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Urban Agriculture: A Review of Prospects and Challenges

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Abstract—*Urban agriculture is defined as an industry that produces, processes, and markets food, in response to the daily demand of consumers within a town or city. It is located either within or on outskirts of an urban settlement. This paper shall bring forward an overview of the concept and practices related to urban agriculture worldwide. Urban agriculture practices are gaining importance because of climate change, migration of rural population and is focused on sustaining food security in urban areas. Social, environmental and economic dimensions of urban agricultural practices are also discussed to analyze the acceptance of the concept. This paper aims to review the research conducted and popular practices in different parts of the world. The two categories of urban agriculture are identified; Controlled Environment agriculture and Uncontrolled Environment Agriculture, which shall be discussed in detail. The paper discusses the concept, issues and challenges of Zero acreage farming, as it was found to be the most popular practice. The study can help in analyzing the Indian scenario and implementation of the ideas in Indian context.*

1. INTRODUCTION

The United Nations has predicted that the world population is projected to pass the 9 billion mark by 2050. More than half of the world's population lives in cities, and by 2030, this figure will increase to more than 60 % [1]. According to UNFCCC, cities consume more than two-thirds of the world's energy and account for more than 70 % of global CO2 emissions in the present scenario, which means that they can play a leading role in decarbonisation by decreasing CO2 emissions. There is a need to find out sustainable solutions for food, water, energy, and transport of food or waste and they should be integrated components of a city's climate change adaptation [2]. It seems difficult to stop the increasing urbanization and therefore there is a need to explore new approaches that should contribute to delivering fresh, local food for cities [3]. It is a challenge to design urban landscapes for a wide range of functions. Besides the high cost of land in urban areas raises questions for food production in context of land availability and accessibility [4].

2. URBAN AGRICULTURE

Urban agriculture as "an industry that produces, processes, and markets food, largely in response to the daily demand of consumers within a town, city, or metropolis, on land and water dispersed throughout urban and peri-urban areas" [5]. Urban agriculture as "an industry located within (intra-urban) or on the fringe (peri-urban) of a town, city or metropolis, which grows or raises, processes, and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products, and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area"[6].

Different types of farms have been identified as [7]:

1. Backyard gardens or private gardens
2. Brown fields and green spaces
3. Rooftop farms
4. Pick your own (PYO)
5. Urban agriculture on the urban fringe
6. Aquaponic farms
7. Agroparks

8. Vertical farming

Urban agriculture has been explained into two categories[8]: Controlled Environment Agriculture (CEA) and Uncontrolled Environment Agriculture or open space agriculture (UEA). UEA includes community gardens, vegetable gardens and rooftop farms. CEA includes any form of agriculture where environmental conditions. These conditions have been identified as, light, temperature, humidity, radiation and nutrient cycling etc. CEA is integrated with urban architecture or green infrastructure. CEA methods include zero-acreage farming (Z-farming), greenhouses and vertical farming/ sky farming. A comparative analysis of urban agriculture methods has been presented in Table 1.

Table 1: Comparative analysis of UEA and CEA [8]

	UEA	CEA
Main Inputs	Low Fertilizer Organic Soil	Fertilizers Pesticides Natural light (seasonal) Artificial light Water-based growing solutions
Application	Urban Peri- urban Small-large scale Use of macrophytes to clean water and feed fish	
Major risks	Exposure to pollutants Open space: uptake of soil-based heavy metals; human and animal manure	High energy inputs Artificial fertilizers Capital intensive Non-labor intensive Vertical farms: plant viruses and disease; high energy inputs
Major benefits	Storm water management Absorption of solar energy Compost organic waste Meet organic requirements	High crop yields Recycle organic waste

Zero Acreage Farming

As it is already stated that the urbanization is unavoidable, the concept of Z Farming can be envisioned as a solution for sustainable cities. But the integration of these areas in cities is to be examined in the light of their acceptance as well as feasibility.

The term ‘‘Zero-acreage farming’’ (Z-Farming) is used to describe all types of urban agriculture which can be understood as non-use of farmland or open space. These might also include the installation of rooftop gardens, rooftop greenhouses, edible green walls, or any other innovative forms such as indoor farms or vertical greenhouses [2]. Z farming is challenging because it requires technical solutions for water, energy, or waste recycling. These issues are of less concern when compared with ground-based agriculture. It creates need for integration of architecture and technology with production of food and therefore becomes a challenge as compared to other forms of urban agriculture. Three main types of Z Farming have been identified [2] as; rooftop gardens/rooftop farms, rooftop greenhouses, and indoor farms. However, some other types exist at conceptual level and they include edible green walls as an outdoor application and vertical greenhouses, which are stacked greenhouses or vertical farms constructed as multistory greenhouses.

3. SUSTAINABILITY ASPECTS OF URBAN AGRICULTURE

Sustainability issues have three dimensions; Environmental, Social and Economical. It is a challenge to satisfy all of these aspects fully.

3.1 Environmental Issues

The environmental issues focus on identification and technical development of environmentally sustainable solutions for urban agriculture. There is a lot of potential from environment point of view. The designers, planners, architects and agriculturalists have to come together for an integrated planning approach to develop such architecture and urban landscape. The development of urban agriculture can also reduce the distances between producers and consumers. The energy currently employed in transportation and packaging can be saved. The harmful emissions released during transportation can be reduced to great extent if food is locally available. It is expected that the CO_2 emissions shall be reduced. Urban agriculture can also save on water resources. Rain water harvesting and reuse of gray water can be employed. The use of rooftop gardens has a potential to use four times less water than conventional farming, on comparison for the same yield of vegetables utilizing hydroponics instead of soil [9].

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Rooftop gardens have a potential in terms of energy savings also. They act as insulating layer to the building [2]. The installation of a rooftop garden could result in a saving of 1–15 % of a building's annual energy consumption [10,11].

The organic waste generated in the cities such as annual waste, plant residues, food industry waste and household waste can also be used in urban agriculture [12].

3.2 Social Issues

Z farming has potential for improving the situation of urban citizens in terms of access to locally grown food. These practices have a wide spectrum ranging from community-based rooftop farming to commercial production which can be done with the help of high-tech green architecture. Such practices can help in improving the food situation and contribute in the welfare of poor residents also, at least in the neighborhoods [2]. It is also observed that such facilities can be experienced as teaching spaces, contribute to environmental education, and also provide opportunities for practical learning [13].

Certain health risks have also been identified by researchers in case the irrigation is carried with waste water that is not treated properly, or if it contains heavy metals because that will increase the probability of contaminated soil and water. There is a need to manage such practices under great supervision.

3.3 Economic Issues

According to many researcher's food production within the city can affect the local economy because a lot of food business prevails in the cities. The commercial farms are set up for the purpose of profit and such facilities may be combined with commercial kitchens to create value-added food products to sell [14]. Many vegetables such as, leaf crops (spinach, lettuce, salad greens), vine crops (tomato, cucumber, pepper, squash, beans, zucchini) or culinary herbs (basil, parsley, chives, coriander), can be grown economically with hydroponic techniques [15].

Certain limitations have been identified such as poor availability of sunlight especially in densely populated areas and high investment cost for creating such integrated systems [2]. The scope of such production is yet to be investigated in depth from all perspectives and justified.

4. INTERNATIONAL PRACTICES

Many practical examples of non-commercial rooftop gardens have been identified all over the world. North America has one of the large-scale or commercial rooftop farms. A well-known example is "Brooklyn Grange" in New York which uses the roof of a former industrial building for urban farming. Another rooftop greenhouse is "Lufa Farms" in Canada. It is said to be the first commercial rooftop greenhouse. "Gotham Greens" having an area of 1400 m^2 is a greenhouse in New York which uses hydroponic production techniques. In Singapore, "Sky greens" established a multi-story greenhouse for urban food production. The "Urban farmers" in Switzerland have also created a business prototype for European cities. The Universitat Autònoma de Barcelona (UAB) in Spain established an "RTG-Lab" for research purposes [16].

5. BARRIERS IN IMPLEMENTATION

Certain barriers have been identified, as mentioned in Table 2, regarding implementation of rooftop green houses [17].

Table 2. Barriers [17]

Fields	Barriers
Economical	High cost of supporting infrastructure High cost of management and investment Narrow profit margin for horticultural products Investor distrust of new products Long-term repayment Labor availability
Technological	Technological complexity Complexity of adapting existing buildings / Rehabilitation Building overloading Possible need to strengthen the structure Lack of simulation models for these agro-architectural hybrid systems
Environmental	Reduction of surface area for rooftop solar panels Environmental impact of the greenhouse construction materials
Social	Incompatible uses Need to train qualified personnel

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6. TECHNICAL ASPECTS

The idea of urban agriculture brings with it the demand for new technology and building materials especially if it is to be integrated with the building. Energy is required for growth of plants in the interiors because the access to sunlight may be limited and artificial daylight may be required. It is a challenging task to incorporate rooftop gardens with the building infrastructure [2]. Some of the technical issues are discussed here [18].

6.1 General Structure

The structure of building has different floors like; production floor, laboratory floor, carousel floor, system floor, poultry floor, and supermarket [19]. Such structures provide fresh food to consumers at reasonable price because the cost of transportation and storage is cut down. The skin façade of such building is made of a self-cleaning and clear material for example ETFE (Ethylene Tetra Fluoro Ethylene), which has a transparency. This enhances the amount of sunlight that enters the building. It is found that materials like ETFE has just 1% of an equal-sized piece of glass weight but on the contrary it permits for 95% light transmission [18].

6.2 Lighting

The main source of lighting is natural light from sun but other options are also required at times like artificial lighting, depending the geographical location. The design and angles of exposure for sunlight are critical issues that need to be handled by designers in collaboration with the agriculturists [18]. LED (light emitting diode) or HPS (high-pressure sodium) are discussed as the available options. The normal range of light intensity utilized is 50-200 mol/m^2/s or about 4100-16400 lx including high-pressure sodium lamps. The research specifies that the amount of light required in closed space for vegetation growth is about 18 hours/day and to achieve this the windows are of the height of the floor [20,21,22]. Solar cells are also employed as renewable source of energy which add to the sustainability factor of vertical farming [18].

6.3 Water Management

Water management has been a matter of concern since decades and more due to its crisis. Good amount of water is required for irrigation purposes in open farms and some of the water is also lost due to evaporation. Besides this there is a likelihood of water contamination also. Many researchers suggest recycled water as a source of water supply for the vertical farming. Rainwater and gray water are identified as sources of water supply after suitable treatment [18,23].

Water can be retrieved back after dehumidification also and reused, as it is the water in pure form. The water that gets evaporated from plants can be collected and sprinkled again when required. It is a natural way of purifying water and helps to collect 220000 m^3 of water every year. It is experienced that this method of farming can use 1.2 times less amount of water than usual farms for production of the same quantity of crops. Countries like Saudi Arabia have been practicing these techniques [21,24].

6.4 Renewable Energy

Sun and wind are identified sources of renewable energy which can be used for vertical farming or rooftop gardens. Many such buildings are designed to use wind power through wind mills installed on roofs for converting wind energy into electrical energy. Solar panels installed on roof tops can produce energy which in turn can be used for artificial lighting through sodium lamps as and when required [18].

6.5 Controlled Environment

HVAC (Heating, ventilation and air conditioning) is the environment control system that helps in managing he temperature, air conditioning and ventilation, and moisture for vertical farming. Natural ventilation and forced ventilation are ways of dehumidifying the greenhouses. The bio-waste generated is to be managed and such waste is approximated to be 2443 tonns/year, as reported by scholars. Smart devices with sensors are also installed for controlling the environment [18]. It is a challenge to optimize resources for an efficient management of energy and yet fulfill all the mandatory requirements of urban agriculture.

7. INTEGRATED APPROACH

The high technology required for the practice of urban agriculture requires an integrated approach [18] as shown in Figure 1. Three different types of approaches have been identified as; Bottom up approach, Top down approach and Commercial approach on the basis of stakeholder's involvement in the project. According to Freeman "a stakeholder in an organization is any group or individual who can affect or is affected by the achievement of the organization's objectives" [25].

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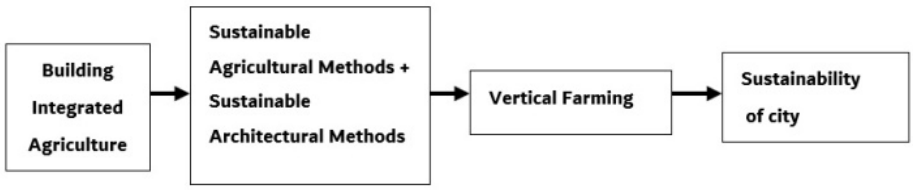

Figure 1: Integrated approach [18]

Bottom-up approach is defined as those practices that originate from the users themselves. The citizens take possession and modify spaces giving them new quality and function (that might be, agricultural, social and enhancing participation and social inclusion). Such examples are like; Jardins Partegés in Paris: the Mairie of Paris.

The top-down approach includes those plans or a project that aim to introduce urban agriculture in order to produce or sell food and modify people habits and make them aware of the importance of a sustainable production of local healthy grown food. Such cases are identified as those where public administration or an association are involved, like London Capital Growth. They develop an urban agriculture project to enhance urban requalification, education, awareness, social inclusion.

The third approach is Commercial approach toward urban agriculture. It includes practices of urban agriculture which are based on business. Such practices are common in North America. Here, urban agriculture is practiced to create new business in the field of local and Km0 food market. These examples consist of actual business or enterprises that produce and sell food products in urban contexts; like Lufa Farms, Gotham Greens, Bright Farms, and Brooklyn Grange. These are the ones which grow and sell their products to local supermarkets [26].

Each approach has its own set of challenges and benefits. Different nature of spaces and sets of technology are to employed depending upon the type of approach adopted.

8. CONCLUSION

The practice of urban agriculture has gained importance in many countries but its scope is yet to be examined in Indian urban architecture. It application and extent depends on the socio-economic conditions of the country because there are economic factors involved in the establishment. A detailed study of its scope in the light of Controlled Environment Agriculture, Uncontrolled Environment Agriculture, the Bottom up approach and Top down approach can help in identifying the scope of such projects. The integrated attempts of architects, designers and agriculturists can bring a revolution in making cities self-sustained in terms of food security.

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