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## Research Article

# Rooftop Gardening and Its Contribution to Income Generation in Dhaka City

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## Abstract

The study evaluated the economic viability of rooftop gardening in Dhaka, Bangladesh, focusing on its potential for income generation and associated constraints. A total of 60 gardeners were selected as samples from Kalabagan, Mohammadpur, Mirpur, Banani, Cantonment and Uttara areas. The data was analyzed using a mixed-method approach that included both descriptive and statistical techniques. The study found that rooftop vegetable gardening is economically viable, with a benefit-cost ratio of 1.32, indicating that every unit of money invested, generated a positive return. Moreover, the gardener's decision to cultivate a particular crop was influenced by the profitability of that crop in different situations. The study also identified that most of the gardeners earned direct or indirect income by cultivating vegetables in their rooftop gardens though the income is not much compared to their total income. Multiple regression analysis revealed that the age of the gardeners, cost of seed/seedling/plant, cost of pesticide and insecticide, and cost of water were the most significant factors affecting the gross return from rooftop gardening. The SWOT analysis identifies strengths, such as food safety and environmental improvement, and challenges, such as low soil quality and limited availability of gardening equipment. According to this study, targeted training programs and market access for gardeners may increase rooftop gardening's popularity and profitability in urban areas.



## Introduction

Rooftop gardening has arisen as a long-term solution to the challenge of rising urbanization and industry, notably in cities such as Dhaka, Bangladesh. With increasing land costs and a sharp decline in urban green spaces, rooftop gardening offers a chance to reuse underutilized urban sites for agricultural purposes, thus contributing to food security, income generation, and environmental sustainability. As of 2014, approximately 54% of the world's population lived in cities and that number is expected to rise to 66% by 2050 (United Nations, 2014). As a result, demand for urban food supply systems will also increase. (Chowdhury *et al.*, 2020). Rooftop gardening has significant potential to meet these demands by providing fresh and accessible food supplies, revenue possibilities, and social benefits (Safayet *et. al.*, 2017).

Rooftop gardening is the process of producing plants on building rooftops using a variety of methods such as container gardening, hydroponics, or green roofs. Rooftop gardens improve urban food security and dramatically reduce family costs by providing fresh vegetables. Environmentally, they reduce the urban heat island effect, improve air quality, and increase biodiversity, hence increasing resistance to climate change (Hossain *et al.*, 2023; Husen *et al.*, 2023). Rooftop gardens enhance mental health, promote social contact and increase self-sufficiency — all of which are especially important in congested metropolitan contexts with little outdoor space (Bhuiyan and Ferdous, 2021; Rashid and Ahmed, 2009).

Despite the proven benefits, rooftop gardening has not yet been fully incorporated into Dhaka's urban fabric due to several obstacles, including expensive setup costs, a lack of technical expertise, a shortage of water, and a

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lack of government aid (Kabir, 2019; Shahidullah *et al*., 2022). Several research reveals that to promote broader adoption, supportive policies such as financial incentives, technical support, and educational initiatives are required (Haque, 2020; Husen *et al*., 2023). The existing study highlights gaps in understanding the entire economic potential of rooftop gardening, as well as the elements that influence profitability and sustainability, particularly given Dhaka's socioeconomic and meteorological circumstances.

Earlier research about rooftop gardening has considered it as a potential solution to several urban concerns. Rooftop gardens have an important role in decreasing air pollution and heat in Dhaka by efficiently lowering humidity and temperature (Hossain *et al*., 2023). Husen *et al*. (2023) evaluated the appropriateness of various roofs for growing chili plants, finding that rooftops up to three stories high produce the best results. Parvin and Islam (2023) investigated the socio-demographic characteristics that influence attitudes toward rooftop gardening, highlighting urban people's favorable perceptions despite constraints such as insufficient training and restricted space. In their policy-focused study, Shahidullah *et al*. (2022) focused on policy implications, highlighting the lack of government support and the need for resources to make rooftop gardening more accessible to urban residents. Quddus (2022) underscored the benefits of rooftop gardening for both food security and environmental health. Other studies provide insight into the economic and health benefits of rooftop gardening. Rooftop gardening brought nutritional, recreational, and economic advantages, especially to middle to high-income households, though time constraints and resource availability remain issues (Tabassum and Rahman, 2022). Rooftop gardens improved urban climate resilience, reduced energy use, and created jobs (Begum *et al.,* 2021). A larger dependency on rooftop gardens for food security, particularly during catastrophes like the COVID-19 pandemic, emphasized rooftop gardening's adaptability to address urgent food demands (Bhuiyan and Ferdous, 2021). Despite these discoveries, economic assessments remain neglected, with research focusing on environmental and social variables over profitability and financial assessments. No research has been done to assess the adjustment to risks of rooftop gardening practices. Moreover, SWOT analysis on rooftop gardening has not been done in any research. In light of these research gaps, the objectives of the study are as follows.

The primary aim of the current study is to address the research gap by assessing the economic viability of rooftop gardens and the potential and constraints associated with rooftop gardening in Dhaka city, focusing on the socioeconomic characteristics of rooftop gardeners, risk management, income generated from the rooftop garden, production practices of gardeners and factors affecting the gross return gained from rooftop gardening. The objectives of the present research are to examine the socioeconomic characteristics of rooftop gardeners and their production practices; to estimate the economic viability of rooftop gardening and its contribution to income generation; to explore factors affecting the gross returns of rooftop gardening; and to identify potential benefits and constraints. It is expected that the outcome of this research can provide valuable insights for urban planners, policymakers, and residents interested in sustainable urban agriculture practices.

## Materials and Methods

### *Study Areas, Sample Size, and Data Collection*

The study was conducted in Dhaka, specifically in six locations including Kalabagan, Mohammadpur, Mirpur, Banani, Cantonment and Uttara. These places were purposively picked for the presence of rooftop gardens and diverse population demographics. The sample, consisting of 60 rooftop gardeners, with 10 chosen from each research location, by applying purposive sampling technique, was interviewed between October, 2023 and March, 2024. This non-probability sampling technique was used to ensure representative data collection, as gathering data from the entire population would be expensive and time-consuming. A pre-tested structured questionnaire was used to collect primary data, while secondary data were obtained from relevant publications, including journals, reports from the Bangladesh Bureau of Statistics (BBS), newspapers, and websites related to rooftop gardening in Bangladesh. Both closed and open-ended questions were included in the questionnaire to capture quantitative data and qualitative insights, respectively.

### *Analytical Framework*

The data was analyzed using a combination of descriptive statistics and advanced statistical analyses in software packages such as Microsoft Excel, SPSS, and Python (version 5.5.1). The estimated values of the analysis were shown for 1000 square feet of rooftop to generalize the findings.

### *Tabular Technique*

Various descriptive statistical measures (i.e., sum, average, percentages, ratios, standard deviation, etc.) were employed to examine the objectives and to test the hypothesis. The tabular analysis included the socio-economic characteristics of sample rooftop gardeners, production practices and their cost and return, income generation capacity, problems faced by the respondents, and their probable suggestions. From the view of individual respondents, the seasonal profitability of rooftop vegetable gardening was measured in terms of gross return, gross margin, net return, and benefit-cost ratio (BCR) (undiscounted). This study considers the vegetables grown in the Rabi season (16 October- 15 March) as main products, as all gardeners from the study area produced vegetables. The profitability was measured for every 1000 square feet for consistency and ease of calculation. The following equations were used to derive the profitability of rooftop gardening:

$$GR = \sum_{i=1}^{n} Q_i P_i,\ GM = GR\text{-}TVC,\ NR = GR - TFC,\ BCR = GR \div TC \text{ .......................... } (1)$$

Where, GR= gross return; GM= gross margin; NR= net return; BCR= benefit-cost ratio; $Q_i$ = quantity of the $i^{th}$ main product (Kg/ season); $P_i$= average price of the $i^{th}$ main product (Tk./kg); TVC = total variable cost; TFC = total fixed cost (Tk); TC = total cost; and i, j = 1, 2, 3…………, n.

In the study area, the gardeners grew certain 3 to 4 varieties of vegetables during the Rabi season on their rooftops. The interviewed rooftop gardeners revealed that they cultivated crops roughly in these six combinations, denoted as C1 (Brinjal +Tomato +Chili +Bottle gourd), C2 (Tomato +Chili +Spinach +Red amaranth), C3 (Brinjal +Bottle gourd +Spinach +Tomato), C4 (Brinjal +Chili +Red amaranth +Bean), C5 (Bean +Jujube +Spinach +Tomato), and C6 (Capsicum +Carrot +Brinjal +Chili) (Table 1). The gross return was calculated by multiplying the main products of the vegetables grown on the rooftops by their market prices. At first, the benefit-cost ratio (BCR) of these six combinations of crops was estimated separately, and then the average benefit-cost ratio (BCR) was calculated.

**Table 1. Crop combinations adopted by rooftop gardeners**

| Combinations | Crops | No. of gardeners | % |
|---|---|---|---|
| $C_1$ | Brinjal +Tomato +Chili +Bottle gourd | 17 | 28% |
| $C_2$ | Tomato +Chili +Spinach +Red amaranth | 13 | 22% |
| $C_3$ | Brinjal +Bottle gourd +Spinach +Tomato | 10 | 17% |
| $C_4$ | Brinjal +Chili + +Red amaranth +Bean | 9 | 15% |
| $C_5$ | Bean +Jujube +Spinach +Tomato | 7 | 12% |
| $C_6$ | Capsicum +Carrot +Brinjal +Chili | 4 | 6% |
| | Total | 60 | 100% |

Source: Field survey, 2024

*Functional Analysis*

The input-output relationship of rooftop gardening was investigated using the multiple regression production function to determine the strength of the association between two or more independent variables and one dependent variable. The linearized form of the Cobb-Douglas production function was used in this study due to its mathematical simplicity and empirical tractability. The nonlinear Cobb-Douglas model was turned into a linear form via logarithmic transformation, allowing Ordinary Least Squares regression to be used. This change simplifies the understanding of coefficients as elasticities and allows traditional econometric approaches to be used. Several diagnostic tests were performed to ensure that multiple linear regression was adequate. The Variance Inflation Factor (VIF) was used to assess multicollinearity and ensure that the explanatory variables did not have strong linear correlations. The Durbin-Watson statistic was used to detect autocorrelation in residuals, and the normality of error terms was determined using conventional plots and statistical measurements. These experiments proved the model's appropriateness, allowing for accurate estimation and inference.

To determine the contribution of the most relevant variables in the production process, the model was specified as follows:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 + \beta_6 X_6 + \beta_7 X_7 + U_i \text{ ............ } (2)$$

where, $Y_i$ =gross return (Tk.); $\beta_0$ =constant or intercept value; $X_1$=rooftop size (square feet); $X_2$=age of the gardener (years); $X_3$=gardening experience (years); $X_4$=cost of seed or seedling or plants (Tk.); $X_5$=cost of fertilizer (Tk.); $X_6$=cost of pesticide and insecticide (Tk.); $X_7$=cost of water (Tk.); $U_i$ =error term; and $\beta_1$ to $\beta_7$=coefficients of the respective independent variables to be estimated.

*SWOT Analysis*

Rooftop gardening's potential and constraints may be analyzed using a combination of qualitative and quantitative methodologies that examine various aspects of feasibility, benefits, and problems. A SWOT analysis is a strategic technique for identifying the important elements that influence the potential and constraints of rooftop gardening. SWOT stands for strengths, weaknesses, opportunities, and threats. A

SWOT analysis helps to discover the positives and negatives within an organization (S-W) and in the external environment (O-T) (Gurel and Tat, 2017) (Table 2).

**Table 2. SWOT analysis matrix**

| | Helpful | Harmful |
|---|---|---|
| **Internal Origin** | Strength | Weakness |
| **External Origin** | Opportunities | Threats |

## Results and Discussion

### *Socioeconomic Characteristics of Rooftop Gardeners*

The socioeconomic characteristics of the gardeners presented in Table 3 indicate that the gardeners differ from each other in respect of age, gender, educational status, occupation, family size, farm size, experience, and others. Mostly, female members of the households work in rooftop gardens (63%) and the majority of the rooftop gardeners were between 40-49 years old which was 34%. Hossain *et. al*. (2023) and Thapa *et. al.* (2020) both found considerable female participation in urban agriculture. With an average family size of four, the majority of rooftop gardeners belong to small households with 1-4 family members and the majority of gardeners are homemakers (32%) since they usually stay at home and can care for the garden better than the other residents. Most of the rooftop gardeners had 1-5 years of experience (45%) and most of them were medium gardeners with roof sizes of 500-1500 square feet (42%). Among the studied rooftop gardens, most of the rooftops had container gardens (90%). Very few gardens had green roofs (7%) and aquaponics systems (3%).

**Table 3. Socioeconomic Characteristics of Rooftop Gardeners**

| Particulars | Information on particulars | Percentages | Particulars | Information on particulars | Percentages |
|---|---|---|---|---|---|
| Age | 20-29 | 19% | Education | Higher secondary | 10% |
| | 30-39 | 10% | | Graduate | 57% |
| | 40-49 | 34% | | Post-graduate | 30% |
| | 50-59 | 29% | | Doctorate | 3% |
| | 60 to above | 8% | Occupational structure | Student | 15% |
| Gender | Male | 37% | | Home-maker | 32% |
| | Female | 63% | | Business person | 10% |
| Average family size | | 4 | | Government employee | 19% |
| Farm holding | Small (500-1000 sq. ft.) | 20% | | Private job | 13% |
| | Medium (1001-1500 sq. ft) | 42% | | Retired | 11% |
| | Large (Above 1500 sq. ft.) | 38% | Years of experience | Below 1 year | 7% |
| Types of gardening adopted by gardeners | Container gardening | 90% | | 1-5 years | 45% |
| | Green roof | 7% | | 6-10 years | 30% |
| | Aquaponics | 3% | | Above 10 years | 18% |

Source: Field survey,2024.

### *Production Practices of Rooftop Gardeners*

The production practices, ranging from the selection of dwarf crop varieties to specific soil requirements, planting techniques, and seed storage—demonstrate the careful planning required to sustain rooftop gardens effectively. For the purpose of growing the desired crops, 90% of gardeners select premium, lightweight potting mix that contains compost and nutrients. Eighty-five percent of gardeners use natural pest control methods like neem oil, pheromone traps, and yellow traps. Seventy percent of gardeners save seeds from mature crops for the following season, and eighty-five percent harvest crops on time to reduce losses (Table 4).

### *Economic Viability of Rooftop Garden*

The economic viability of rooftop gardening was estimated in terms of gross margin, gross return, net return and benefit-cost ratio. For calculating total cost of production, total variable costs and total fixed costs were taken into consideration. The variable cost items were: (1) cost of seed/seedlings/plants, (2) cost of fertilizers, (3) cost of water, (4) cost of compost, (5) cost of trail, and (6) cost of insecticides and pesticides. The fixed cost items were: (1) cost of family labor, (2) soil cost (3) cost of tubs/pots/containers, (4) cost of gardening tools and equipment, and (5) initial investment in infrastructure. In case of soil, tubs/pots/containers, and gardening tools and equipment, the depreciation cost of these items was considered

**Table 4. Production Practices of Rooftop Gardeners**

| Production steps | Way of practice | % of gardeners followed |
|---|---|---|
| Selection of varieties | Compact/dwarf varieties for confined spaces | 85% |
| Soil management | High-quality, lightweight potting mix with compost and nutrients | 90% |
| Planting techniques | Sowing seeds at proper depth, planting seedlings | 80% |
| Nutrient management | Slow-release fertilizers; regular liquid feedings | 85% |
| Weed control | Regular inspection and removal of weeds | 40% |
| Pest and disease control | Organic pest control, like neem oil | 85% |
| Growth regulation | Pruning and staking plants | 65% |
| Temperature control | Positioning plants to receive sunlight or using shades/greenhouses | 80% |
| Harvesting | Timely harvesting to minimize losses | 85% |
| Post-harvest practices | Cleaning containers and replacing soil | 75% |
| Seed storage | Collecting seeds from mature crops for storage | 70% |

Source: Field survey,2024.

It is clear from Table 5 that the total cultivation costs per 1000 square feet for combinations C1, C2, C3, C4, C5 and C6 amount to Tk.3202, Tk.3257, Tk.3685, Tk.3859, Tk.4028 and Tk.3880, respectively. The corresponding net returns for these combinations were Tk. 1150, Tk. 921, Tk. 973, and Tk. 1219, Tk.1219 and Tk.1466 per 1000 square feet, respectively. As a result, the BCR for the total costs were 1.36, 1.28, 1.26, 1.32, 1.30 and 1.38 for crop combinations C1, C2, C3, C4, C5 and C6, respectively. The average BCR was 1.32, which implied that rooftop vegetable gardening in Rabi season was profitable, and BDT 1.32 would be achieved by expending BDT 1 per 1000 square feet. If the crop combinations were considered separately, it was identified that the gardeners adopting the crop combination C6 (Capsicum +Carrot +Brinjal +Chili) achieved the highest BCR (1.38), while those selecting the crop combination C3 (Brinjal +Bottle gourd +Spinach +Tomato) achieved the lowest BCR (1.26).

**Table 5. Cost and return (Tk./ 1000 sq. ft.) of different crop combinations on rooftop garden**

| Particulars | C1 | C2 | C3 | C4 | C5 | C6 | All | % of total cost |
|---|---|---|---|---|---|---|---|---|
| Variable costs | | | | | | | | |
| (i) Seed/seedling /plant cost | 368 | 328 | 411 | 398 | 453 | 436 | 399 | 11 |
| (ii) Fertilizer cost | 359 | 381 | 432 | 458 | 540 | 505 | 446 | 12 |
| (iii) Water cost | 300 | 239 | 243 | 276 | 347 | 322 | 288 | 8 |
| (iv) Compost | 425 | 542 | 645 | 568 | 489 | 452 | 520 | 14 |
| (v)Trail and stake cost | 243 | 278 | 254 | 283 | 292 | 285 | 273 | 7 |
| (vi) Insecticide and pesticide cost | 493 | 357 | 416 | 389 | 429 | 428 | 419 | 11 |
| Operating capital | 2188 | 2125 | 2401 | 2372 | 2550 | 2428 | 2344 | 64 |
| Interest on operating capital | 88 | 85 | 96 | 95 | 102 | 97 | 94 | 3 |
| **A. Total variable cost** | **2276** | **2210** | **2497** | **2467** | **2652** | **2525** | **2438** | **67** |
| Fixed costs | | | | | | | | |
| (i) Family labor | 583 | 657 | 753 | 845 | 736 | 688 | 710 | 19 |
| (ii) Soil cost | 140 | 162 | 174 | 239 | 285 | 269 | 211 | 6 |
| (iii) Tubs/pots/containers | 136 | 156 | 183 | 204 | 238 | 263 | 197 | 5 |
| (iv) Gardening tools and equipment | 68 | 72 | 78 | 104 | 117 | 135 | 96 | 3 |
| (v) Initial investment in infrastructure | 137 | 162 | 174 | 157 | 167 | 182 | 163 | 4 |
| **B. Total fixed cost** | **926** | **1047** | **1188** | **1392** | **1376** | **1355** | **1214** | **33** |
| **C. Total cost (A+B)** | **3202** | **3257** | **3685** | **3859** | **4028** | **3880** | **3652** | **100** |
| **D. Gross Return** | **4352** | **4178** | **4658** | **5078** | **5247** | **5346** | **4810** | |
| **Gross margin (D-A)** | **2076** | **1968** | **2161** | **2611** | **2595** | **2821** | **2372** | |
| **Net return (D-C)** | **1150** | **921** | **973** | **1219** | **1219** | **1466** | **1158** | |
| **BCR over total cost (D/C)** | **1.36** | **1.28** | **1.26** | **1.32** | **1.30** | **1.38** | **1.32** | |

Source: Author's calculation based on field survey, 2024.
Note: C indicates the Crop combination

Consistent with these findings, Begum *et al.* (2021) observed a positive net present value (NPV) of rooftop gardening, implying economic sustainability. Washi (2021) found the potential of rooftop gardening in agribusiness prospects in different areas of Dhaka city, as the benefit-cost ratio for rooftop gardening was more than 1 for every area. Dreesti and Keshav (2019) explored the economic viability of rooftop gardening in the Kathmandu area of Nepal and proved that rooftop gardening was profitable, resulting in a benefit-cost ratio of 1.24. Kundu *et al.* (2024) considered some crop combinations adopted by farmers of the coastal areas of Bangladesh in both plain land farming and sorjan cultivation and found that the benefit-cost ratio was more than 1 in each area in both methods.

### *Adjustment to Risk*

Agricultural activities are subject to varying degrees of external risk from weather, environment, and market uncertainty (Chavas *et al*., 2010). Farmers use various strategies to mitigate risk, one of them is choosing more reliable enterprises based on historical data on variability in costs, prices, yields, and profits. The association between reliability and profitability is demonstrated by comparing enterprises with varying degrees of expected returns and risks (Kahlon, 1980). The current study examined the profitability of brinjal (eggplant), tomato, okra, and carrot for five years in three situations- extremely good, most probable and extremely bad. According to estimated statistics, the reliability of these crops was determined as follows:

- Brinjal: Demonstrated the highest reliability, with consistent profitability across all five years due to its resilience to rooftop conditions and moderate pest resistance.
- Tomato: While generally reliable, tomato profitability showed some variability due to susceptibility to pests and diseases, particularly during the rainy season.
- Okra: Less reliable compared to brinjal and tomato, with profitability fluctuations influenced by climate variability and pest pressure.
- Carrot: The least reliable crop in this analysis, with significant profitability variability due to its sensitivity to temperature and water availability.

Farmers' decisions to adopt crops are most likely impacted by the amount of profitability and risk associated with each crop (Kamruzzaman, 2023). In this study, gardeners mostly select vegetables that exhibit less fluctuation in terms of profitability across different settings. In the research locations, all gardeners grow brinjal since it exhibits less variability in diverse conditions. Carrots were cultivated by just 6 to 7 gardeners due to their low profitability and significant unpredictability (Table 6). In Figure 1, profitability vs reliability of the selected vegetables across 3 different situations is shown.

**Table 6. Percentage of gardeners cultivating vegetables on reliability basis**

| Vegetables | % of reliability of that vegetable | % of gardeners cultivating that vegetable |
|---|---|---|
| Brinjal | 100% | 100% |
| Okra | 70% | 80% |
| Tomato | 40% | 60% |
| Carrot | 10% | 11% |

Source: Field survey, 2024.

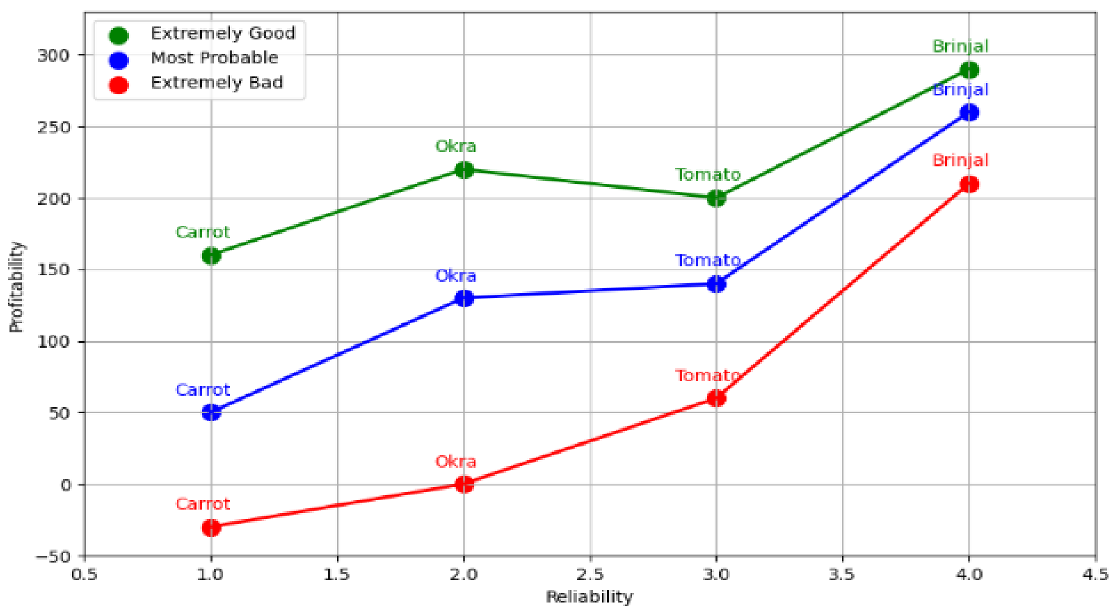


Figure 1: Profitability vs reliability across different situations

*Income Generation*

Rooftop gardeners earn indirect revenue by growing fresh food such as vegetables, herbs, and fruits on their own and not buying these products from markets. Some rooftop gardeners earn directly from their garden by selling fruit and flower seeds/seedlings and ornamental plants like cacti, succulents, pothos etc. Furthermore, some rooftop gardeners take advantage of waste management by making compost from organic waste, which is then utilized in their gardens to increase productivity and lower external input costs. In this study, most gardeners earned from growing vegetables on their rooftops (82%) (Table 7). So, in this study, vegetable production was prioritized over other produces. Moreover, different vegetables were grown in different seasons. To avoid complications, only vegetables of Rabi season were considered.

**Table 7. Indirect and direct income sources of rooftop gardeners**

| Sources | No. of respondents | Percentage |
|---|---|---|
| Fruit production | 38 | 63% |
| Vegetable production | 49 | 82% |
| Flower cultivation | 16 | 27% |
| Ornamental plants selling | 10 | 17% |
| Gardening inputs selling (ex. Special soil mix, organic fertilizers etc.) | 1 | 2% |

Source: Field survey, 2024.

Though a certain portion of the total income came from rooftop gardening activities, it was not so significant. This is because most of the gardeners considered rooftop gardening as a secondary means of income, and they were busy in their primary occupations. Additionally, many of the gardeners did gardening as a hobby. So, they were not aware of the income incurred from rooftop gardening. Only 1-10% of the total income of most gardeners came from rooftop gardening (57%). 25% gardeners earned 11-20% of their total income from rooftop gardening, 11% earned 21-30% of their total income, 2% earned 31-40% of their total income and 5% earned 41-50% of their total income from rooftop gardening (Table 8).

**Table 8. Percentage of total income earned from rooftop gardening**

| % of total income | No. of respondents | Percentage |
|---|---|---|
| 1-10% | 34 | 57% |
| 11-20% | 15 | 25% |
| 21-30% | 7 | 11% |
| 31-40% | 1 | 2% |
| 41-50% | 3 | 5% |

Source: Field survey, 2024.

*Factors Affecting Gross Return of Rooftop Gardening*

The amount of gross return gained from rooftop gardening is influenced by various factors such as rooftop size, age of the gardener, gardening experience, cost of seed/seedling/plant, cost of fertilizer, cost of pesticide and insecticide and cost of water. The estimated equation for determining the most important factors affecting the gross return gained from rooftop gardening is as follows:

$$Y_i=1.699-0.00017X_1-0.01736X_2-0.013X_3+2.60X_4+1.80X_5+0.655X_6+0.736X_7$$

It is clear from Table 9 that the gross return from rooftop gardening is influenced by a combination of factors, with the age of the gardener, cost of seed/seedling/plant, cost of pesticide and insecticide, and cost of water being the most significant contributors. The F-value of the model is 27.303, which is significant at 1% probability level, implying that all the included explanatory variables in the model are important for explaining the variations in gross return. The coefficient of multiple determinations, $R^2$ is 0.786, which indicates that 78.6% of the total variation in gross return from rooftop gardening is explained by the factors included in the model.

**Table 9. Results of Multiple Regression Model on Factors Affecting Gross Return**

| Variables | Coefficient (β) | Standard Error | *p* values | Interpretation |
|---|---|---|---|---|
| Constant | 1.699** | 0.7409 | 0.0259 | Baseline gross return without factors being considered |
| Rooftop size ($X_1$) | -0.00017 | 0.00015 | 0.2797 | Larger rooftop gardens decrease the gross return |
| Age of the gardener ($X_2$) | -0.01736** | 0.00759 | 0.0264 | Age of the gardener significantly affects the gross return and the effect is negative |
| Gardening experience ($X_3$) | 0.013 | 0.019 | 0.4972 | Experience in gardening can bring more gross return |
| Cost of seed/seedling/plant ($X_4$) | 2.60*** | 0.6954 | 0.0004 | The higher the amount of seed/seedling/plant, the greater the gross return |
| Cost of fertilizer ($X_5$) | 1.80 | 1.368 | 0.1923 | High fertilizer dose can bring more return |
| Cost of pesticide and insecticide ($X_6$) | 0.655** | 0.2542 | 0.0128 | High amount of pesticide and insecticide significantly increases the gross return |
| Cost of water ($X_7$) | 0.736*** | 0.2305 | 0.0023 | The effect of water is highly significant on the gross return |
| F-value | | | | 27.303 |
| Prob> F | | | | 0.000 |
| R – squared | | | | 0.786 |
| Adj R - squared | | | | 0.757 |

Note: *** and ** indicate 1% and 5% probability levels, respectively.
Source: Authors' estimation based on field survey,2024.

### *SWOT Analysis*

A SWOT analysis was done to identify the potential and difficulties of rooftop gardening. SWOT analysis identifies the positives and negatives within an organization (S-W) and in the external environment (O-T) (Uddin *et al*., 2018). Table 10 represents the SWOT analysis on rooftop gardening which reveals that the major strength was ensuring safe food (stated by all respondents). Rooftop gardening enhances the environmental quality of Dhaka city which was stated by 92% of respondents. As a major weakness, 87% of respondents gave an opinion about the low soil quality of their rooftop garden as a result of soil pollution in Dhaka city. Moreover, gardening equipment is not so available to the city dwellers and unavailable gardening equipment is considered as a weakness of their rooftop garden according to 70% of the respondents. The major opportunities include biodiversity conservation as well as waste reduction through rooftop gardening (according to 98 % and 93% of respondents). All respondents identified heavy rain, and storms are the main barriers to rooftop gardens as serious threats (Table 10).

**Table 10. SWOT analysis on rooftop gardening**

| Strengths | % of responses | Weakness | % of responses |
|---|---|---|---|
| i) Ensuring safe food | 100 | i) Low soil quality | 87 |
| ii) Enhances environmental quality | 92 | ii) Unavailable gardening equipment | 70 |
| iii) A place to enjoy leisure time | 89 | iii) Lack of sunlight | 42 |
| **Opportunities** | **% of responses** | **Threats** | **% of responses** |
| i) Biodiversity conservation | 98 | i) Heavy rain and storm | 100 |
| ii) Waste reduction | 93 | ii) Infrastructural decay | 78 |
| iii) Urban heat reduction | 79 | iii) Strict policy | 32 |

Source: Field survey, 2024.

### *Problems and their Probable Solutions Suggested by the Gardeners*

Though rooftop gardening is bringing much potential to the urban agriculture system, there are many problems faced by rooftop gardeners that affect production as well as profitability. The gardeners were asked about the important problems and some possible solutions to the problems mentioned by them. Those problems were then ranked and arranged in order based on the priority of the problem. The problems faced by the rooftop gardeners and the suggestions to triumph over the problems are shown in Table 11.

**Table 11. Rank order of the problems faced by the rooftop gardeners and their suggestions**

| Problems | % | Rank | Probable solutions suggested by the gardeners |
|---|---|---|---|
| a) Lack of proper infrastructure | 89 | 1 | Making the roof suitable for gardening at the time of construction of the building |
| b) Pest and disease management | 82 | 2 | Making better communication with the extension officer and knowing about different pests and diseases and their treatments |
| c) Extreme weather conditions | 80 | 3 | Providing updates about weather conditions weekly and giving advice accordingly by the extension office |
| d) Watering and irrigation problems | 74 | 4 | Constructing a drip irrigation system and rainwater harvesting system by the building owner to conserve water |
| e) Poor soil quality | 69 | 5 | Utilizing kitchen waste as compost and also making chemical fertilizer available to the local stores by the fertilizer companies |
| f) Lack of knowledge and skills | 57 | 6 | Organizing workshops and training programs for gardeners |
| g) Labor scarcity | 45 | 7 | Promoting rooftop gardening as a paid job |
| h) Marketing and selling produce | 17 | 8 | Using social media and digital marketing tools to promote produce |

Source: Field survey, 2024.

*Limitations of the study*

Almost all the research studies have some common limitations in terms of time, funds and personnel. The present study is not an exception. In Dhaka city, most of the buildings have high security and do not let strangers enter the building. So, the researcher had to collect some data over social media. It was a time-consuming procedure. Moreover, most of the gardeners did not keep a record of the costs and returns as they considered gardening as a hobby. They gave information based on their memory. So, the accuracy of data fully depends on their memories and sincerity. Most of the gardeners are occupied in other professions. So, they are busy most of the time. The researcher had to visit them at weekends and wait for a long time. The present study is based mainly on one-year data and the results presented may vary from year to year. Despite these limitations, the findings of the study might be helpful for researchers, policymakers and other concerned authorities for conducting further comprehensive research.

## Conclusion and Recommendation

This study concludes that rooftop gardening in Dhaka is economically viable with the potential for income generation and some constraints. Socioeconomic characteristics and production practices highlighted that rooftop gardening was mostly managed by graduates, with a significant female involvement. This study also reveals that rooftop gardening was profitable, and rooftop gardeners earned direct and indirect income from their gardens, though the amount earned was not significant. Factors such as the age of the gardeners, cost of seeds, pesticides, and water significantly impact returns, with increased seed costs leading to higher returns. The potential highlighted by all gardeners was the ability of rooftop gardening to ensure safe food, while extreme weather conditions like heavy rain and storms posed significant constraints for smooth production. The study suggests that targeted interventions and policy support could enhance the adoption and profitability of rooftop gardening in urban areas. It also suggests the establishment of urban farmers' markets or online platforms for rooftop gardeners which could help them to sell the rooftop produce directly to local consumers, maximizing income.

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