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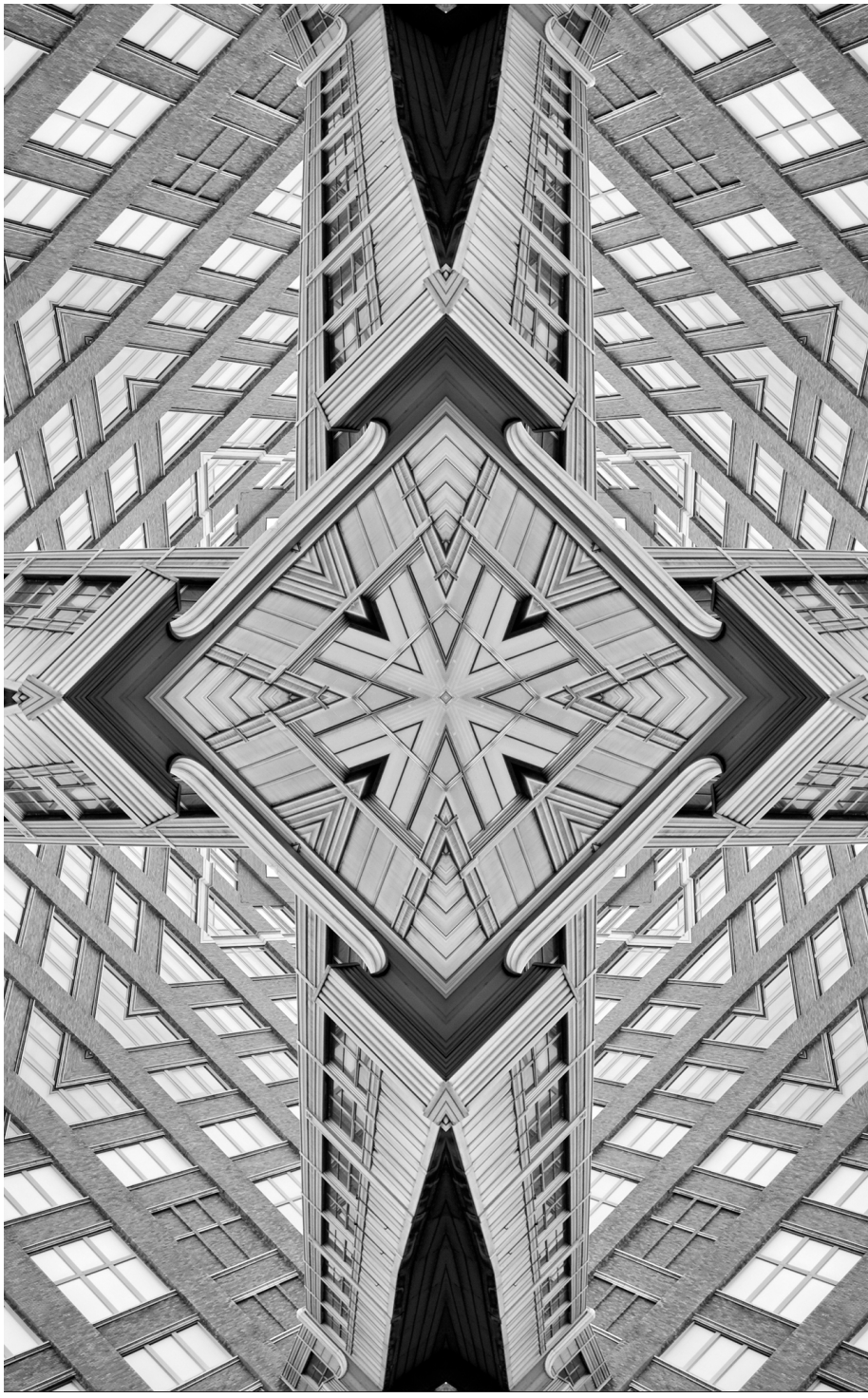

Optimising Urban Agriculture: A Pathway to Food Security in India

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Abstract

As global and urban populations continue to grow, and climate change threatens food security, it is imperative that cities—often the largest food consumers—contribute to its production through urban agriculture. Urban agriculture comprises food and non-food products grown for self-consumption or sale. Entrepreneurs, non-governmental organisations, and citizens worldwide are adopting new technologies to optimise production amid space constraints in urban areas. Urban local bodies can promote such activities through supporting land-use regulations, knowledge inputs, and awareness programmes.

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Introduction

Urban agriculture refers to agricultural practices in urban and peri-urban areas.[1] Peri-urban areas are those transitioning from rural land uses (such as for agriculture or livestock production) to urban ones (such as the built environment, manufacturing, services, and utilities), and are located between the outer limits of urban and regional centres and the rural environment.[2] Urban agricultural practices are geared towards cultivating or growing a wide range of food and non-food products, and include activities such as rearing livestock, aquaculture, beekeeping, and commercial-scale floriculture.[3,4] However, despite the variety of agricultural activities attempted under urban agriculture, it is unlikely to include the cultivation of staple foods due to the complexities involved (such as soil management, irrigation, transplantation, mechanisation, and harvesting) and the vast land space required. Food products that can be cultivated through urban agriculture will predominantly be those that contribute micronutrients,[5] such as fruits, vegetables, dark leafy greens, fish, and legumes. These are compounds that are needed in minimal quantities and aid in the human body's growth, development, and maintenance.[6] Urban agriculture comprises various livelihood systems, from subsistence production at the household level to more commercialised agriculture.[7] This is one of its main attributes, as it can be adapted to a wide range of urban situations and to the needs of diverse stakeholders.

Urban agriculture is increasingly being adopted in cities worldwide[8] by urban local bodies (ULBs), entrepreneurs, non-governmental organisations, community groups, and citizens.[9] Indeed, as per the United Nations' Food and Agricultural Organization, urban and peri-urban agriculture have a significant role in global food and nutritional security, and so it is seeking to encourage such activities through the Urban Food Agenda.[10] The Urban Food Agenda comprises policies, programmes, and initiatives developed and implemented in partnership with civil society, academia, international agencies, city entities, and the private sector.[11] In recent years, urban and peri-urban areas worldwide are estimated to have produced between 5 percent to 10 percent of legumes, vegetables, and tubers, and between 15 percent to 20 percent of all food.[12]

The world is increasingly becoming more urban, with 68 percent of the global population—estimated to rise to 9.8 billion by 2050[13]—expected to reside in urban areas by that year,[14] meaning cities will also consume the

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majority (80 percent) of all food produced globally.[15] Importantly, by 2050, the arable land per person will have decreased to one-third of what was available in 1970[16] due to climate change, declining fisheries, and degradation from overfarming and poor production practices.[17] In this context, the "social, economic and environmental sustainability of food systems and evolution of urban diets will largely depend on managing food systems in urban and peri-urban areas. Therefore, a greater focus on the Urban Food Agenda is long overdue"[18] so ULBs and other relevant stakeholders can begin planning urban areas adequately.

As the primary food consumption centres, cities have an ethical responsibility to contribute to food production so that hunger and malnutrition can be prevented. Furthermore, climate change-induced impacts on rural food systems are expected to result in increased distress migration from rural areas to cities,[19] making it even more imperative for cities to adopt urban agriculture to optimise food production. This paper argues for the promotion of urban agriculture in Indian cities. India is still in the process of significant urbanisation, and its cities, therefore, have the opportunity to mainstream urban agriculture through appropriate planning and design. India is predicted to have the world's largest population by 2023[20] and, by inference, will eventually have the largest urban population, and so its cities should also emerge as the largest urban food producers. This would be a considerable service to food security in India and elsewhere.

Although cities worldwide constitute only about 3 percent of the total geographical area,[21] urban agriculture appears to have considerable potential to produce food. Despite the relatively small size of urban areas, one study—using the Google Earth Engine software alongside population, meteorological, and other related data—determined that, if fully implemented in cities around the world, urban agriculture could produce an annual yield of about 180 million metric tons of food, or approximately 10 percent of the global output of legumes, roots and tubers, and vegetable crops.[22] With further innovation and technological and regulatory support, this production capacity can be enhanced.

Technology initiatives

Entrepreneurs and organisations worldwide are employing various technologies to optimise food production in cities. High-tech indoor farms in countries such as France[23] and Singapore[24] have showcased what can be done in urban agriculture through innovative methods. In France, for instance, certain software gives farmers access to cross-referenced information on their smartphones about the weather, spraying dates, seeds, fertilisation plans, and regulatory compliance.[25] In India and the US, mobile applications can help connect urban growers and local consumers.[26] Technology also helps food growers in precision farming, which involves mapping and monitoring geological and plant data for a field so that inputs can be adapted to suit ultralocalised needs.[27] Local communities can be helpful in the gathering of such data.

AeroFarms in Newark, US, builds and operates vertical indoor farms to enable local production at scale and increase the availability of safe and nutritious food. The company uses aeroponics to grow leafy greens without sun or soil in a fully controlled environment. The technology enables year-round production with less water consumption and high yields per square metre.[28] In Paris, a startup called Agricool grows strawberries in containers across the city. The company retrofits old, unused containers to accommodate LED lights and aeroponics system to grow strawberries year-round. These 'cooltainers' are powered by clean energy and use about 90 percent less water than traditional farming activities. This can also create job opportunities for city residents in the agricultural sector.[29]

Urban Agriculture and Technology

In London, UK, GrowUp Urban Farms works on developing commercial-scale controlled environment production (CEP) solutions to grow fresh food in communities across the city. The CEP farms use aquaponics—a combination of aquaculture (growing fish and other aquatic animals) and hydroponics (growing plants without soil)—to farm fish and grow leafy greens in a soilless system, turning previously unused brownfield sites into productive areas.[30] While plants are fed the waste of aquatic animals, vegetables clean the water that goes back to the fish.[31] Over the long run, the company aims to replicate the aquaponics system to build urban farms in other cities, creating employment opportunities for the youth and using agriculture to make communities more self-sustaining.

In Tokyo, Japan, Pasona Urban Ranch runs an animal farm in the heart of the city. The ranch houses eight animal species, including cattle and goats. Visitors can attend seminars on dietary education and dairy farming. Previously, the Pasona Group gained renown for growing 100 regional crops in an underground farm in downtown Tokyo.[32] Sustenir, a vertical farm in Singapore, promotes high-quality food with a low carbon footprint. The farm uses hydroponics and smart indoor farming technologies to produce leafy greens, tomatoes, strawberries, and fresh herbs.[33]

India also has several urban agriculture initiatives. For example, city residents in Bengaluru, Hyderabad, and Surat can rent 600 sq feet of farmland through Farmizen, a mobile-based platform, to grow organic produce. Users can visit the farm anytime to grow and harvest chemical-free produce. Farmworkers oversee the plots when users return to the city, earning up to three times more than through conventional farming. The app currently has 1,500 subscribers and 40 acres of land under cultivation.[34] Additionally, a host of Indian urban farming startups such as Barton Breeze, Clover Ventures, Homecrop, and Growing Greens are working on growing crops in a controlled microclimate in peri-urban farms.[35] Apart from greenhouse farming, they also assess the viability of vertical indoor farms in Indian cities by adapting global techniques to suit local conditions. Such adaptations could be in the use of material, in local know-how, and in the use of fertilisers.

Community efforts

In several countries, community organisations and city residents have taken up small-scale agricultural activities on private and public lands, facilitated by city administrations.[36] In response to the growth of spontaneous collective gardens on vacant urban lots, the Paris government granted legal status to the gardens via the '*Main Verte*' (green thumb) programme, which allows the community to use such lands for urban agriculture activities until the lots are reclaimed for development.[37] In Greater London, of the 13,566 ha of farmland, 500 ha are used to cultivate fruits and vegetables. Moreover, 800 ha of public land is used for market gardening.[38]

Cities in Russia, Spain, Portugal, the Netherlands, Israel, and many Latin American and African countries also practice urban agriculture.[39] There are also several community-led initiatives in several Indian cities. For instance, in Mumbai, Dream Grove (a community farming initiative within an 800 sq ft public park), produces nutrient-rich soil through composting to grow over 50 varieties of edible plants, including fruits and vegetables.[40]

> "If fully implemented in cities worldwide, urban agriculture could produce an annual yield of about 180 million metric tons of food, or approximately 10 percent of the global output of legumes, roots and tubers, and vegetable crops."

According to World Bank data, India's agricultural area makes up 60.2 percent of the country's physical geography.[41] In 2010-11, a total of 159.6 million hectares of land were estimated to be used for agricultural production in the country,[42] while another estimate places this figure at around 95 million hectares in 2012-13.[43] Still, in Indian cities with extremely high built densities, urban agriculture activities must contend with space limitations. India's total urban area has been estimated at around 222,688 sq km, or about 6.77 percent of the country's geographical area.[44] This small area is home to around 35 percent of India's population, around 500 million Indians.[45] Notably, this does not include peri-urban areas. Since such areas do not get computed as a separate genre of settlement, no accurate figure can be presented for them. However, in reality, urban agriculture activities can be initiated in peri-urban areas.

If Indian cities were to allocate 10 percent of their geographic space for greens (gardens, playgrounds, public parks and the like), as suggested in the Urban & Regional Development Plans Formulation & Implementation guidelines,[46] this would mean 22,268 sq km of the total urban area is available to convert into public green spaces. Even if half of this area (111,34 sq km) were used for urban agriculture instead of parks, gardens, playgrounds, and horticulture, this is a mere 5 percent of all urban area and 0.56 percent of all land under agriculture in the country. This showcases the space constraints that urban agriculture must tackle.[47] However, there is great potential to initiate urban agriculture activities using the latest technologies.

Urban constraints and technology

Traditionally, urban agriculture concentrated on producing vegetables and ornamental plants in open lots for home consumption or local sale. However, over the years, urban agriculture practitioners have adopted an array of technological solutions to get healthier harvests and maximise the use of available space. These include growing crops in soil in raised beds or container gardens, using closed-loop aquaponics systems, vertical farming, rooftop farming, and indoor farming.

Raised bed farming is the agricultural technique of building freestanding crop beds above the existing soil level.[48] In certain instances, raised beds are covered with plastic mulch to create a closed planting bed. The method helps reduce

soil compaction and allows better control of the soil. The planted area also gets protected in case of excess rainfall. This method affords far greater productivity than regular farming. Bengaluru-based platform Farmizen uses raised bed techniques in its farms.[49]

Container gardening refers to the practice of growing plants in containers instead of planting them on the ground. Containers could include polyethene plastic bags, clay pots, plastic pots, metallic pots, milk jugs, ice cream containers, bushel baskets, barrels, and planter box bottles.[50] Most vegetables grown in backyard gardens can be grown in containers.

A closed-loop aquaponics system is an organic strategy that draws on the strengths of the basic ecological foundations of the nitrogen and carbon cycles.[51] Nutrient-rich fish water is used to fertilise and water plants. This system requires only a few inputs—primarily energy and some of the basic plant nutrients.[52]

The vertical farming model essentially aims at increasing the amount of agricultural land by stacking many racks of crops vertically, thereby having many levels on the same space of land. American microbiology professor Dickson Despommier first propounded vertical farms in 2010[53] as a way of tackling urban space constraints. In India, firms such as AeroFarms, Plenty, GP Solutions, and Growing Greens have adopted vertical farming technology.[54]

Under rooftop plant production (RPP) systems, food crops can be grown using raised beds, row farming, or a hydroponic greenhouse. Hydroponics is the practice of growing plants in a nutrient solution with or without a soilless substrate to provide physical support.[55] RPP systems maximise the cultivation area with artificial lighting. RPP can be used to grow crops that require higher light intensities and more vertical space. The environmental benefits of RPP can be a great asset to sustainability and resource-use efficiency, while also providing net-positive enhancements to the local community.[56] Ten percent of Singapore's food is produced through rooftop farming.[57]

Technology has also enabled indoor urban agriculture through the 'plant factory with artificial light' (PFAL) mechanism.[58] The most suitable plants under the PFAL systems are those that grow well at a relatively low light intensity and high planting density, such as edible leaves, stems, and roots.[59] In these multi-level PFAL systems, the annual productivity per unit land area with ten

tiers is approximately 100 times that of an equivalent open field. Furthermore, this productivity is not affected by climate or soil fertility. PFALs, therefore, can be built in virtually any location and in any building. PFALs reduce water consumption by about 95 percent compared to open-field production by recycling the water transpired by leaves, using the air conditioning system as a condenser.[60] Despite the cost of equipment and electricity consumption, PFAL systems are cost-effective because they achieve substantial economies through the optimum utilisation of space and significant reductions in water use. As such, PFAL systems are beneficial in India's urban areas, where land is at a premium, by providing clean, fresh vegetables for local consumption.

Role of urban local bodies in promoting urban agriculture

Urban agriculture has generally not been on the radar of India's ULBs. But as an important aspect of sustainable urban growth, civic administrations must begin to focus on it. As a starting point, ULBs should prepare a policy and a plan for promoting urban agriculture in their cities. The experience of Seattle, US, is noteworthy; the Seattle city government has developed a Food Action Plan[61] that provides a roadmap for a local food system and guides departmental coordination. The policy in Indian cities should specify the forms of urban agriculture that will be permitted, the conditions for permission, and the operating standards for urban agriculture activities.[62]

ULBs can examine their development control regulations to ensure they support a proactive urban agriculture strategy. This would mean allowing small-scale urban agriculture activities in residential zones, even if their character is commercial.[63] ULBs could then make some of the unutilised public lands, especially those not likely to be developed in the near future, available for urban agriculture. These can be leased to private parties through an agreement with mutually beneficial terms and conditions. Indian cities have preferred open spaces to carry ornamental vegetation. However, to promote urban agriculture, public spaces can have partly edible landscapes. Trees can be fruit-bearing, and vegetables can be grown in raised beds, containers, or vertical frames.

Civic bodies could zone lands for urban agriculture in their development and master plans for a period during which they are not likely to be pressed into service for other purposes. The ULBs will need to discuss and arrive at

ways to incentivise such activities without financially burdening their revenue streams. Additionally, as a disincentive, ULBs can impose a vacant plot tax on private plots that are undeveloped, in disuse, and not put to agricultural use. Alternatively, if such plots are used for urban agriculture, they should be incentivised innovatively.[64]

ULBs can also provide technology extension services through soil and water testing laboratories. The Indian government also runs the Soil Health Card Scheme[a] to assist rural farmers. City governments can extend a similar programme can to urban areas.[65] Additionally, ULBs could provide standards for the use of terraces, balconies, and other open spaces within private/cooperative housing society compounds for urban agricultural use. In densely populated cities, where land availability is a severe constraint, a different approach may be needed to overcome the scarcity of space for urban agriculture, including developing vertical and rooftop farming.[66]

> "Urban local bodies should prepare policies that specify the forms of urban agriculture that will be permitted, the conditions for permission, and the operating standards for urban agriculture activities."

a An Indian government initiative, the Soil Health Card Scheme issues soil cards to farmers. The card has soil health indicators and advisories on the application of fertilizers, their quantity, and soil amendment required for the farm.

Advantages of Urban Agriculture

Urban agriculture has several advantages. First, it creates better linkages between urban and rural food systems. Even if the volume of food grown through urban agriculture is modest compared to the country's total food production, it can provide sustenance to many people and enhance food security through the proper use of technology. If the traditional benchmark[b] of 50 sq m per person for fruits and vegetables is used,[67] 222 million people (or about 58 percent urbanites, as per the 2011 Census) can be served by cultivation in the 111,34 sq km—half of the total urban area available for public green space—that could be used for urban agriculture activities. Small-scale decentralised production can also be done to supplement diets at the household or community level. Lands that are not suitable for construction can be utilised for urban agriculture. This will help mitigate urban disasters such as landslides and floods, as the holding ability of lands will improve and permeability will be retained. Furthermore, urban agriculture has local employment value. Being labour-intensive, it can add to the number of jobs, improve livelihood opportunities in cities, and generate some income, especially for the poor.[68]

Second, urban agriculture has a significant role in urban environmental management as it can combat urban heat-island effects and function as an urban lung. This is in addition to its visual appeal. It would also help reduce greenhouse gas emissions.[69] Additionally, it encourages purposeful recreation that has a direct impact on city health. Urban agriculture has the potential to save around 15 billion kwH of energy globally, assist in nitrogen sequestration of between 100,000 and 170,000 tons, and avoid stormwater runoff between 45 and 57 billion cubic meters annually.[70]

Third, urban agriculture helps city dwellers establish linkages with nature and educate them in its richness and diversity. Urban thinkers have long stressed the disconnect between urbanites and nature, and have been considering way to reestablish this interrelationship. Urban agriculture provides a good opportunity for such engagement and ecocultural learning.[71] It also helps to develop community bonds and a sense of sharing through community agriculture, where people come together and share their experiences in growing a variety

b This is the surface area traditionally used to supply one person with fruits and vegetables.

Advantages of Urban Agriculture

of food. Pedagogic farms aimed at educating different age groups and types of people have proved extremely useful.[72] This could also lead to community-level farming in common spaces.

Fourth, urban agriculture can also be helpful in waste management and disposal. Using suitably treated wastewater for urban agriculture can reduce the demand for freshwater, including groundwater, and help in wastewater disposal. Such nature-based systems will have a significant overall economic benefit. Moreover, organic waste from the city can be composted and used in food and floriculture, reducing the total quantum of waste and its dumping on land, thereby curbing the requirement for landfills. This is one of the most advisable forms of waste recycling for cities in the future.[73]

The advantages of urban agriculture can be considered as ecosystem services, defined as the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as the regulation of flood, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, and other non-material benefits.[74]

> “Urban agriculture enhances food security, promotes urban environmental management, establishes human-nature links, and is helpful in waste managment and disposal.”

Conclusion

Climate change already has widespread impacts worldwide in the form of floods, heat waves, and other calamities. Additionally, droughts in the countryside will likely trigger increased migration to cities. As urban populations grow, urban agriculture must become vital to municipal functions. Similarly, urban plans must include urban agriculture in their land-use strategies.

Urban agriculture faces several constraints—spatial, planning design, and local development regulations. But each of these can be overcome by adopting a range of technologies, establishing urban agriculture initiatives in peri-urban areas, launching community initiatives in common spaces, and altering planning parameters and city regulations to include urban agriculture as a ULB activity. Conflicts could certainly emerge when considering the appropriate use of public open spaces (for instance, whether it should be for recreation and health or urban agriculture). Stakeholder consultations on open-space design can help arrive at a consensus. However, given the future imperatives regarding food security, city dwellers, as the prime food consumers, have an ethical responsibility to make compromises and support urban agriculture.

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