



Research Article

Volume 3 Issue 3 - December 2021
DOI: 10.19080/JOJHA.2021.03.555611

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Urban Agriculture on the Rooftop



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Submission: November 18, 2021; **Published:** December 10, 2021

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Abstract

Significant productive spaces are locked as unused roof spaces in high and medium density areas of cities and towns. A rooftop garden could act as a useful platform for regenerating urban spaces and have immense potential to grow fresh vegetables, herbs and fruits. This research focuses on 'rooftop garden' and intensive green roofs as typologies of urban food production spaces. These spaces are productive or actively growing food through horticulture processes on formal rooftop urban farms or informal household and community rooftop gardens. A desktop review of rooftop urban farms, community gardens, and home gardens was conducted to comprehend how these spaces functioned and contributed through the production of vegetables, herbs, and fruits. Six rooftop case studies from different countries were selected, analysed, compared and recommendations are formulated. The analysis established that functioning productive landscapes already exist on the rooftops of many cities. The rooftop gardens evolve through time and contribute positively to the community, environment, ecology, economy, and society. Planning and designing rooftop gardens, especially suitable rooftops in denser urban areas, could initiate place-making through urban agriculture.

Keywords: Rooftop Garden; Urban Agriculture, Rooftop Urban Farm; Local Food; Green Infrastructure

Abbreviations: GIS: Geographic Information Systems, LUSH: Landscaping for Urban Spaces and High-Rises, LEAF: Landscape Excellence Assessment Framework, TKPS: Telok Kurau Primary School, SGIS: Skyrise Greenery Incentive Scheme, FAO: Food and Agriculture Organization, DAE: Department of Agricultural Extension, NGO: Non-Governmental Organisations

Introduction

Global cities are getting compact and more densified with rapid population growth. Efforts to recreate lost cultivation opportunities on ground spaces as productive rooftop gardens emerge more than ever in high-density cities. Although this is not a new concept, rooftop urban agriculture has been practiced informally and formally for a long time. The historical records provide evidence that ziggurats of ancient Mesopotamia built between 4,000 and 600 BC had roof gardens, and the famous Hanging Gardens of Babylon established plantings on landscaped terraces Azzario [1]; Stone [2]. Informal rooftop gardening in cities is common to this date. Urban greening on rooftops has been implemented increasingly in contemporary cities in retrofitting existing and new build developments. The rooftop garden has some flexibility, including growing beds of different types and containers for food production and an intensive green roof with sufficient soil depth to cultivate produce. Urban agriculture can provide significant social, environmental, economic and health benefits of growing food within the city limits. This research focuses only on 'rooftop garden' as one of typologies of urban food production spaces. There are different urban agricultural

sub-typologies within 'rooftop garden' category Nasr, Komisar, De Zeeuw [3] This research focuses on rooftop gardens and intensive green roofs that are productive or actively growing food through horticulture processes on formal rooftop urban farms or informal household rooftop gardens. This research aims to review the extent to which rooftop gardens are used for productive purposes in high and medium density areas and contributes as a platform for social interaction, local economic development, and environmental and ecological benefits.

Methodology

The methodology of the review commenced with a desktop review of productive rooftop gardens in formal and informal settings in medium and high-density urban areas. Six rooftop urban agriculture case studies were selected from the USA, Canada, Bangladesh, Singapore and Hong Kong were analysed and compared. The analysis determined the functioning and contributions of the productive rooftop gardens in local production of vegetables, herbs, and fruits. Recommendations were formulated to maximize the rooftop gardens' uptake.

Review and Analysis

Measuring available rooftop spaces potential

Common dimensions of urban agriculture are scale; products; destination; economic activities; location and areas Mougeot [4]. Urban form structure, density, higher density-built form typology (such as apartments), solar orientation, building heights, and community motivations are important drivers and determinants for integrating rooftop productive gardens in the medium and high-density cities. Australian Government's recommendation requires on average, five to six servings of vegetables in a daily diet. Up to 99% of all Australians, 2 years to 18 years, and 19 years and over, do not eat the recommended daily serves of vegetables [5]. Vegetables and herbs are important for health and can be grown easily on the rooftops.

Urban rooftops are potential sites for social networking, improving the local economy, and providing locally grown healthy and nutritious food. Melbourne CBD existing rooftop garden area as a baseline has been mapped using spatial Geographic Information Systems (GIS) methods. This spatial mapping provides spatial information on existing rooftop garden adaptation and available roof areas for future retrofitting opportunities for productive rooftop gardens in a dense city. More than 20 cm depth of green roofs could support a heavier load or vegetated or food landscapes [6]. Multi-Criteria Analysis for intensive green roofs had been conducted considering roof load-bearing capacity, useable roof area, roof pitch or slope, access for use and maintenance and access for construction. In Melbourne CBD, there were 40 rooftop gardens and a total of 236 ha for intensive green roofs suitable for food production depending on appropriate solar orientation [6]. Up to 169 ha or 72% of rooftop areas in Melbourne CBD have no constraints or high adaptation potential, and the rest 67 ha or 28% low constraints to rooftop adaptation. In addition, 121 hectares of moderately constrained intensive green roof areas are available in Melbourne CBD [6].

This analysis provides evidence that significant roof areas in high-density areas of cities could engage in horticultural uses. Kaplan [7] conducted an Estimated Roof Area Analysis (EVRAP) using spatial GIS to calculate rooftop areas in publicly and privately owned buildings in Bronx, New York and created a landuse classification database. The analysis included 10,000 sq. feet /1 ha or more sizes of roof areas as useful for rooftop gardens. In the Bronx, 4227 buildings with average stories of 4.4 could add 1712 acres or 697 hectares of vegetated roof areas equivalent to two Central Parks [8] to Bronx landscape [7]. Rooftop spaces have emerged as a separate land use category where horticulture could be conducted effectively. The construction aspects of these spaces need to be designed and horticultural training for professionals and communities is essential for rooftop gardens. Appropriate urban agriculture policies are to be formulated. The following subsection discusses selected rooftop food production case studies in further detail.

Review of selected case studies and analysis

With a population density of 7,485 people per square km, Singapore is a highly urbanised wealthy city-state in southeast Asia and had a total population of 5.5 million people in 2021 [9]. Singapore is a pioneering city in green infrastructure integration within the dense city despite extensive limitations of ground spaces. Singapore's policies and programs align well to promote local food production on the rooftop areas. 'Landscaping for Urban Spaces and High-Rises (LUSH) program and The Landscape Excellence Assessment Framework (LEAF) developed along with 'Sustainable Singapore Blueprint 2015' [10]. Singapore's Skyrise Greenery Program to increase rooftop and vertical greenery has expanded its new possibilities to grow local food on the rooftops in Singapore [11]. A rooftop farm has been established on the 110 sq. m of unused roof space of a multi-storied Telok Kurau Primary School (TKPS) and was co-funded by under National Parks' Skyrise Greenery Incentive Scheme (SGIS) in Singapore [11]. Only 10 per cent or 1500 sq. feet of a total rooftop space 15,000 square feet houses a rooftop garden, Kampong Farm, in Singapore. This space is managed by 20 people or residents and grows a wide variety of herbs, vegetables and fruits such as spinach, radish, lettuce, eggplant, tomato, pumpkin, bitter gourd, watermelon, musk melon, okra, long beans, chilli, Thai basil, rosemary and others [12]. A rooftop garden, Tiong Bahru on the multi-storey carpark at Block 119A Kim Tian Road in Singapore set up on a 1,020 square m rooftop area where 40 volunteers are living in that estate work in this garden. It grew ten types of vegetables ready for harvesting equivalent to 230 bags of fresh produce.

The produce was distributed among the residents of the estate and the NTUC Health Senior Activity Centre [13]. Using unused rooftops and adaptive changes to multi-storied buildings for food production have opened up new horizons of growing food locally, alternative sources of production and Agribusiness opportunities within the high-density Singapore. Hong Kong is a high-density high-rise city with a population of 7 million people: a population density of 6,757 people per sq. km, and exports 98% of the city's vegetable demand Gottlieb [14]. In 2011, up to 300 rooftop farms existed in the high-rise buildings in Hong Kong, and rooftop planter boxes could be rented for growing food Gottlieb [14]. The rooftop farms in the University of Hong Kong's rooftop in Central and City University of Hong Kong in Kowloon Tong and many residential rooftops gardens grow vegetables. From 2008 to 2019, up to 60 urban rooftop projects covering 15,000 sq. m of unutilized roof spaces have been implemented in Hong Kong. A higher percentage of these farms are located on industrial or institutional buildings. It has been estimated that up to 595 hectares of available roof spaces could be suitable for rooftop farming Wang, Pryor [15].

New York is one of the densely developed cities with 8.8 million people in 2020 [16]. Eagle Street Roof top farm in NYC [17] and Brooklyn Grange Rooftop Farm [18] are two best practice examples of successful rooftop urban farming which provides locally grown, healthy and nutritious food and contributed to

improving Agribusiness opportunities and local economy (Table 1). Zone Green Text Amendment by New York City Department of City Planning [8] allows up to 25 feet high greenhouses for urban agriculture on the building rooftops that have no residences and provides exemption from specified height and floor-area restrictions [8]. New York delivers examples how sustainable food systems could be integrated into the rooftops of a high-density

city. These two rooftop urban farms in New York and Boston's Higher Ground Farm Boyer [19] are practical examples of rooftop urban farming driving social change and improving local economy through new job creation and marketing possibilities. Building partnerships with local organizations, local governments, non-profit and private organizations and community groups are significantly important for uptake.

Table 1: Comparison of selected rooftop garden case studies.

Rooftop case studies	Area, and type	Local production of fruits and vegetables	Local management and economy	Comments
Brooklyn Grange Rooftop Farm, New York, USA Brooklyn Grange [18]	Altogether 3 rooftop farms in New York. Total area: 135,000 sq. feet or 13.5 hectares, Urban farm, privately owned, formal, commercial.	Produces over 36,287 kilograms or 80,000 pounds of organically grown vegetable annually - tomatoes, herbs, carrots, fennel, and many other crops & 40 honey beehives managed naturally.	Have a Community Supported Agriculture (CSA) program; Promotes local economy, job creation, with large rooftop area under cultivation.	Unused spaces transformed into productive spaces. New knowledge generated.
Eagle Street Rooftop Farm, New York, USA [17]	Area: 6000 sq. ft. or 557 square meters, Urban farm, on a rooftop, formal, commercial.	Produces 30 types of vegetables, cucumbers, kale, peppers, carrots, tomatoes, eggplants, spinach, radishes, peas, beans, salad greens and flowers	For-profit farm; supports a small CSA program; supplies vegetables to an onsite market and local restaurant, provides education and training.	Promotes local economy, job creation, unused spaces transformed into productive spaces.
Higher Ground Farm, Boston, USA [19]	40,000-sq. ft. rooftop urban farm on Boston Design Center, formal, commercial.	Grows fruits, vegetables, herbs and flowers	Vegetables sold via a CSA program to local restaurants & community through an onsite shop.	Promotes local economy & job creation
Trent University Rooftop Farm, Canada [20]	Area: 2787 sq. ft. or 259 sq. m Urban farm, informal, Institutional.	Grows 30-40 different produces sweet potatoes, carrots, radishes, broccoli, peppers, zucchini, beans, pumpkins and others.	Produces are donated to Seasoned Spoon, an on-campus café, local community organisations for free meals to people.	Closed loop food system; effective and successful; produces donated.
Kampong Farm, Singapore [12]	Area: 1453 sq. ft. or 139 sq. m Private rooftop community garden, informal.	Grows Thai basil, rosemary, chilli, spinach, radish, lettuce, tomato, egg-plant, okra, pumpkin, bitter gourd.	Sells vegetables from the farm at the farm shop.	Medium size, Excellent community engagement project.
Rooftop garden Dhaka, Bangladesh Momtaz [23]	Area: 1227 sq. ft. or 114 sq. m Private rooftop garden on a five storied apartment, informal.	Uses 25 concrete planters for fruit production and grows large and small fruit trees.	Produces for personal use and sharing.	Predesigned, household motivation for individual gardening

Both New York and Hong Kong have high density, high-rise and compact urban structure. Rooftop community gardens and small to large rooftop urban farms are feasible in these locations considering roof adaptation potential, building heights and solar orientation. In New York, urban agriculture policies linking to green infrastructure are already under action while Hong Kong policies are implemented. Rooftop gardens in educational institutions contribute hugely to sustainability, social benefits, skill development and educational and training opportunities. Engagement and inclusion of students, staff and community through food production create successful social networks, educational prospects and training. In Canada, Trent University's

[20] rooftop garden and McGill University's [21] rooftop garden in containers are notable examples. These rooftop gardens act as platforms for understanding biodiversity protection, improving health, mental wellbeing and livelihoods, sharing knowledge and creating useful connections. Students grow and harvest food supplied to the on-campus cafe, thus forming a shorter food system cycle [20].

In Sydney, St Canice Kitchen Garden, Kings Cross (Figure 1) is an excellent initiative and under 'GROW' horticulture therapy program funded by the City of Sydney in this garden. Outpatients from St Vincent Hospital, Mental Health Service could access this

garden for therapeutic benefits Ghosh, Accarigi, Giovanangeli [22]. This rooftop garden supplies vegetables to 'Inside Out Organic Soup Kitchen' located at the ground floor of the Refugee Centre. The garden has fruit trees, medicinal herbs, indigenous and non-indigenous vegetables, and edible flowers [22]. Dhaka City, a megacity is the capital of Bangladesh and has a population of 12 million people. Research has noted that 78% of all rooftops incorporate some form of informal rooftop urban agriculture

Momtaz [23]. A rooftop food growing gardening project funded by Food and Agriculture Organization of United Nations (FAO) in collaboration with the Department of Agricultural Extension (DAE), Ministry of Agriculture in Bangladesh, has been implemented in Dhaka and Chittagong cities in Bangladesh Momtaz [23]. Table 1 presents a comparison of selected rooftop garden case studies from different countries.



Figure1: St Canice Kitchen Garden.

Results and Discussions

Significant focus on rooftops gardens producing food within denser environments establishes their immense importance within the medium and high-density built-up areas. As a new landuse category, rooftop gardens could support suitable horticultural practices for growing vegetables, herbs, crops and fruits. They are unique as they recreate lost green spaces on the ground enabling urban regeneration. Community development and engagement is initiated as people from different socio-economic backgrounds work together close to nature to grow food in a social networking space Foss, Quesnel, Danielsson [24]. Eagle Street roof-top farm [17] and Brooklyn Grange Farm [18] in New York showcase the local economic development pathways and improvement of public health. Trent University's long term or 20 years old rooftop garden continued to supply vegetables to the University Cafe and other environmental management benefits provide evidence feasibility and operational potential of rooftop gardens as local food growing places. Kampong Farm, Rooftop Community Garden, Singapore is a community effort to establish small rooftop community gardens where culturally appropriate vegetables could be grown, distributed and sold. The private rooftop garden growing a wide variety of fruits establishes the importance of integrating urban agriculture considerations at the design and planning phases of the buildings so that the rooftop could take the adequate load.

This case study demonstrates that it is possible to grow moderate size trees on the rooftop in the city of Dhaka. In this research, only a selected set of case studies have been discussed. The analysis in this research proves that functioning productive landscapes already exist on the rooftops of many cities. These rooftop gardens evolve through time and contribute positively to the community, environment, ecology, economy, and society.

The rooftop gardens have some limitations. The height of the rooftop garden impacts of wind and available solar radiation, the capability of the roof to take the soil and plant loads and technologies available to retrofit an existing roof area are to be explored to understand the suitability. Watering, stormwater drainage and rainwater collection provisions, funding, access to the rooftops and transporting materials and plants to and from the rooftops are to be analysed and checked before starting. Future research should explore these gaps and focus on developing appropriate technologies, useful horticultural practices and guides for rooftop farming. The collective performance of rooftop urban farms, community and private rooftop gardens could contribute notably to improving food security and mitigating climate change impacts in denser human settlements. Recommendations for the uptake of rooftop urban agriculture follow [25].

a) Explore and formulate practical horticultural guidelines, planting suggestions, crop rotation and growing methods for

year-round vegetables, fruits and herbs production in different types of rooftop gardens in medium and higher density settings considering air pollution, various climatic regions and climate change impacts.

b) For the uptake of rooftop urban agriculture, setting up demonstration rooftop gardens and organising cooking and planting events, open days, cooking classes and horticulture training programs could encourage social networking, engagement and participation across communities, businesses and government and non-government organisations in cities.

c) Develop innovative sustainable technologies and practices for the rooftop gardens that contribute to environmental/ecological, economic and social benefits.

d) Formulate appropriate organisational management and monitoring methods and adapt complete food system approach (including production, distribution, processing and disposal) for smooth functioning of the rooftop gardens over a longer time frame.

e) Develop useful collaborations with non-governmental organisations (NGOs), government and private organisations, local governments and developers.

f) Create socially interactive places on rooftop urban agricultural production sites for knowledge exchange, sharing, experiencing nature where people could spend their time with friends and nature.

Conclusions

Significant productive spaces are locked as unused roof spaces in high and medium density areas of cities and towns. A rooftop garden could act as a useful platform for regenerating urban spaces. The rooftop gardens have immense potential to grow fresh vegetables, herbs and fruits, build food resilience and provide carbon and microclimatic benefits (such as carbon storage and sequestration and urban cooling). They can improve biodiversity, promote social participation and local economic growth, cultivate cultural continuity and foster community engagement opportunities. Planning and designing rooftop gardens, especially suitable rooftops in denser urban areas, could initiate place-making through urban agriculture and transform rooftops into productive and interactive spaces.

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DOI: [10.19080/JOJHA.2021.03.555611](https://doi.org/10.19080/JOJHA.2021.03.555611)

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