Assessment of the linkage of urban green roofs, nutritional supply, and diversity status in Nepal

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Abstract: Rooftop garden is growing in popularity and can be seen as a green roof for the local production of crops in urban buildings. This study focuses on the nutritionally important plants grown in the rooftop garden and their diversity index and evenness in urban roofs. A total of 103 respondents were selected randomly and interviewed using a semi-structured questionnaire from the 12th of February to 23rd of May 2020. The findings suggest that the average area under rooftop gardening is 13.52% in Dhillikhel and 7.32% in Kathmandu and all of the respondents have a positive response regarding its continuation because of its multiple benefits from rooftop gardens. The plant species used for edible purposes were 43 species among the reported 91 species. The Shannon diversity index of Kathmandu was 3.58 and of Dhillikhel was 3.04. Due to lack of technical knowledge and fear of heavy load, rooftop garden in Nepal is suffering. Still, the respondents had problems regarding its management and further extension. Thus, this paper recommends the management of proper training to the growers regarding rooftop gardening, its management, and further extension and continuation. Also, much more research is necessary for developing a good crop calendar for rooftop farming.

Subjects: Environmental Sciences; Agriculture and Food; Urban Studies

Keywords: urban farming; Shannon-Weaver index; roof damage; reduced urban waste; nutritional supply

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PUBLIC INTEREST STATEMENT

The introduction of a rooftop garden in the urban ecosystem does not have along history but in the present context, it is of high importance. The linkage of urban green roofs is direct with nutritional supply and also various ecosystem services directly or indirectly. Thus, the establishment of a rooftop garden from household waste materials and few planting materials is recommended to be benefited from its various nutritional supply and also for healthy living. Nowadays rooftop gardens are established to minimize the risks of high pesticide usage by the farmers. Due to which rooftop gardens are established and suggested to establish an organic model of farming/gardening.
1. Introduction

Rooftop gardening is an innovative way of farming activity done on the top of buildings by utilizing the open spaces in roofs or terraces. In urban areas, it is usually done by using green roofs, hydroponics, aeroponics, or container gardens (Asad & Roy, 2014). It can be established through open-air and protected technologies and used for different purposes. Green roofs can be categorized as intensive and extensive roofs based on their purpose and characteristics. The first records of rooftop gardening date back to ancient Etruria and Rome (Barreca, 2016). In the present context, the issues related to urban welfare and sustainability of cities can be overcome by rooftop gardening (Holloway et al., 2009; Hough, 2004). It may seem a small step, but it is a leap ahead for sustainability and combating the havoc of climate change hazards (Kumar et al., 2019). Occupying unused rooftops for agriculture has great potential for wide-scale implementation in urban areas, including major cities (Astee & Kishnani, 2010; Rodriguez, 2013). For instance, a city such as Bologna (Italy) could fulfill 77% of its vegetable demand with rooftop farms with productivities of 15 kg/m² (Orsini et al., 2014). The short-term implementation of rooftops in a logistic park in Barcelona with 13 ha of suitable rooftop area could produce 2,000 tons of tomato annually, which would fulfill the demand of 150,000 people (Sanyé-Mengual et al., 2015).

The microclimate of the surroundings can be modified by rooftop gardening to mitigate the temperature on the roof as well as the room below the roof garden (Gupta & Mehta, 2017). Studies also show green roofs have lower temperatures than conventional roofs (approximately −1.11 to 4.44°C). The garden on the roof helps in reducing carbon in the atmosphere. It cuts off 30% of all CO₂ emissions for heating or cooling the building (Kumar et al., 2019). Also, it can assist urban areas by reducing storm water management costs. The rainwater is captured through absorption by the vegetation in the garden reducing the overflowing impact on roads (Thapa et al., 2020b). Furthermore, rooftop garden indirectly lowers the carbon footprint caused by trucks used to transport food into the city (Rowe & Getter, 2006).

It aids in reduction of air pollution, enhancement of noise muffling, provides acoustic insulation, carbon sequestration, replacement of displaced landscape, increment of biodiversity, provision of recreational and agricultural spaces, increased roof lifespan, retention and delay of storm water, energy savings, and mitigation of urban heat island (Whittinghill & Rowe, 2012). In a similar manner, green roofs reduce electromagnetic radiation penetration by 99.4% (Herman, 2003). Research published by the National Research Council of Canada found that an extensive green roof reduced the daily energy demand for air conditioning in the summer by over 75% (Liu, 2003). Recently, the world’s largest rooftop greenhouse has been opened in Montreal to meet the growing demand for locally sourced foods.

Rooftop gardens can also succor in the re-naturalization of cities, making them more sustainable. Rooftop gardening also decreases the urban waste as kitchen waste is mainly degradable and used as compost. Also, unrecycled plastic waste can be used as planting material for a short period (Thapa et al., 2020a). Harmful chemicals, inorganic fertilizers, and pesticides used to increase production, etc. are increasing at an alarming rate. In this circumstance, to partially solve these problems by growing vegetables on the rooftop can be a potential solution. Rooftop vegetable farming can help to meet food demand by supplying fresh and hygienic vegetables, diminution of household expenditure for buying vegetables, creating healthy surroundings. Ensuring food security is a major concern worldwide (McGuire, 2015). RTGs, while being aesthetically attractive, can lead to increased biodiversity in the urban environment, achieve more sustainable conditions, including those necessary for the production of food and improve the overall quality of urban living (Bennett, 2003; Maas et al., 2006; Miller, 2005; Sanye’-Mengual et al., 2013; Shariful Islam, 2004). From a food and nutrition point of view, roof gardens help to increase the availability of and facilitate the access to fresh fruits and vegetables, which is perceived as a contribution to balanced diets for all and the decrease of malnutrition affecting especially the urban poor. In terms of productivity and efficiency, roof garden systems are a living example of what can be achieved more with less in line with the “save and grow” principle (FAO, 2011). Green roofs can offer potential long-term job opportunities for both skilled and unskilled people around the globe.
Over time, green roofs became very popular; nevertheless, their cost disadvantage has been very challenging to the industry. In general, green roof’s experts agree that the reasons for these higher costs are usually due to materials lifting with cranes to the roof tops, expensive labor cost, high insurance premiums, and limited choice of plants. In addition, green roofs add more weight to the roof, which leads to changes in the structural design where columns, beams, and slabs must be modified, resulting in a more expensive structure. Heavy load may create the problem of seepages in the roof. Green roof’s experts justify the need to introduce materials like plastics into the market as it can reduce the overall weight and improve the performance of waterproofing layers without compromising the benefits of green roofs (Bianchini & Hewage, 2012). Ceiling dampness/Roof dampness can be a fear and threat to people. Placing the containers, drums, and pots above brick or any firm substance can avoid such problems. Polymer materials that are used in green roof causes pollution that needs elimination to protect the environment. Although green roofs are initially more expensive to construct than conventional roofs, they can be more economical over the life span of the roof owing to the energy saved and the longevity of roof membranes (Porsche & Köhler, 2003).

In Nepal, currently, a limited number of households are adopting rooftop gardening with the support of NGOs, municipalities, and the Ministry of Agriculture Development (MOAD). Kathmandu Metropolitan Council has decided to provide funding support to 500 households to expand the rooftop gardening program with aims to encourage local food production and municipal waste management more efficiently. Though the program focused on expanding the rooftop garden in Kathmandu, the average area covered by a rooftop garden and its linkage with functional category and possible crop diversity of the area was not reported. Furthermore, these trainings were not sufficient and households are facing more and more challenges. Thus, this survey was conducted to highlight the status of rooftop gardening. Lack of technical knowledge, availability of true to type plant varieties, lack of support and cooperation from the government sector, and lack of leisure time are some problems faced by people. Still more research is ongoing into the implementation and effective performance of green roofs in different parts of the country. The main objective of the study is to explore the assessment of urban rooftop gardening with nutritional supply in Nepal. This paper also focuses on the benefits from the urban sustainability perspective and different practices adopted along with the challenges faced by people for establishing rooftop gardening.

Methodology

Study area

The study area selected for the study is Kathmandu (Capital city of Nepal) and Dhulikhel of (Kavreplanchok) (Figure 1). Both the study areas lay in province no. 3 which is one of the fastest-growing and the most developed province of Nepal in comparison to others. Kathmandu lies at an altitude of 1420 masl, the average temperature ranges from 14°C to 33°C annually and precipitation of 1505 mm. Similarly, Dhulikhel lies at an altitude of 1550masl and annual temperature ranges from 11°C to 31°C and precipitation of 1711 mm (Climate data, 2012). The high population increase and greater speed of urbanization are due to favorable climate and hope for better opportunities. However, still, urban water management is a great problem in these areas (Pandey, 2020). The main reason to select these places as the study area is the high rate of increasing green roofs due to lack of home gardens and open space on the ground.

Sampling technique and sample size

The research design was a simple random sampling survey (probability sampling) where the respondents were selected randomly. The sample size was adjusted to 103 households (HH) and a key informant interview was conducted with the rooftop maintainer. The main reason for the key selection of rooftop maintainers was to collect in-depth information on research questions (Thapa & Rawal, 2020) and to know about the present issues and constraints associated with RTGs. Two focus group discussions were also conducted at the end of the survey, one in each study area. The main aim
of focus group discussion was to know about the constraints of rooftop gardening in detail and also share the farming experiences among the participants. At local level what might be the adaptation strategy and further recommendations to reduce the fear of initiating RTGs were discussed.

Research instruments

A semi-structured questionnaire was prepared (Thapa et al., 2020a, 2020b) and pilot testing was done in both study areas with 10 respondents each to adjust the accuracy of the questionnaire and to collect the more precise information in the study area. The information collected during the pilot testing was not considered for analysis as the questionnaire was edited after pilot testing. The survey questionnaire was pulled from Thapa et al. (2020a &b) and Kumar et al. (2019). The survey was started on the 12th of February and was finished on the 23rd of May 2020. The key informant survey and two focus group discussions are the sources of primary information. A focus group discussion was also done to triangulate the information collected and to obtain some additional information. Secondary information was collected from national and international open access journals, conference papers, web pages, and published thesis of graduates and doctorate students, cited in the manuscript.

Data analysis

The collected primary information from key informant surveys was entered into MS-Excel 2013, and specific coding was given for the variables. Data analysis includes descriptive statistics and inferential statistics which were analyzed using Statistical Package for Social Sciences (Stockemer, 2016). Also, the diversity index, Shannon–Weaver diversity index, Simpson 1-D, and effective number of species were interpreted using PAST 4.0 (Hammer et al., 2001). Tables and figures were created using MS-Word, MS-Excel, and SPSS V.20.

1.1. Shannon–Weaver diversity index
The Shannon—Weaver index is the most commonly used diversity indicator in plant communities, and it takes a value of zero when there is only one species in a community, and a maximum value when all species are present in equal abundance (Shannon, 1949).
\[ H = \sum_{i=1}^{S} - (pi \times \ln pi) \]

where; \( H \) = Shannon-Weaver diversity index;

\( pi \) = fraction of the entire population made of species \( i \);

\( S \) = number of species encountered;

\( \Sigma \) = sum from species 1 to species and “ln” is the natural logarithm to the base e (log).

**1.2. Simpson's index of diversity 1-D**

The value of this index ranges between 0 and 1, the greater the value, the greater the sample diversity. In this case, the index represents the probability that two individuals randomly selected from a sample belong to different species. Simpson's index of diversity is subtracted from Simpson's diversity indices (D) by one (Semu, 2018) and mathematically represented as follows:

\[ D = \left( \sum_{i=1}^{S} pi \right) \]

where; \( N \) = Refers to total number of all species;

\( n \) = Refers to the total number of a particular species.

**1.3. Evenness measure**

Evenness measure as \( E = H/H_{max} \), i.e., the ratio of observed diversity to maximum diversity (Magurran, 2004).

**1.4. Effective number of species**

It is calculated by taking the exponential value of Shannon–Weaver diversity index as explained by Peet (1974).

**2. Results and discussions**

**2.1. Socio-economic characteristics**

In both the study areas, higher frequency of female respondents were recorded (Table 1) and were statistically indifferent \( (\chi^2 = 0.435) \). Among the surveyed respondents, 76.9% were Janajatis, 7.7% each were Brahmins and Chhetri's, 5.8% were Newar, and 1.9% were Dalits in Dhulikhel. And in Kathmandu, 46.1% were Brahmins, 26.9 were Chhetri’s, 21.2% were Newar, and 5.7% were Janajatis. The average family size & economically active population in Dhulikhel and Kathmandu was 4.38 & 2.02 and 4.42 & 2.12, respectively. In both the study areas, maximum respondents have a male head in family and decision-making. None of the key respondents in the study area were illiterate and higher percentage of them have completed secondary level \( (\chi^2 = 12.26, \ p-value = 0.05) \) and is statistically significant. The details of the socio-economic characteristics are presented in Table 1.

**Size of rooftop farms**

The average area of the roof is almost similar in both study areas; however, in comparison, the average area covered by the rooftop garden in Dhulikhel is twice as much as covered by Kathmandu (Table 2). In contrast to average, the percentage share of the rooftop garden is higher by a range in Kathmandu. This might be due to the small size of the roof and covering a wide space by the garden.
Table 1. Socio-economic characteristics of the study area

| PARAMETERS             | Dhulikhel (N = 51) | Kathmandu (N = 53) | Overall | Chi-sq value | P-value |
|------------------------|--------------------|--------------------|---------|--------------|---------|
| Sex                    |                    |                    |         |              |         |
| Male                   | 44.2               | 42.3               | 43.25   | 0.435*       | 0.51    |
| Female                 | 55.8               | 56.7               | 56.25   |              |         |
| Ethnicity              |                    |                    |         |              |         |
| Brahmin                | 7.7                | 46.1               | 26.9    | 11.757*      | 0.465   |
| Chhetris               | 7.7                | 26.9               | 17.3    |              |         |
| Janajatis              | 76.9               | 5.7                | 41.3    |              |         |
| Newars                 | 5.8                | 21.2               | 13.5    |              |         |
| Dalits                 | 1.9                |                    | 0.95    |              |         |
| Education              |                    |                    |         |              |         |
| Primary                | 24.6               | 19.9               | 21.8    | 12.26*       | 0.05    |
| Secondary              | 50.4               | 39.9               | 45.15   |              |         |
| High school            | 19.2               | 5.8                | 12.5    |              |         |
| University             | 5.8                | 35.3               | 41.1    |              |         |
| Family size            | 4.38 ± 0.278       | 4.42 ± 0.13        | 4.40    | 26.02 ns     | 0.67    |
| Economically active population | 2.02 ± 0.108 | 2.12               | 2.07    | 10.9 ns      | 0.28    |
| Head of family         |                    |                    |         |              |         |
| Male                   | 73.1               | 73.1               | 73.1    | 0.011 ns     | 0.9     |
| Female                 | 26.9               | 26.9               | 26.9    |              |         |
| Land ownership         |                    |                    |         |              |         |
| Male                   | 50                 | 80.8               | 65.4    | 2.66 ns      | 0.44    |
| Female                 | 50                 | 19.2               | 34.6    |              |         |
| Decision-making        |                    |                    |         |              |         |
| Male                   | 53.8               | 55.7               | 54.75   | 1.307 ns     | 0.52    |
| Female                 | 13.5               | 34.6               | 24.05   |              |         |
| Both                   | 32.7               | 9.7                | 21.2    |              |         |

Source: field survey, 2020. *means significant at 5% level of significance, ns means non-significant.

2.2. Planting material used in rooftop farming

The diversity of planting materials recorded from the study area and the selection of planting material was identified by the nature of crops. Mostly, vegetables were grown in styrofoam crates and waste bags, flowers were grown in earthen pots, plastic pots, and bottles (bottle gardening was reported in few houses of Kathmandu). Also, vegetables like tomato, eggplant, okra, and chili were found to be planted in recyclable materials like waste bags and waste jars. The details of the types of planting materials reported from the study area are as shown in Figure 2. The utilization of planting materials, especially by recycling the waste bags, bottles, cans, and jars, is also one of the contributing factors for a reduction in waste and reducing garden maintenance costs (Thapa et al., 2020a). The use of household waste materials as planting materials for promoting sustainable urban ecosystems and reduction in waste generation has been recommended by Sanyé–Mengual et al. (2015).

Table 2. Size of rooftop garden in study area

| Parameters                  | Dhulikhel       | Kathmandu       | F-test |
|-----------------------------|-----------------|-----------------|--------|
| Area of roof (m²)           | 325.8 (90–885)  | 326.3 (90–698)  | 2.35***|
| Area of rooftop under farming (m²) | 44.05 (0–125)  | 23.90 (0–120)   | 2.19***|
| % share of rooftops to farming by area | 13.52% (0–26.67%) | 7.32% (0–43%) |        |

(Source: field survey, 2020). Figures in the parenthesis indicate the range. *** indicates the significance level at 1%.
2.3. **Nutritional category and diversity indices of the plant in the rooftop garden**

Rooftop agriculture ameliorates various ecosystem services (Grard et al., 2018), enriches urban biodiversity, and reduces food insecurity (Walters & Midden, 2018). About 91 plant species were recorded from home garden among which around 43 were found to be nutritionally important (vegetables, fruits, medicinal plants, and spices & condiments) (ANNEX 1). Similar to our findings, Kim et al. (2018) also reported that the structure of rooftop garden comprises diversity of crops ranging from edible vegetables and fruits to ornamental plants for aesthetic purposes. The continuous supply of fresh, healthy, and chemically unpolluted products is one of the great reasons for continuing the rooftop garden. The evidence of nutritional supply and its benefit has been reported by Baudoin et al. (2017) and Zande (2006). The nutritional supply of rooftop garden and diversity of crops in a past study reported in Dhulikhel comprises medicinal plants, fruits, vegetables, and some cereals like maize and jowar (Thapa et al., 2020a). Boneta et al. (2019) suggested that tomato, chard, lettuce, pepper, and eggplant are the most productive and suitable crops for rooftop gardens. The diversity profile of the species categorized into groups is shown in Table 2. The highest number of ornamental plants was recorded from the study area followed by vegetables, medicinal plants, spices, and others. Typically, the value of Shannon–Weaver diversity lies between 1.5 and 3.5 and is rare to be above 3.5 (Neelamegam et al., 2015). Our study result is in line with typical values reported for Shannon diversity, i.e., 3.58. Though being a rooftop in a small area, species diversity was found to be high in Kathmandu as compared to Dhulikhel, but vegetable crops diversity was dominated by Dhulikhel both in terms of Shannon–Weaver and an effective number of species. The details of the diversity indices reported from roofs of Kathmandu and Dhulikhel are shown in Table 3.

2.4. **Satisfaction and benefits from the rooftop garden**

The level of satisfaction was measured in 4 groups highly satisfied, satisfied, moderately satisfied, and unsatisfied. Eighty-five percent of the rooftop growers are highly satisfied, 6% are satisfied, 7% are moderately satisfied, and only 2% of the respondents were found to be unsatisfied in the study area. The details of the satisfaction are shown in Figure 3. The benefits of rooftop gardens in the study area varied from respondents to respondents. The supply of green and fresh organic vegetables is one of the important and most satisfying benefits of rooftop garden owners. Similarly, continuous supply of vegetables, the supply of organic veggies, utilization of rooftop garden for recreation and refreshment, use of roofs for green decorations, and aesthetic importance of rooftop gardens is also promising for its continuation. Rooftop gardens are of high value...
nowadays for urban sustainability and promotion of green roofs. It also reduces the monthly expenditure on vegetables and fruits to some extent (Jafari et al., 2015). The trend of adopting a rooftop garden is also increasing and garden owner satisfaction is also worth increasing (Kumar et al., 2019). However, no modern and hydroponics techniques were found to be adopted in the study area, only, traditional means for continuing farming were recorded. The adoption of hydroponics and greenhouse people’s response was not satisfactory due to its high cost of establishment and maintenance. The adoption of modern technology in urban roofs for farming is a great challenge in developing countries like Nepal due to a lack of effective policy and decision-making. Moreover, constraints in adopting modern technology in urban roofs have also been reported from developed countries like Canada, America, Italy, etc. (Sanyé–Mengual et al., 2015). Rooftop agriculture was severely affected by governmental policies in Denmark due to ignorance of its benefits (Delshammar et al., 2017).

Table 3. Diversity status of the plant reported in the study area

| Criteria  | Shannon (H) | Simpson 1-D | Evenness | Effective number of species |
|-----------|-------------|-------------|----------|---------------------------|
| Kathmandu | Overall     | 3.58        | 0.95     | 0.38                      | 35.87                             |
|           | Vegetable   | 2.077       | 0.83     | 0.38                      | 7.9                                |
|           | Fruit       | 1.79        | 0.74     | 0.52                      | 5.9                                |
|           | Flower      | 3.07        | 0.91     | 0.45                      | 21.5                               |
|           | Medicine    | 1.67        | 0.78     | 0.67                      | 5.3                                |
|           | others      | 1.02        | 0.57     | 0.69                      | 2.77                               |
| Dhulikhel | Overall     | 3.04        | 0.89     | 0.32                      | 20.9                               |
|           | Vegetable   | 2.51        | 0.812    | 0.64                      | 12.3                               |
|           | Fruit       | 1.07        | 0.071    | 0.33                      | 2.9                                |
|           | Flower      | 3.46        | 0.82     | 0.68                      | 31.8                               |
|           | Medicine    | 1.67        | 0.77     | 0.45                      | 5.31                               |
|           | Others      | 1.06        | 0.52     | 0.63                      | 2.88                               |
2.5. Cost of establishment and maintenance

All the respondents were positive regarding the establishment of rooftop gardens as once the base is created it will not cost a huge amount to maintain and manage gardens. The amount of money for establishment and maintenance differed from respondents to respondents and also differed from the size of roofs. The average cost of establishment and maintenance in Dhulikhel is Rs. 1854.23 and Rs. 668.12 and in Kathmandu id Rs. 1775 and Rs. 501, respectively (Table 4). The main reason for the high cost of maintenance and establishment might be due to the average share of the roof to the farm is higher in Dhulikhel than that of Kathmandu. The cost of maintenance is allocated for introducing new plants, fertilizers, seeds, and the exchange of old planting materials from the rooftop garden. However, the investment of pesticides by rooftop growers was found to be nil in the surveyed households. The need for maintenance to the rooftop garden and consumer’s willingness to pay for it has been reported by Safayet et al. (2017) in Bangladesh. Consumers willingness for maintenance of rooftop garden might be due to the benefits and huge B/c returns from rooftop garden (Hui, 2011) and their multiple ecosystem services (Grard et al., 2018).

2.6. Knowledge on rooftop farms and training

People’s knowledge of rooftop farming was mainly through the internet, social media, and sharing of ideas among friends and neighbors. Around 82% of the respondents in Kathmandu and 75% of the respondents in Dhulikhel gained information on rooftop gardening practices through the internet and 3% by friends and neighbors in Kathmandu and 12% in Dhulikhel, respectively. Training specially designed for rooftop growers was found to be conducted in the study area; 35.2% of the respondents in Dhulikhel and 31% of the respondents in Kathmandu have participated in training for continuing and managing rooftop gardens.

2.7. Constraints of rooftop farms

Constraints faced by the respondents in rooftop gardening varies from respondents and also the place of research (Figure 4). Generally, for extending the load of rooftop garden, 15.4% of the respondents of

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**Table 4. Cost of establishment and maintenance**

|                | Dhulikhel    | Kathmandu   |
|----------------|--------------|-------------|
| Cost of establishment | 1854.23 (600–3000) | 1775 (400–2500) |
| Cost of maintenance   | 668.12 (200–1200)  | 501 (200–900)   |

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**Figure 4. Constraints faced by respondents in rooftop gardening.**
Kathmandu and 33.6% in Dhulikhel have a fear of heavy load. Similarly, lack of technical knowledge on management and care of rooftop garden was 25% and 21% in Kathmandu and Dhulikhel, respectively. Lack of leisure time to maintain the home garden, roof damage, and lack of manpower to manage home gardens were also the contributing factors for affecting in extending and not the reason for long-term continuation of the rooftop garden. The constraints faced by the rooftop practitioners and non-practitioners are almost similar but differ in terms of establishment and continuing (Thapa et al., 2020a, 2020b). The fear of roof damage is one of the major problems for both the rooftop growers and non-rooftop growers (Kumar et al., 2019; Walters & Midden, 2018). Also, the lack of technical knowledge and unfamiliarity with the initial procedure of rooftop garden establishment is still preventing the adoption of a green roof (Specht & Sanyé-Mengual, 2017; Walters & Midden, 2018). The use of lightweight soil minimized the additional load to the building from the green roof (Kim et al., 2018). Specht & Sanyé-Mengual (2017) reported that for the commercial adoption of the rooftop garden, competition with large enterprises and other rooftop growers is likely to affect the sustainability of business and also the associated technology is too complex.

3. Conclusion
Rooftop garden is of high value in an urban ecosystem due to their multiple benefits. The nutritional supply of the rooftop garden is so promising for the gardeners to continue the farm. They are benefited by fresh and healthy organic vegetables and fruits including some spices, condiments, and even medicinal plants. The food supply of the rooftop garden helps in solving food security problems directly or indirectly and even contribute to aesthetic value addition and even ecosystem benefits. The use of urban wastes like plastic bags, fish crates, and even trash bags as a planting material has reduced daily household wastes. However, there still exists a problem in continuing a rooftop farm sustainably due to their lack of technical knowledge on managing how to extend how and even how to manage the roof from being damaged. It might be a serious threat to the urban ecosystem if these problems exist.

4. Recommendations
• Further case studies in rooftop farming might enlarge the knowledge of the sustainability performance of crops, growth systems, and rooftop farming forms.

• Enhance inclusive rooftop farming models to address social gaps in urban areas and to boost local involvement in local food systems.

• Further case studies in vertical farming might provide new knowledge of the sustainability performance of other innovative forms of local production (e.g., indoor farming, aquaponics) and should also profile local food systems to enhance sustainability.

• Training and extension services related to rooftop gardens most be provided by the concerned bodies, especially the local organizations working in the field of urban agriculture and even agriculture knowledge center.

5. Limitations of the study
This study typically focuses on the household survey and all the data associated with this research have been collected from a semi-structured questionnaire. Also, the outcome of this research focuses on increasing the rooftop adoption and its economic importance along with solving rooftop constraints. This paper does not answer for life cycle assessment, the average production of rooftop in a designated area, and any experimental results. This paper is an outcome of household surveys.

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