Paper ID: CE 0177

Urban Sustainability Assessment, Incentives & Impediments Towards Rooftop Farming Practice in Dhaka City, Bangladesh

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Abstract

The present drift of development practice in Bangladesh is mostly adapted toward the planning of cities and towns. The recent infrastructural development of these cities has expanded to incorporate green roofs, with the main objective being to make the cities more buoyant and less reliant on external resource inputs through more efficient energy utilization. Rooftop gardens function as an eco-friendly option for cooling the interior of residences as the plants diffuse the effect of sunlight, resulting in low temperatures and superior air quality. This paper outlines the importance of rooftop farming as a step towards urban sustainability in Dhaka city and highlights the glaring factors that have been acting as significant hindrances to implanting rooftop gardens. Hence, the research embraced a survey along with systematic field data analysis. Detailed field data were collected from practitioners of buildings consisting of rooftop gardens, and an online questionnaire survey was conducted to correlate the views of practitioners and non-practitioners. The result shows that rooftop gardens are achieving relevance as they possess the potential to cooperate with the ever-increasing demand for food, boost the ecosystem, and protect biodiversity. Moreover, some recommendations have been made considering the socio-economic condition and the mindset of the people of Bangladesh, as rooftop farming can act as an emerging tool along with being an integrative approach towards sustainable urban development.

Keywords: *Urban sustainability; Rooftop Farming; Food value; Incentives; Impediments.*

1 Introduction

Unprecedented population increases and urbanization have led to indicative problems like food security and global warming. Miscellaneous estimates predict that between 2010 and 2050, the urban population will nearly quadruple, creating an enormous demand for resources, particularly essential food supplies (IRP, 2018). The annual rate of urban population increase in Dhaka for the previous few years has been 3.39% *(Dhaka, Bangladesh Metro Area Population 1950-2023 | MacroTrends*). At the current rate of expansion, the population of urban areas is predicted to double by 2047 (Amegnaglo (ONU), 2018). Only 3% of the earth's surface is covered by cities, but they eat up to 70% of all food produced globally *(Urban Food Agenda | Food and Agriculture Organization of the United Nations*). Urban food consumption also contributes significantly to global greenhouse gas emissions that contribute to global warming (Pang *et al.*, 2020). Urban areas commonly experience problems including undernutrition, micronutrient deficiencies, obesity, and diet-related illnesses because they consume readily available refined foods with reduced nutritional values (Khor, 2002). It is extensively believed that a food security catastrophe will eventually affect the world's metropolitan population. Due to this, there is an increasing need for urban spatial reformation with resource-efficient construction and a shift in behavior. Food security and global warming may be addressed via rooftop farming in heavily populated urban areas. Integrated rooftop farming can lower urban heat island effects by reducing food demand and bringing fresh, locally produced food to consumers (Yang, Yu and Gong, 2008). Integrated rooftop farming can lessen the effects of urban heat islands by reducing food demand and bringing consumers fresh, locally produced food (Wong and Yu, 2005). According to several studies, rooftop farming across Singapore can satisfy 35% of the city-state's diurnal vegetable needs while cutting carbon emissions by 9052 tons annually (Safayet, Arefin and Hasan, 2017). Dhaka one of the oldest cities in South Asia, has grown

to become the capital of Bangladesh. Dhaka's population has grown rapidly in recent decades, and the city government has accommodated enormous visible expansion by altering agricultural lands to meet the city's growing needs (Ahmed and Bramley, 2015). The city government of Dhaka has adjusted agricultural areas to satisfy the city's expanding needs the outcome of the city's speedy population growth in recent decades. Urban farming in Dhaka can guarantee fresh food, a healthier diet, and a more environmentally friendly environment in light of the current scenario (Chowdhury *et al.*, 2020). 810,000 Katha of Dhaka's 1,800,000 Katha of roof space is suitable for rooftop farming, according to a Green Savers study *(Demand for organic produce drives rooftop gardening | Dhaka Tribune*). It is essential to mark that most of the rooftops in Dhaka are constructed of coarse reinforced concrete, which is perfect for rooftop farming (Hossain *et al.*, 2019). Numerous studies on rooftop farming systems have been carried out in numerous nations across the world. The advantages and disadvantages of a small-scale farming system in the surroundings of Dhaka have not, however, been studied. As a result, this study aims to evaluate rooftop farming's contribution to urban sustainability as well as the advantages and disadvantages of doing so in Dhaka.

2 Urban Sustainability through Rooftop Farming

A sustainable city is one that satisfies the demands of the present without endangering the capacity of future generations to satisfy their own wants- experts' opinions (*Making the Modern World - Introduction*). Urban sustainability is already a topic of discussion at the international municipal level.

Figure 1. An Overview of Rooftop Farming Practice in a Building (Location: Kuril, Dhaka, Bangladesh)

In Figure 1, an outline of a rooftop farm in a residential building is shown. This rooftop farm is practiced by a housewife named Lily Akter lived in Kuril, Dhaka, Bangladesh. Here she planted several types of vegetable plants, such as tomato, papaya, eggplant, bitter gourd, bean, ladies' finger, lemon, pepper, kalmi shak, kochu shak, and lau shak, as well as some fruits, such as mango, oranges. Also shown here are some vegetables that originated from her rooftop farm.

This is Urban sustainability is the conception that a city may be structured without being overly reliant on its surroundings and that it can supply its own energy needs using renewable resources. The objective is to reduce the city's total impact on climate change while also leaving the smallest possible environmental footprint and pollution by using land wisely, composting spent materials, recycling them, or turning trash into electricity. (Hui, 2011)

By responding to social, economic, and environmental challenges, urban sustainability can be attained. Others have noted the social, economic, and environmental advantages of urban farming and rooftop farming. As a result, urban rooftop farming, together with other projects and efforts, plays a crucial role in ensuring the sustainability of cities in the near future. In conclusion, social sustainability can be attained through active community

participation and consistency in shared green spaces and rooftop gardens, community consistency when allocating specific knowledge and gathering fresh food, the creation of local employment, the creation of shared facility space for exercise and recreation, and the creation of shared aesthetic aids (Hui, 2011).

The development of roof durability, a decrease in the cooling load and energy expenses of buildings, an increase in the availability of biofuel, an extension in local food production and sales, an improvement in food security and property value, etc. are all aspects of the development of economic sustainability through rooftop farming. The reduction of carbon emissions from food transportation, using less packaging, composting organic waste, reducing urban heat islands, boosting biodiversity, improving air quality, managing urban stormwater, and other measures can all help to achieve environmental sustainability. (Hui, 2011)

3 Provisioning and Regulating Benefits of Rooftop Farming

Rooftop farming, commonly referred to as rooftop gardening or urban agriculture, has a number of temporary advantages. Rooftop gardening has several benefits, although the specific advantages may vary based on the situation and region. Rooftop gardens are the best way to use rainwater since plants on green roofs consume it immediately, and sometimes extra rainwater is collected and stored for later use. Rooftop gardens have the ability to retain up to 80% of their rainfall in the summer and just 40% in the winter (Cerón-Palma *et al.*, 2012). Green roofs provide shade, remove heat from the air, and lower the temperature both inside and outside. By integrating absorbent, wet surfaces in regions governed by streets, parking lots, conventional roofs, and other hard, dry exteriors, they mitigate the effects of urban "heat islands". They can reduce the ambient temperature by 5°F in the neighborhood (Cerón-Palma *et al.*, 2012). Green roofs can reduce energy use by 7% in the summer and 3% in the winter by dispersing heat from the air and acting as insulators for buildings (Cerón-Palma *et al.*, 2012). In addition to the plants and the process of photosynthesis, rooftop gardens also encourage the evacuation of contaminated air from the growing area. Green roofs may also help to lessen the production of pollution and the spread of airborne dust, which lowers greenhouse gas emissions in metropolitan areas. Green roofs encourage a variety of food-growing opportunities. Growing seasonal vegetables like lettuce, it can significantly contribute to meeting domestic vegetable demand. Additionally, it provides plenty of opportunity for birds, bees, and insects to thrive by satisfying their dietary needs since they mostly rely on natural food. By enabling the equipment and technologies utilized in the building to have a longer lifespan, rooftop gardens may help reduce household and environmental waste. This can involve conserving energy by using fewer HVAC systems and covering the roof with waterproofing materials (Cerón-Palma *et al.*, 2012). In metropolitan locations where there are insufficient natural spaces, green roofs offer a haven for vegetation, insects, and birds. Roof gardens offer great habitat- supporting areas for birds and other wildlife. In addition to growing a variety of trees, plants, shrubs, herbs, and bushes, rooftop gardens can also be an excellent home for many birds and serve as a layover for roving species, allowing two different species to interact (Safayet, Arefin and Hasan, 2017). Stress can be decreased with the aid of green roofs.

4 Barriers and Obstacles in Rooftop Farming Practice

Severe environmental problems have hampered the city's development. It has become imperative to find means of expanding green areas, reducing environmental pollution, and enhancing the ecological system of the environment, all while fostering sustainable urban development.

a. *Social Barriers*: The most noticeable social barriers are typically those (Cerón-Palma *et al.*, 2012) related to the need for knowledge and information about rooftop farming practices, such as preconceptions, uncertainties, a lack of ongoing examples and awareness, a lack of support from the government, and the belief that rooftop farming will bring more challenges than benefits, as well as the lack of social cohesiveness (Cerón-Palma *et al.*, 2012) and the low level of community involvement in the accomplishment of such types of practices.
b. *Legal and Administrative Barriers*: Another obstacle to the deployment of UAGR is the volume restriction on buildings, as certain laws are onerous in terms of structural bolstering or greenhouse services. Rooftop greenhouses encounter a hurdle to improvement since certain buildings have a floor-to-area ratio (FAR) that prevents an extension to the building from being made. Prior to starting a rooftop garden, it is important to thoroughly understand the local regulations. In some circumstances, it might be forbidden or require obtaining permission from the local government. Therefore, it is preferable to resolve all of these issues and ambiguities beforehand to avoid wasting time, effort, and money.
c. *Economic Barriers*: This barrier denotes the costs for maintenance and facilities, as well as labor and materials. Additionally, it also alludes to the financial disparity between the price of the UAGR components and the needed structural strengthening. Maintenance costs and a lack of understanding of UAGR's benefits are also significant barriers because they are anticipated as extra expenses, and as a result, there is little longing to

invest in them.

d. *Structural Barriers*: A rooftop garden's most important component is the soil. Depending on the size of the garden, different amounts of soil are needed. A perfect balance between water retention and penetrability must be maintained in the soil. Additionally, it's necessary to take into account the soil's granular size, pH level, and thickness. Lightweight rooftop soil will help keep the roof structure from being unduly burdened.

e. *Cultivation Barriers*: When choosing particular plant species, take into account the quantity of sunlight the rooftop receives overall, the breeze, and the humidity. Dehydrated and heat-tolerant plants are preferable. These plants have a good chance of surviving because they are less delicate. Therefore, it is advantageous to plant decorative plants and avoid planting big trees because they tend to put a lot of weight on rooftop structures.

5 Methodology

The study used two different methodologies: the analysis of field data and an online questionnaire survey comprising closed- and open-ended multiple-choice questions. This made it easier to document the answers of both rooftop farming practitioners and non-practitioners. The respondents were asked to rate their agreement with the incentives and obstacles on a scale of one to five, ranging from "strongly disagree" to "disagree," "neutral," "agree," and "strongly agree." The arithmetic mean and standard deviation of the data were initially computed, and the final judgment was based on the data's coefficient of variation. The study's approach is illustrated in Figure 2.

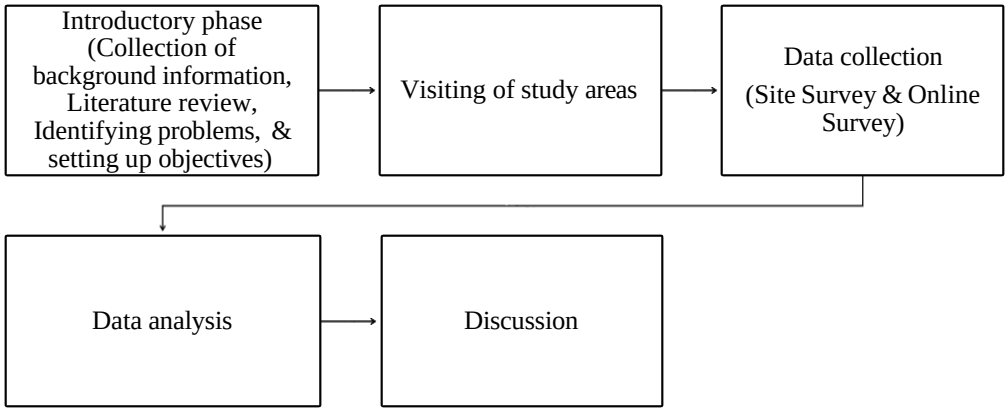

Figure 2. Research Methodology

6 Result and Discussion

Mean: The mean value of a sample is calculated by dividing the total collected values by the sample size.

$$\mu = \frac{x_1 + x_2 \ldots + x_n}{n}$$

Standard Deviation: We calculated standard deviation from the following formula:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

Coefficient of variation: The standard deviation is calculated as the mean divided by the coefficient of variation.

$$c_v = \frac{\sigma}{\mu}$$

(*Chapter 4.4 Mean, variation, standard deviation and coefficient of variation - Textbook Animal breeding and Genetics - HBO (EN) - Wiki Groen Kennisnet*)

(i) Incentives from rooftop farming practice:

The benefits of rooftop farming practices are shown in Table 1 below. Here, we can see that the estimated means and standard deviation have been used to compute the coefficient of variation of the incentives. The first incentive among the others, with its fluctuation being the least from its predicted mean, is the reduction of noise pollution.

Table 1. Incentives from Rooftop Farming

Benefit	Mean	Std. Deviation	t of Variation (%)	Rank
Increases aesthetics	2.09	1.08	52.11	6

Reduces temperature	1.91	1.03	53.87	7
Improves rainwater discharge	2.21	0.889	39.77	2
Improves air quality	1.8	0.928	51.50	5
Enhancing a building's energy effectiveness	2.64	1.075	40.75	3
Adds value to the property	2.5	1.075	42.92	4
Reduces noise pollution	3.31	0.92	27.55	1

(ii) Impediments to implementing rooftop farming:
The difficulties and obstacles to implementing rooftop gardens are shown in Table 2. As can be observed, the greatest obstacle to implementing this practice is the growth in structural loading on buildings. Other major obstacles include a shortage of competent labor and rising construction costs.

Table 2. The difficulties and obstacles to implementing rooftop garden

Challenges of IRF Implementation Rank	Mean Deviation	Std. Deviation	oefficient of Variation	Rank
Deficient knowledge	2.13	0.984	46.37	7
Absence of ownership/customer interest	2.05	0.945	46.50	8
Additional design and construction cost	2.51	1.000	40.08	3
Governmental inaction and an absence of incentives	2.51	1.114	44.22	6
Higher structural loading	2.83	0.999	35.30	1
Inadequately skilled workforce	2.42	0.929	38.38	2
Cost of upkeep rises	2.53	1.041	41.41	4
Require regular maintenance	2.21	1.053	47.65	9
The breakdown of social bonds	2.44	1.065	43.65	5

7 Recommended Strategies for Promoting Roof top farming practices

Implementing rooftop farming practices in Bangladesh can provide numerous benefits, such as increasing food production, promoting green spaces, mitigating urban heat island effects, and enhancing community engagement. Here are some recommendations to consider when implementing rooftop farming in Bangladesh.

a) *Policy and Regulation*: Create legislation and support policies that promote and aid rooftop farming. This covers zoning laws, financial rewards, and support for efforts including rooftop agriculture.
b) *Education and Awareness*: Promote the merits of rooftop farming through informational campaigns and offer educational opportunities for those who are interested. Encourage people to learn more about water conservation, waste reduction, and sustainable farming methods.
c) *Technical Assistance*: Help people and groups that are interested in rooftop farming by providing them with technical support and training. Workshops, training sessions, and demonstrations can be provided on subjects like soil management, crop selection, irrigation methods, and pest control.
d) *Infrastructure and Design*: Determine whether or not the building's structure can handle the weight of rooftop farming. Working together with building designers, engineers, and urban planners, rooftop gardens can be added to brand-new construction or existing buildings. Think about things like how much weight they can hold, how much water they can get, how well they drain, and how much sunlight they get.
e) *Community Engagement*: Involve local residents by coordinating rooftop farming projects with institutions like schools and non-profits in the area. Establish community gardens, host harvest celebrations, and provide knowledge-sharing platforms to encourage a sense of belonging and participation.
f) *Monitoring and Evaluation*: Establish a monitoring and evaluation mechanism to keep tabs on the development, effects, and difficulties of rooftop gardening initiatives. Utilize this information to enhance your implementation techniques, share your successes with others to motivate them, and improve them.

8 Conclusion

Food demand and prices are increasing in tandem with Dhaka's continuously growing population. As a consequence, the likelihood of cultivating additional and diverse agricultural foods is diminished. Once again, food contamination is on the rise, with deadly chemicals being applied to ripe fruits, hazardous inorganic fertilizers being used to boost output, and so on. In this circumstance, establishing a rooftop farm could be a viable and plausible solution to these problems and a means of retreat. Rooftop farming can assist to meet the world's food needs by providing fresh and hygienic food products, reducing household spending on fruit and vegetable purchases, saving

municipalities money by retaining stormwater, improving air quality, absorbing carbon dioxide from the atmosphere, and reducing the effects of climate change. With the aid and feedback of this study, any additional research is possible, such as calculating the advantages of rooftop farming in local, regional, and national contexts, systematizing the constant elements of monetary valuation, and constructing a repeatable rooftop farming model. With the aid and feedback of this study, any additional research is possible, such as calculating the advantages of rooftop farming in local, regional, and national contexts, systematizing the constant elements of monetary valuation, and constructing a repeatable rooftop farming model.

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