower contains 22–26 tiers of growing troughs; and is spun around the aluminum frame at a speed of 1 mm/sec for steady radiation of sunlight, proper airflow, and irrigation for all the edibles growing in the tower. The rotation system is powered by a unique gravity-aided water-pulley system that uses only 1 L of water per 16-hour cycle, which is collected in a rainwater-fed reservoir. The water used in powering the frames is recycled and filtered before returning to the plants. The organic wastes produced on the farm are composted and reused [15].

IV. DISCUSSION OF FINDINGS

Sustainable approaches like the Biophilic approach to the secure food system are applicable in vertical farm projects. This innovation can be a reality after a series of design considerations related to the climate, technical studies on the availability of needed resources, and advanced technological investigations to adopt suitable technology depending on the environmental situation [16]. It has substantial impacts on the economic, social, and environment of the city. It is challenging to apply traditional agriculture systems and methods for the natural environment and is not applicable in all agriculture environments. In many cases, it causes failure in the soil due to cultivation, irrigation, and additives (agrochemicals). Moreover, the intergovernmental panel on climate change (IPCC), pointed out that the



current practiced food system (traditional farming) causes 1/3 of GHG global emissions, which has a detrimental impact on the environment and natural life cycle. Thus, initiating a sustainable food system will diminish GHG emissions, while building solid and healthy communities [17]. On the other hand, the indoor integrated agricultural system will consequently have a positive impact on food production as it will not be affected by the harsh outdoor weather and will grow safely year-round. The integration of the food source with an urban fabric will lead to making each municipality have a secure local food source. The use of the highly sustainable design application in the vertical farm building will help improve the surrounding environment in the city and make it more sustainable and healthier to live in.

V. CONCLUSION AND RECOMMENDATIONS

Vertical farms that create sustainable systems within urban areas would solve several problems associated with environmental demolition. Technology plays a vital role in the vertical farming process; it can merge the agricultural procedure with the urban environment by employing a controlled indoor environment. By moving agriculture to urban life, nature will heal up, and restore what was damaged by traditional agriculture. Due to the absence of the soil needed in vertical farms, it is an excellent opportunity for countries that suffer from unsuitable soil for farming to produce local food. To adopt this technology, this research further recommends that the following points should be considered and not overlooked –

1. Schools of agriculture should offer specialized degrees in urban farming, which could not only train city dwellers to work in urban farms, but also stimulate them to work in them, further driving growth in the sector.
2. Diversifying the crop selection could further contribute to the success of vertical farms; since most today focus on highly productive leafy green vegetables
3. As the industry matures, indoor farming gains visibility, and the advantages of vertical farming become obvious, it will get easier to get approval for their construction from city planners and other stakeholders, so that vertical farms will gain a lasting place in urban centers.
4. Urban agriculture has been growing, but vertical farming; has been lagging as it requires more expensive technology. Vertical farms remain relatively expensive to build, maintain, and endure. Hence, the urban-financial models adopted in places such as Japan, Singapore, Taiwan, and the US, where people have high purchasing power should be studied and adopted by poorer populations like India, Africa, South East Asia, and, Latin America.

VI. DISCUSSION OF FINDINGS

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