Exploring Prospects of Urban Agriculture in Indian Built Environment For Self-Sustainability

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ABSTRACT
There is an increasing demand on metropolitan regions, and the cities may have ecological consequences that extend beyond their political borders, consuming resources and producing wastes that have global implications for environmental and social well-being. Since the 1990s, urban biogeochemical cycles have been studied, and urban planning and design practises have applied this knowledge and investigated many approaches for restoring biological functionality to the built environment. The load on rural production structures to meet expanding demands for fruits and vegetables in urban markets based on the above facts and needs may be answered by establishing a self-sufficient urban system. This research aims to identify and propose a sustainable system of agriculture in urban societies through Case Study of an apartment society in India. A mixed approach research methodology is adopted. Qualitative data is collected through case study of an apartment building and quantitative data collection includes closed ended questionnaire survey from residents of society, to understand their perspective towards sustainability issues. This research concludes that the occupants are aware of global warming and sustainability issues and are willing to participate in promotion of urban agriculture. Finally, a design was proposed for upgrading the existing apartment building into a self-sustainable society by exploring the urban agricultural possibilities serving the needs of an urban society.

Keywords: Rooftop gardening, container gardening, reuse, land utilization, social well-being

I INTRODUCTION

The Food and Agriculture Organization statistics reported that more than 6 billion people would live in cities by 2050, nearly doubling the current population of 3.5 billion. According to the United Nations' state of the world population report from 2007, 40.76 percent of India's population will live in urban areas by 2030 [1]. Urban agriculture (UA) is referred to as growing plants and raising livestock, including aquaculture and apiculture, as well as harvesting, processing, and distributing food and non-food products made from aromatic and therapeutic herbs. These could occur on different scales within urban and peri-urban settings. Increased per unit food production in available land would be required to meet the growing population and demand for food. It is believed that 80% of the food produced in the globe ends up in cities, where farmland is rapidly disappearing. In urban India, decorative plants are commonly found in public spaces whereas the creation of edible landscapes and green infrastructure is yet to be explored. Urban planners and landscape architects can properly utilise public spaces and provide inhabitants with opportunities to appreciate nature's richness, that in turn will produce revenue for local governments while also attracting urban agriculture tourists. To begin, public institutions and workplaces, particularly those that provide residential services, could be encouraged to develop green corners in their facilities by cultivating greenery that is regularly consumed by inhabitants. Agriculture, which is primarily connected with rural practise, is rarely mentioned in urban design principles. For example, agriculture is mentioned in India's Urban and Regional Development Plans Formulations and Implementation (URDPFI) criteria for creating city plans. However, there is limited support for incorporating agriculture into city designs, despite the fact that UA and vertical farming are highlighted as climate mitigation and adaption techniques. The Green India Mission is one of eight goals outlined in the National Action Plan on Climate Change, with the goal of increasing forest and tree cover, restoring degraded lands, and promoting agro-forestry in urban areas. It is an opportunity to reflect on and change the way we produce and consume. The professionals in the fields of architecture, planning, agriculture, social sciences, and private developers, together with the citizens must co-create productive green urbanisation for a sustainable future and self-sustained societies [2].

For the urban population, UA contributes to food and nutrition value, livelihood and income production, and poverty alleviation. The benefits include having access to a wide variety of healthful foods, saving money on food purchases and generating income, and having a steady supply of food (food security). UA can be either land-based or hydroponic, depending on land availability. According to the World Health Organization (WHO), the average person consumes 360 to 400 grammes of vegetables each day (i.e. per-capita consumption). However, compared to the worldwide average, land availability in countries like India is lower [3].

II LITERATURE REVIEW

India generates 62 million tonnes of garbage (mixed waste includes both recyclable and non-recyclable waste) every year, according to the Press Information Bureau, with an annual growth rate of 4% [4]. Organic trash (all types of biodegradable garbage), dry waste (or recyclable waste), and biomedical waste are the three major categories of waste generated (or sanitary and hazardous waste). Every year, India produces 277.1 million tonnes of solid garbage, which is expected to rise to 387.8 million tonnes by 2030. Small towns and metropolis generate very different amounts of waste per person per day. While inhabitants in small towns can accumulate roughly 0.17 kg per person per day, city dwellers can accumulate about 0.62 kg per person per day [5].

The new guidelines for Municipal Solid Wastes (Management and Handling) require waste to be separated at the source in order to channel waste into riches through recovery, reuse, and recycling. Before handing over waste to the collector, waste generators must now separate it into three streams: biodegradables, dry (plastic, paper, metal, wood, etc.) and domestic hazardous waste (diapers, napkins, insect repellents, cleaning agents, etc.) [6].

The practise of cultivating, processing, and retailing food and food products in and around urban areas is known as urban agriculture, urban gardening, or urban farming [1]. Urban agriculture is a growing movement addressing a variety of urban sustainability goals, such as; food security, food equity, efficient food supply chains, storm water management, urban heat island mitigation, and waste management with compostable waste [7,8,9]. In terms of environmental and economic performance, constructed urban ecosystems differ from traditional ecology subjects, but they are direct consequences of urban planning and design intentions, which are significant and verifiable issues for understanding and improving connected human-natural systems [10].

Table 1
The different types of urban agriculture

Type	Location	Benefiters	Scale	Advantage	Revenue
Kitchen gardens	Vegetable and herb cultivation in and around the home	Small family on a daily basis	Small scale and Self-sustained to meet their daily needs	• used for domestic purposes alone. • reduce reliance on market supply	No surplus to sell
Rooftop gardening	Growing vegetables and herbs on the roof of a house or apartment	Single family or a group of families	Small scale and Self-sustained to meet their daily needs	• make use of the empty space on the rooftop • lessen reliance on the markets	No surplus to sell
Vertical farming	The cultivation of crops in layers that are piled vertically. Observed in high-rise buildings, abandoned old buildings, and on walls	Neighbourhood	Medium to large scale	• higher crop production per unit space used. • increase the minimum space available for vegetable production.	Surplus to sell
Street landscaping	Vegetables can be grown in the vacant space along the side of the streets, neighbourhood, unoccupied land along public roadways etc.	Neighbourhood	Medium scale	• Utilization of vacant spaces	The veggies grown here can be sold in the neighbourhood or at adjacent markets.
Greenhouse gardening	Huge unoccupied spaces in and around the neighbourhood	Single person, a community, or a business	Medium - large scale	• Produce high-value crops under controlled environment • generate more produce than open-field cultivation	High-value crop production
Wasteland utilisation	Unoccupied and abandoned government areas for fruit and vegetable cultivation.	Interested farmers	Medium to large scale	• lower shipping and commission costs	Sold in local marketplaces.
Container gardening	Using waste items (plastic bottles, torn shoes, broken containers such as drums, buckets, mugs) to grow food in containers	Family or a group of families	Small scale and Self-sustained to meet their daily needs	• reducing, recycling, and reusing waste items that contribute to pollution in cities	No surplus to sell

- **Types of urban agriculture -** Urban agriculture can be divided into a variety of forms based on the size of the area, the type of product produced, and the many methods and mediums utilised to cultivate it. The following types of frequent urban agricultural types [1], can be summarized as shown in Table 1:
- **Types of vegetation in Indian climatic**
- **Condition**

An investigation was carried out to identify vegetable species that can be easily grown by habitants at small scale in Indian climatic conditions. A summary of such species is presented in Table 2 [11,12].

Table 2
Suggested vegetation in Indian urban cities

S. No.	Name of Plant	Suggested Area of Growth
1	BOTTLE GOURD	6 inch deep
2	SPINACH	6-8 inches deep
3	ONION LEEKS	at least 10 inches (25 cm.) deep, but should be several feet (1 m.) wide
4	BITTER GOURD	12 inches deep and 10-inch width
5	LIME	at least 12 inches deep
6	TOMATOES	12-inch (30 cm.) deep pot with the same diameter is suitable for most plants
7	CAULIFLOWER	12 inches deep
8	CABBAGE	12 inches deep
9	LETTUCE	12 inches deep
10	BEET ROOT	12 inches deep
11	POTATOES	12 inches deep
12	ONIONS	12 inches deep
13	CARROTS	1.5 - 2 ft deep
14	EGG PLANT/BRINJAL	1.5 - 2 ft deep
15	PEPPERS	1.5 - 2 ft deep
16	LONG DAIKON RADISH	wide (either long or round with a large diameter) and at least 24 inches deep

A study was also conducted to identify plant species that are easy to grow in smaller plastic containers such as plastic bottles, and it found that herbs such as: Basil, Mint, Coriander, Lemon Grass, Garlic; Small seasonal flowering plants; Succulents, and Money plant can be grown [13].

(i) Advantages of urban agriculture

Bhat et al. [1] have summarized the benefits of urban agriculture as follows: **1) Nutritional and quality food:** The period between transit, storage, packing, and processing is essentially non-existent, resulting in fresh and high-quality produce delivered right to your door. The vitamins and minerals loss are minimized and the product is more nutritionally dense as the processing is less, **2) Health benefits:** The probability of consuming fresh, healthy produce is increased as fruits and vegetables are grown in and around human settlements. As urban garden crops are less exposed to pesticides, heavy metals, and sewage waste, food contamination is lower, which has a favourable impact on human health. **3) Environmental justice:** Urban farming has a number of environmental benefits, including reduced plastic pollution due to recycling and reuse of waste plastic containers, reduced air pollution, and reduced water pollution, among others. As a result, urban agriculture is doing great justice to the environment in an era of climate change where urban areas are highly resilient. **4) Efficient utilization of time (develop as a hobby)**: In this age of information and technology, people can take up agriculture as a pastime and devote important time to learning about crop and animal husbandry, beekeeping, mushroom production, and aquaculture. Children can also be educated and encouraged to take up farming as a pastime. **5) Efficient utilization of land and resources**: Vacant and abandoned lands in metropolitan areas can be used for agriculture by allocating lands to needy and motivated farmers, thereby assisting them in earning a living as well as at the same time urban green trash can be used as manure, kitchen and bathroom waste can be used for irrigation, and biodegradable garbage can be composted, among other things. **6) Social and emotional wellbeing**: community-based urban farming encourages social connection among residents; children can learn about agriculture; people can share their produce with neighbours; and social interactions will improve with time. Agriculture as a pastime is a great way to improve mental and physical health while also improving the emotional well-being. **7) Economic benefits:** Urban agriculture gives jobs and income to low-income women and other marginalised populations. Women in cities might spend their time farming and earning money to help support their families financially. The poor and disadvantaged can be given waste government lands on which to practise farming and earn a living and the profit for production goes straight to the grower because the chain is small. Further, Luckett, K. 2009) discussed storm water management as another benefit of UA as they utilize an unused spatial resource and keep the water at its source. Green roofs and rooftop farms hold water during heavy rains, delaying runoff and increasing the amount of water returned to the atmosphere via evapotranspiration. The runoff rate is most affected by the depth of the substrate. In general, the lower the run-off rate, the deeper the substrate layer. On a yearly basis, the storm water retention capability of intensive green roofs (median substrate depth: 6") can range from 75 percent to

45 percent for extensive green roofs (median substrate depth: 4") [14].

Proksch [15] adds that rooftop farms with continuous surface beds and deep substrate layers contribute insulation and thermal mass to buildings, allowing them to perform better and mitigate temperature changes. However, container rooftop gardens with a small proportion of growing area coverage and uneven substrate distribution across the roof area, as well as rooftop gardens with elevated beds, do not give these building performance advantages. When compared to conventional roofs, the air temperature above vegetated roofs can be up to 30°C cooler [16]. The intensive green roofs and planted rooftop farms could make a substantial influence to the air quality in cities as urban carbon sinks [17].

(ii) Risk associated with Urban Agriculture

Urban agriculture has certain disadvantages also as the producers frequently operate without obtaining permissions. Many localities do not provide public support or oversight to the sector because it is supposedly "invisible". Urban agriculture has health and environmental dangers, including the possibility for contaminated soil and water, as well as the improper application of pesticides, fertilisers, and raw organic manure, which can pollute water supplies. Significant reduction in infiltration of precipitation into the soil that may lead to depletion of groundwater. Higher production costs, difficulty managing pests and weeds, and fluctuating weather are the main challenges faced by urban farms [1]. All these issues need to be addressed for successful practice of UA.

Rooftops in our cities offer a huge amount of currently underutilised area. Green roof technology is becoming regular practise in many places throughout the world, transforming these urban rooftops into an environmental and ecological resource. A new type of green roof - rooftop farms - is emerging as a result of the increased interest in urban agriculture [15].

The cost of installing green roofs is determined by several factors, including the location, availability of green roof construction techniques, substrate depth, composition, and vegetation kind. Green roofs can cost up to three times more than low-cost, conventional roofs (with a lifespan of only 15 years) [18]. For a long-lasting product with minimum care and environmental benefits, a higher initial investment for green roofs will be justified many times over. [15].

(iii) Considerations for Design of roof top

Green roofs are made up of three layers: vegetation, a substrate (or growing media) layer that holds water and anchors the vegetation, and a drainage layer (or reservoir board) that drains or stores surplus water [14]. These water-carrying layers are separated from the actual roof structure by a root barrier and waterproofing membrane, which comprises of an insulating layer and the roof slab or structural support. The environmental qualities of the roof, the plant selection that may be grown, and the weight and thus the structural requirements of the roof are all determined by the depth of the substrate. The substrate, which is defined by its composition, depth, and weight, is the most important factor in the success of a green roof or rooftop farm. Substrate is often consisting of 80 percent (or more) mineral, generally lightweight aggregate, and 20 percent (or less) organic material for long-term sustainability [19]. The porous mineral components help to reduce weight, store water, and break down slowly enough to keep the growing medium's volume constant. The organic components quickly degrade and become available to the plants as nutrients and must be renewed and recharged on a regular basis with fertilising compost or organic matter [15]. As a result of the reduced heat transmission into the building, the building's performance and energy efficiency improve. This is especially noticeable during the hot summer months, and it reduces the energy demands for the cooling system in the structure [17]. ISO certified fabric bags, specified as 48x24x12 Inches (4x2x1 Ft) - 220 GSM HDPE Rectangular Grow Bag, are easily available in market for roof terraces [20].

III RESEARCH METHODOLOGY

The study examines the available secondary data through existing literature to understand the importance of green roofs, and possibilities of transforming the existing terraces and vacant spaces into green spaces for sustainability. The research initiates with questions like; what is the concept of UA? What are the ways of promoting urban agriculture? How to transform an existing area into self-sustained green area? After thorough investigation of literature, a framework was designed to carry out further research. Mixed approach was adopted including both qualitative and quantitative data collection through case study and close ended questionnaire survey. An apartment society in Indian city was identified as case study. The criteria for selection of case study were convenience based. Qualitative study of case study included data collection related to the apartment, including the site plan. This plan was finally used for transforming the spaces into green spaces from the perspective of UA. The questionnaire survey was designed to collect data from the residents of this society, with the aim to understand the perspective and responsiveness of residents of the society.

IV DATA COLLECTION AND ANALYSIS

The selected case study is G+3 apartment building having 72 flats, with nearly 60% occupancy rate. The close ended questionnaire survey comprised of simple questions that aimed to understand the current scenario of waste generated and collection, as well as the acceptance of UA in their residential society. The survey form was manually distributed to each of the occupant and the response rate was 66% as some of the occupants were not available at the time of data collection. The total number of residents (including all family members) in the society is approximately 252. 50% of the occupants have lived in the apartment for more than 10 years. 100% residents agree that the garbage is collected from door and 59% of them agree that they dispose segregated waste. 95% residents were aware of global warming and sustainability issues. 45% occupants accepted that approximately 1-5 plastic containers including bisleri/cold drink bottles were weekly disposed by them. This implies that approximately 25-30 plastic bottles are weekly disposed of. The garbage collectors from municipal corporation collect garbage every morning, after door-to-door collection by staff of the apartment. The occupants were also enquired about their preference for participation in development of roof terraces, gardening, growing vegetables for daily use in lawn, or they do not like the idea. The responses of occupants are presented in Figure No . 1.

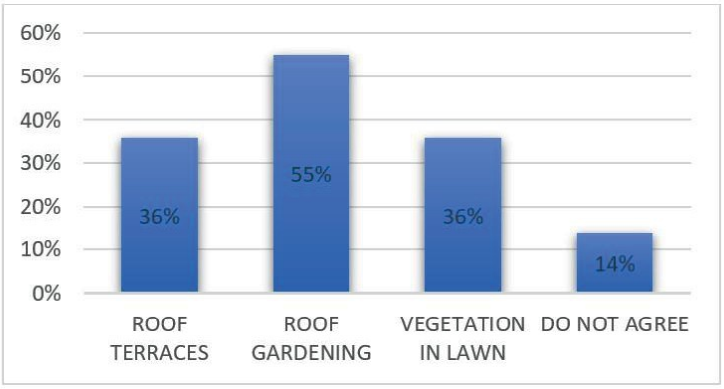

Fig. 1 Willingness for participation in urban agriculture

The positive response of the occupants for waste segregation and willingness towards participation is encouraging towards promotion of UA in the residential society. A design proposal is prepared for the existing apartment building to convert it into green apartment and also promotes UA to some exten.

V THE DESIGN PROPOSAL

The existing site plan is shown in Figure No. 2. Presently, there are two types of underutilized open spaces on the site, in the form of paved court and ill-maintained green covered lawn. Apart from these, there is huge potential for developing the terraces, as the covered area is considerable.

Fig. 2 The existing site plan.

Based on the willingness to promote UA by residents, a small-scale proposal has been prepared that can be adopted in phased manner for the introduction of roof terraces, gardens as well as for growing vegetables on small scale. This includes transformation of roof terrace, porch terrace, boundary walls and front lawn into green spaces, as shown in Figure No. 3.

Fig. 3 The proposed site plan

The estimation of cost is beyond the scope of this research. A thorough investigation shall be further required for preparing the estimation of the entire project. No roof terraces conversion for growing grass is proposed as the building is 15+ years old structure. The focus was to create pleasant green spaces without disturbing the structure, as it may not have designed for extra dead load. Hence, light weight containers have been proposed for roof terraces, which are of reasonable cost.

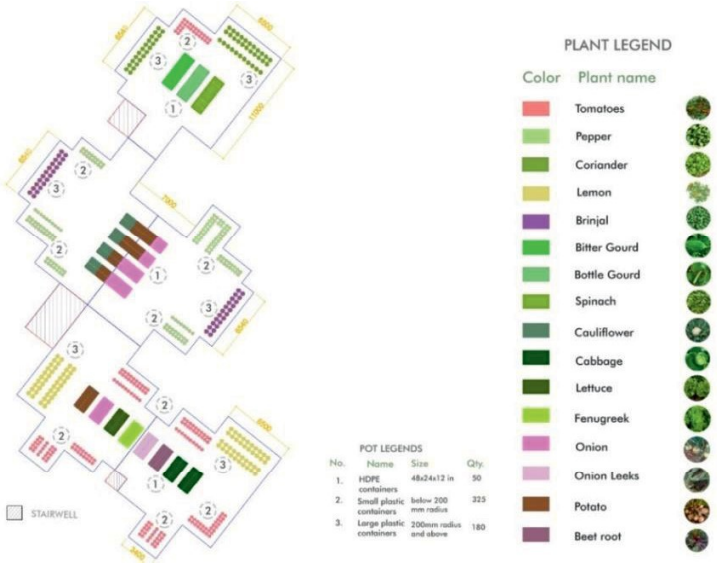

Fig. 4 The proposed vegetation on roof top

Figure No. 4 demonstrates the design proposal for roof top farming, where varieties of vegetables that can easily be grown within these containers, in the region have been proposed. The design has been created in such a way that the development can take place in a phased manner, keeping in mind the acceptability and participation from the residents, so that the change is gradual and acceptable in terms of finance and physical efforts.

Fig. 5 The views of proposed design for roof top farming and re-use of waste plastic containers as planters

VI GENERAL RECOMMENDATIONS

General recommendations are suggested with the aim of promoting this proposal and also increasing the participation of residents in transforming their society into a self-sustained society. A committee can be formulated within the societies with active participation, roles and responsibilities of Senior citizens and children below the age of 12 years. As it is observed that people of these age groups are likely to contribute more time and energy towards these activities. The communication among these age-groups shall enhance the social and emotional well-being of the residents that is often ignored in an urban setup. Such community-based urban farming has high potential for encouraging social connection among residents and giving the children an opportunity to learn about agriculture, as stated by many researchers [1]. The government agencies and development authorities can mandate the neighbourhoods to dedicate some percentage of their underutilized open area for urban agriculture. This shall in turn create job opportunities for low-income groups, marginalised populations, poor women in cities as they can earn money to help support their families financially.

VII CONCLUSION

The study aimed at identifying the potential for urban agriculture in existing Indian societies for the promotion of Green India Mission on small scale by efforts of urban citizens of India. A thorough study of secondary data available was conducted to identify the types of urban agriculture and possibilities of vegetation that can be grown at small scale by common man. An apartment building was identified for case study and qualitative as well as quantitative data was collected from occupants to examine the potential of urban agriculture on small scale by residents of the society. it was observed that they are aware of the issues like sustainability and are also willing to participate in the development of roof terraces, gardens and growing vegetation on small scale. Further a proposal was prepared for existing apartment society that focussed on the introduction of vegetation on small scale in phased manner so the residents re-utilize the wet waste generated by themselves as compost and develop their building into self-sustained society to some extent.

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