Rooftop Gardening as a Supplement to Urban Household Food and Nutrition Resilience in Dhaka City, Bangladesh

Nazmun Nahar[1], Asib Ahmed[1*] and Md. Shamim Hossain[2]

[1]Department of Geography and Environment, University of Dhaka, Dhaka 1000, Bangladesh
[2]Department of Geography and Environmental Science, Begum Rokeya University, Rangpur, Rangpur-5400, Bangladesh

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ABSTRACT: Increasing food demands along with shrinkage of agricultural lands make urban dwellers vulnerable to food insecurity. This leads to practice rooftop gardening (RTG) by the dwellers living in an urban area. The present research assessed the potentiality of rooftop gardening as a supplement to urban household food and nutrition resilience in Dhaka city of Bangladesh. The study follows a mix-method approach (i.e. qualitative and quantitative) to fulfill the objectives. Currently, the city has 257.95 ha area of RTG (i.e. 0.32% of 80,220 hectares of continuous roofs), which can fulfill the demand of about 0.3% fresh vegetables and fruits of the dwellers of Dhaka city. Moreover, yearly practices of RTG by the inhabitants of the city can contribute about 362 million BDT. The present study shows that contribution to household level resilience for vegetables and fruits produced from RTGs are about 6% and 18% respectively. The RTG practitioners consume about 75% cultivated fruits and vegetables. Utilization of rooftop spaces for gardening could be a potential solution to household food and nutrition insecurity in DMA.

Keywords: Dhaka City; Food and Nutrition Security; Resilience; Rooftop Gardening

INTRODUCTION

Dhaka is the greatest and fastest growing city of Bangladesh having 30,093 populations per square kilometers (Statista, 2022). Moreover, Dhaka attracts a large number of people by its numerous facilities (e.g. employment, education, treatment etc.). For instance, Dhaka experiences the highest urban influx in the country during recent times (i.e. 2000 people/day). This population required huge amount of settlement to live in the city. Consequently, agricultural lands become residential and industrial area at a faster rate compared to other cities in the country and hence, arable lands have been converting to built-up area noticeably (Islam and Ahmed, 2011). On an average, about 2.5% land is being used for agricultural activities in Dhaka city (Rahman et al., 2013). Moreover, population pressure from natural disaster induced migration to Dhaka city leading to increasing demand for food (Sajjaduzzaman et al., 2005). The food demand of the residents of Dhaka city cannot be fulfilled from the supply inside the city and hence, supply from outside of the city is inevitable to meet the needs of the city. Over 9,000 tons of rice, fish, pulses, spices, fruit, vegetables, edible oil, meat, eggs, and wheat need to bring every day into Dhaka (Bohle et al., 2010). This gives raise the concern of government and residents about the production and consumption of food of the residents.

There are about 80,220 hectares of continuous roofs in the Dhaka city, which is about 65% of the city's surface area. The Department of Agricultural Extension of Bangladesh reported around 6,000 rooftop gardens in the city (Nur et al., 2022). A total area of 10,000 ha rooftop of the city can be utilized for rooftop gardening that would fulfill nearly 10% food and nutrition demand of the city dwellers (Wardard, 2014). However, current rate of household cultivation practices in Dhaka city cannot meet the daily vegetable needs of the city dwellers (Etzold and Keck, 2009). Previous estimates identified that only less than one percent of the existing space on the building roofs has been utilized for gardening in Dhaka city (Kabir et al., 2011). Given this situation, rooftop gardening (RTG) can be an alternative strategy

*Corresponding author: Asib Ahmed
Email: asib01geo@du.ac.bd

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to decrease urban food and nutrition problem, prepare urban residents more food-resilient and easy the supply of fresh vegetables to the dwellers (Islam, 2002). Moreover, RTG would be a key element of making the city more sustainable and habitable. Hence, it was urgently needed to conduct a comprehensive study to assess the role of rooftop gardening as a supplement to urban household food and nutrition resilience of Dhaka city.

There have been several researches conducted around the world on different issues of rooftop gardening (RTG). Most of the researchers focused on the potentiality and barriers of rooftop gardening (Islam, 2002), thermal benefits of rooftop garden (Wong et al., 2003), residents' perception and expectation on rooftop gardening (Yuen and Hien, 2005), techniques for efficient rooftop gardening (Sanyé-Mengual et al., 2015), effects of rooftop gardening (Barreca, 2016), as well as ecosystem services of rooftop gardening (Nur et al., 2022).However, very little attention was given to the role of rooftop gardening on urban household food and nutrition resilience. The present study addressed the existing gap on food and nutrition resilience by examining the contribution of rooftop gardening to household level resilience status of the city dwellers. The knowledge of the present study could be beneficial for the individuals, as well as the community people of the city. Moreover, findings of the study could be more useful for the policy makers, environmental managers, agriculturists, academicians and researchers to conduct further study on food resilience of the city.

STUDY AREA

Dhaka is one of the world's fastest-growing metropolitan cities, has been the capital of a developing country like Bangladesh (Fig. 1). Dhaka is characterized by rapid urbanization that attracts people to migrate to the city for employment opportunities. Consequently, the increasing number of people put pressure on cultivable lands to transform into built-up area arbitrarily to satisfy increasing demand of population (Islam and Ahmed, 2011). In this circumstance, implementing RTG in Dhaka city can be a possible solution to reduce food insecurity. On the other hand, the existing condition (e.g. size, availability of sunlight) of the roofs of the city are favorable for gardening practice before any major changes (Islam, 2002; Chowdhury et al., 2020).Hence, Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC) areas (considered as Dhaka city) were selected to accomplish a detailed analysis on the role of rooftop gardening as a supplement to resilient household food and nutrition security.

METHODS AND MATERIALS

The current study used a mix-method approach by using both primary and secondary data. The present study used a valuation formula to identify the food production benefits of an RTG in the study area. It determined the economic advantages of fruits and vegetables separately. Using this technique, the study calculated the monetary value and estimate their cost savings, which could otherwise be spent on purchasing fruits and vegetables from the market (Tomalty and Komorowski, 2010). Moreover, the study determined the household level resilience status in terms of food (i.e.vegetables and fruit) from rooftop gardening by the practitioners. To assess household level resilience status to food and nutrition of the residents from RTGs, a field study was conducted in 2023 by using an in-depth questionnaire survey on the demand and supply of food considering the economic class of the respondents. The survey was comprised with the monthly food intake (i.e. vegetables, and fruits), cost of foods, dietary habits, and total calorie intake from rooftop gardening at household level. Besides, a total of ten Key Informant's Interviews (KIIs) and four Focus Group Discussions (FGDs) were accomplished to validate the results obtained from field studies.

Household level resilience status to food (i.e. vegetables and fruits) from rooftop gardening of the residents was examined by using the following formula:

$$\% \text{ Self- resilience} = \left\{\frac{Area \times Yield}{Intake}\right\} \times 100$$

Moreover, the value of the food production benefit (Tomalty and Komorowski, 2010) was estimated using the following formula:

$$b = p \times g \times a$$

Here,

b= value of benefit (annually)

p= productivity (BDT per square meter per month)

g= length of growing season (12 months)

a= area of garden roof (square meter)

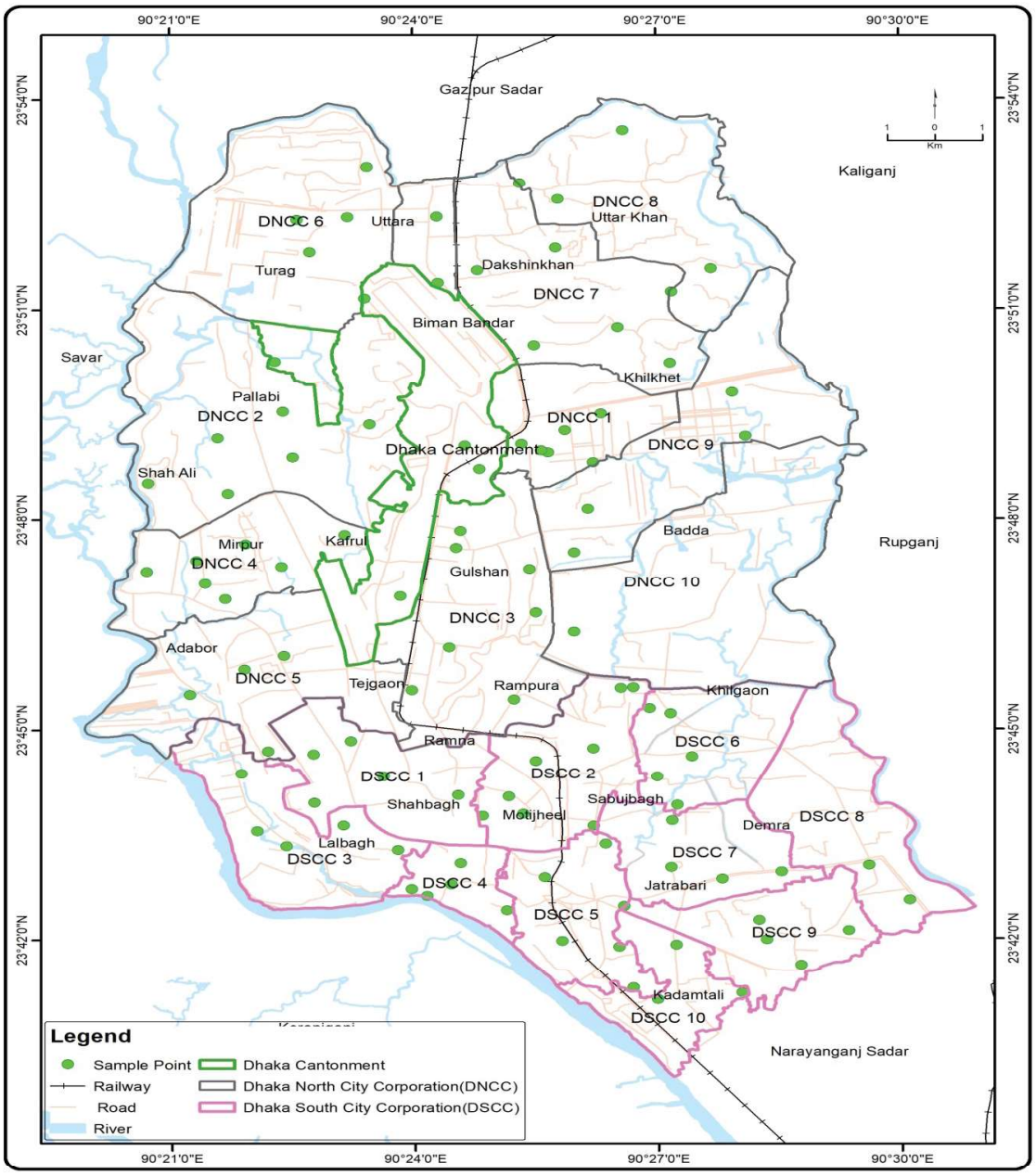
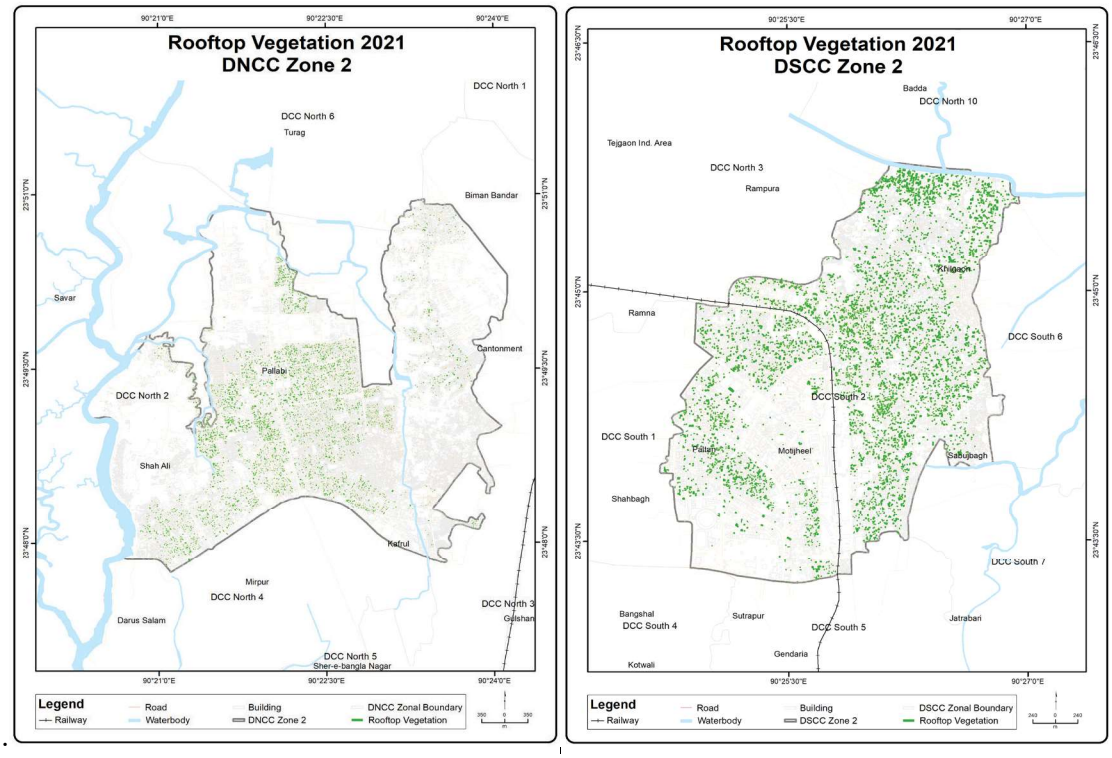


Figure 1: The Locations of the Rooftop Gardens Selected for Household Survey (Source: The Authors, 2023)

The study identified the total number of space of roofs for assessing the present state of rooftop gardening in the city. The total roof spaces were then used to identify the proportion of rooftop space utilized by the households for gardening. To do this, open-source Landsat satellite images were used in Geographic Information System (GIS) and Remote Sensing (RS) platforms that helped to conduct the study with considerable accuracy (Fig. 2). The datasets for building roof area and rooftop gardening spaces of the city were prepared in ArcGIS environment followed by geo- processing, editing, area calculation and preparation of maps (Fig. 1 and Fig. 2). The graphs, tables and charts were prepared by using Microsoft Excel. Secondary data were collected from the Department of Agricultural Economics and Rural Sociology, Bangladesh Agricultural Institute, and scholars' article from different academic journals.



(**Source**: The Authors, 2023)

Figure 2: Examples of the Identification of RTG Practices in the DMA in 2021

Sampling Method

Since, there is a lack of authentic database on the number of households currently practice rooftop gardening, the present study considered the sampling size for unknown population. The study used the following formula to identify the number of households in which, normal variant (z) was 1.65 with 10% maximum error where the value was 0.01. Hence, the value of n was calculated as:

$$n=\frac{z^2pq}{d^2}$$

$$n=\frac{(1.65)^2 \times 0.50 \times 0.50}{(0.01)^2} = \frac{0.6806}{0.01}$$

Here, z = the normal variant

P = target proportion (p= 0.50)

P + q = 1, therefore, q= 0.50

D = desired error (0.05)

However, a total number of 100 households having well established rooftop garden were identified by purposive random sampling from the study area (Fig. 1) after the analysis of satellite images. The selected sample points were then justified by conducting a field-based ground truth survey. The distribution of samples was proportionate to the 20 administrative zones of DSCC and DNCC (10 zones of DSCC and 10 zones of DNCC) considering four different income groups or classes. Households with a monthly income below 100,000, between 100,000 and 200,000, between 200,001 and 300,000, and above 300,000 were categorized as income class-1, income class-2, income class-3, and income class-4, respectively. The samples (households) were selected zone wise because of covering the full administrative area of DMA. Moreover, zone wise selection of samples helps to include different economic groups of the study area. In case of selecting the households, the present study selected the samples that own healthy rooftop gardens and ignored the RTG, which covers only smaller portion of the roof. There were some inclusion criteria as follows: (i) vegetation coverage more than 50% of the rooftop, (ii) the RTG

must have a variety of fruits and vegetables, and (iii) the RTG must be more than five years old.

RESULTS

Contribution of Rooftop Gardening to Food Production

The field survey identified different types of vegetables and fruits that were practiced in the rooftop gardens of the city. The choice of the gardener and availability of seeds determine what types of fruits and vegetables they wish to produce on the RTGs (Table 1). The study identified that spices as well as medicinal plants are also produced on the RTG.

Table 1: Types of Common Vegetables and Fruits Found in the Rooftop Gardening of Dhaka City

Name of vegetables Cauliflower, Cucumber, Eggplant, Okra, Potato, Pumpkin, Radish, Spinach, Tomato, Red Amaranth, Bean, Bottle Gourd, Sponse Gourd, Snake Gourd, Green Chili, Stem Amaranth, Papaya, String Bean, Ribbed Gourd, Drumstick, Indian Pennywort, Basil (Indian Spinach), Coriander, Wax Gourd, Bitter Gourd, Arum etc.	
Name of fruits Mulberry, Guava, Ber/Jujube, Pomegranate, Sapodila/ Sapota, Pumelo/Shaddoc, Malta, Mango, Hog Plum, Olive, Berry, Sugarcane, Dragon, Banana, Papaya, Carambola, Water Apple, Custard Apple, Bilimbi etc.	

(Source: Field Survey, 2023)

The present study has calculated that on an average a rooftop garden can produce 22,500 kilogram vegetables annually from per hectare area. On the other hand, the city dwellers get about 67,500 kilogram fruits annually from per hectare area. However, the annual food production, including vegetables and fruits from RTG, varies significantly among different socio-economic classes of urban dwellers with RTG. Income group-4 typically invests more money and utilizes larger areas to grow vegetables and fruits, resulting in higher per-hectare production compared to other income groups (Table 2).

Table 2: The Contribution of Different Classes of People in Urban RTG

Socio-economic classes of urban people in RTG	RTG annual vegetables production (kilogram/hectare)	RTG annual fruits production (kilogram/hectare)
Income class-1	17,665	57,815
Income class-2	20,415	67,165
Income class-3:	22,833	69,683
Income class-4:	27,335	77,185

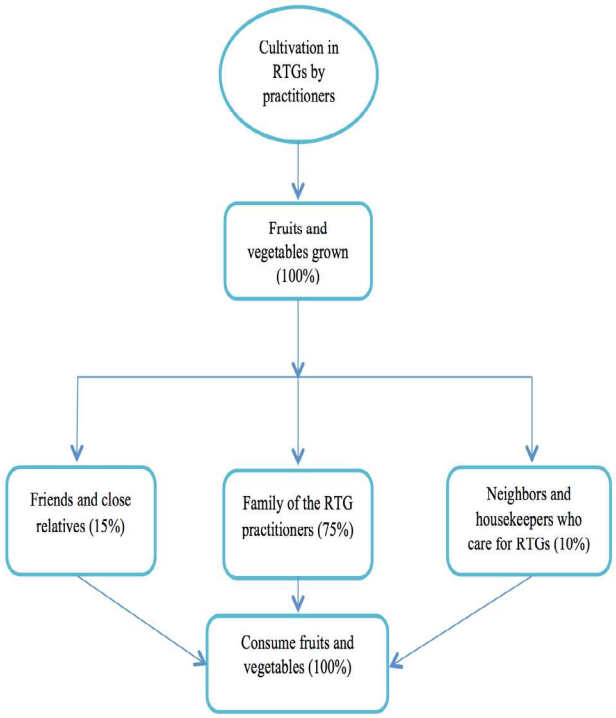
(**Source:** Field Survey, 2023)

Value of Foods and Monetary Shifting

Present study shows that the value of vegetables production from rooftop farming of the practitioners of the city is approximately 3,727 BDT per annum. On the other hand, the value of fruits production from rooftop gardening practice in the study area is approximately 7,647 BDT per annum. The monetary value of fruits

production from rooftop gardening is more compared to the value of vegetable production. The residents of the city use more rooftop space (about 75% of the total space) for the cultivation of fruits and rest of the spaces (i.e. 25% of the total space) is used for vegetables production. Since they use more space for fruits so the yield of fruits is more in this area and hence, food production value of fruits is high in the study area. In addition, yearly practices of RTG by the inhabitants of the city within 257.95 hectares area can contribute about 362 million BDT to the city area.

At the initial stage of gardening, usually family members of RTG practitioners consume most of the vegetables and fruits that are produced in the RTG. Afterwards, when the production is gaining some momentum from the next cultivation period, RTG gardener consumes about 75% vegetables and fruits. Then they share some portions of (15%) fruits and vegetables with friends and close relatives. Moreover, RTG owners also give some portions (10%) of fruits and vegetables to the neighbors and housekeepers who care for RTG. Thus, the cultivated fruits and vegetables are consumed at different levels (Fig. 3).



(Source: The Authors, 2023)

Figure 3: Share of Foods Produced in Rooftop Gardening of Dhaka City The RTG practitioners need to spend money for the development and maintenance of RTG. It is found that during the earlier stages of RTG on an average 60,000 BDT is required for the establishment of a single RTG. However, development cost of RTG varies according to the size of the RTG. For instance, setting up a new RTG requires a higher cost (Shahidullah et al., 2022). Rahman estimated that the initial cost of a small-scale RTG setup range from 80,000 to 100,000 (Rahman, 2012). On the other hand, few people are engaged in cutting and grafting of trees available in the RTG. Moreover, different types of input such as fertilizers, soil, insecticides, pesticides, seeds, vegetables and small plants of fruits were found to be used in the gardens. Therefore, the seller of such products earns money. The RTG owners spend money at different stages of gardening thus, contributing to the monetary shifting.

Household Level Resilience to Food (Vegetables and Fruits)

The present study shows that the contribution of RTG to household level resilience for vegetables is about 6% (i.e. 5.865%) and for fruits is about 18% (i.e. 18.365%) in the city. It is found that the household level resilience to fruits is higher than the vegetables due to some reasons such as the residents of DMA use more space for fruits and cultivate more fruits at the rooftop gardening. Moreover, about two-thirds of people (i.e. 75% people) are more interested to cultivate fruits since it is the hobby of many people to grow fruits and give fruits to friends, relatives as well as neighbor. Furthermore, in most of the cases, small plant of fruits can be planted for a single time and it is easy to look after. On the other hand, in most of the cases, vegetables need to grow seasonally which needs time-to-time collection of seeds and manure.

Household Level Resilience to Nutrient

The study on the sample households in Dhaka city shows that the households can get approximately 21420 calories annually (i.e. about 1785 calories per month) from vegetables by doing rooftop gardening. However, household level yearly intake of calorie from fruits is about 60972 (i.e. about 5081 calories per month) in the city by practicing rooftop gardening. It is found that, on an average a family gets more than 2 times calorie yearly from fruits compare to vegetables. It is also observed that the higher income group (i.e., income class-4) obtains comparatively more calories from RTG (Table 3).

Table 3: Month Wise Average Calorie Intake by Urban People from RTG

Different income classes of urban people in RTG	Month wise average calorie intake from RTG	
	Vegetables	Fruits
Income class-1	1480	1610
Income class-2	1677	1958
Income class-3	2016	2530
Income class-4	4320	8140

(**Source**: Field Survey, 2023)

DISCUSSION

Fewer than 25% urban agricultural land use could supply all calories required by 15.8% of the total population (Mcdougall et al., 2020). Moreover, yearly usage of about 0.05 ha (i.e. 5,000 square feet) RTG for vegetables can fulfill the shortage of daily vegetables of a family (Malik, 2019).Further, practices of RTG increase the local food production, employment and supply of fresh, organic and nutritious food to the local marketplace at a cheap cost (Sprouting Good Urban Farming Sydney, 2014; Haque, 2020; Thapa et al., 2020).

There is a very little amount of agricultural land remaining in Dhaka city (Rahman et al., 2013). Therefore, the city dwellers are practicing rooftop gardening (RTG) for reducing their food dependency on rural people. The number of RTG practitioners in Dhaka city is increasing day by day. It is found that nearly 89% RTG in the city is setup during the last decade. Presently, the city has 257.95 ha (2579477.099 square meter) area of RTG, which can fulfill the demand of about 0.3% fresh vegetables and fruits of the city dwellers. Similarly, another study has revealed that if approximately 416.25 ha area of the RTGs of Dhaka city can be used, it will fulfill the demand of 0.42% fresh vegetables of the city dwellers (DFS, 2022). If the city dwellers use 50% of the total area of roofs (40, 110 ha) for the rooftop gardening it will fulfill the demand of nearly 46.65% fresh vegetables and fruits of the city dwellers. However, if the total roof area of (i.e. 80, 220 ha) of the city can be used for RTG it will fulfill the demand of about 93.3% fresh vegetables and fruits of the dwellers of Dhaka city.

The RTG practitioners of Dhaka city are produced different types of fruits and vegetables, which have significant food value. For instance, the food value of vegetables and fruits from a single RTG are approximately 3,727 Taka and 7,647 Taka per annum respectively. Another study has found that annual values of food production (i.e. vegetables and fruits) from RTG are about 1200 and 1486 BDT respectively (Uddin et al., 2016). Annual practices of RTG by the inhabitants of Dhaka city within 257.95 hectares area can contribute approximately 362 million BDT to the city. Safayet et al. (2017) have identified that food production value from RTG in Mirpur area was anticipated to be between 4,73,846.79 and 47,38,467.936 Bangladeshi Taka annually. However, the household level resilience to food in Dhaka city is far away from the developed countries such as Singapore. The RTG practices in Singapore city bring more contribution to household level resilience for food, which is about 35.5% (Astee and Kishnani, 2010).On contrary, the contribution to household level resilience for vegetables and fruits are 6% and 18% respectively in Dhaka city.

CONCLUSIONS

The present study concludes that the utilization of rooftop spaces of Dhaka city for RTGs can be a possible and potential source of food supply in the city considering the current rate of 0.3% fresh vegetables and fruits in the study area. The contribution of RTG to household level resilience for vegetables is about 6% (i.e. 5.865%) and for fruits is about 18% (i.e. 18.365%) in the city. Besides, the households can get approximately 21420 calories annually (i.e. about 1785 calories per month) from vegetables by doing rooftop gardening. However, household level yearly intake of calorie from fruits is about 60972 (i.e. about 5081 calories per month) in the city by practicing rooftop gardening. Resident's initiatives as well as government and NGO's interventions are essential to accelerate such eco-friendly practice. Proper trainings on hybrid, modern and technology based farming for rooftop gardening should be initiated by the government, non-governmental organizations (NGOs)

and the community. In addition, the government should establish one stop service cell where every type of RTG inputs will be available. The present study would widen the scope of further research such as evaluation of economic and non-economic benefits from rooftop gardening in different levels such as local, national and global scales, effective gardening models etc.

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