Rooftop Hydroponics: Opportunity for Urban Agriculture in Godawari Municipality of Nepal

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ABSTRACT

Urbanization is growing in Nepal at a rapid pace with an increasing number of municipalities. Due to rapid urbanization, agricultural lands have been converting into buildings and infrastructures. This has negatively impacted the urban environment with decreased greeneries, open space, local food production, and groundwater recharge. In this context, this study aimed to explore the opportunity of roof-top hydroponics for urban agriculture in Godawari Municipality. A questionnaire survey was done in ward-14 of Godawari Municipality from November 2018 to December 2018 with a sample size of 64 households. A stratified random sampling method was applied for the household selection. Out of 64 respondents, 45 (71.31%) achieved high opportunity scores based on eight factors: Space, Willingness, Affordability, Manpower, Time, Knowledge, Technology, and Acceptance with incentives. Thus, roof-top hydroponics has a high opportunity for practicing urban agriculture to provide greeneries, fresh vegetables and fruits to the city dwellers locally in Godawari Municipality for realizing the concept of Food Green City.

Keywords: Food green city, food security, rooftop farming, urban environment, urbanization.

1. INTRODUCTION

Globally, the urban population is increasing rapidly. It has reached to 55% and is expected to increase to 68% by 2050 (United Nations 2019). Due to the increasing trend of urbanization, there is a massive demand for food supply for urban dwellers. With urbanization, food insecurity issues come out and urban agriculture could be a means to decrease food supply risks (Corbould 2013). Urban agriculture can play a valuable role in sustainable food systems with many benefits (Nogeire-Mcrae *et al*. 2018). The advancement of urban and peri-urban agriculture can help to manage urban waste for food production; provide support for weak economic sections of people; better public health due to greenery and help to improve urban management (MoUD 2017). National Planning Commission of Nepal (NPC 2016) mentioned in the 14th plan to promote urban agriculture in the urban areas to produce food itself to some extent and maintain greenery by realizing the concept of Food Green City (FGC) i.e. integrating urban agriculture with urban planning (Shrestha

2019). FGC has great potential to contribute to sustainable urban development and Low Carbon Society (Shrestha *et al.* 2012).

To solve food security problems and promote sustainable agriculture, roof-top gardening is necessary for present urban settlements (Thapa *et al.* 2020). Roof-top farming in urban areas is generally practiced using hydroponics, aeroponics, green roofs or container gardens (Asad & Roy 2014). A green roof is an emerging way to fulfill the increasing demand for fresh food and also it helps to improve the quality of life of urban dwellers with many benefits like purifying air, acting as a storm water reservoir and carbon dioxide absorbent (Jha *et al.* 2019). For example, the 5,000-square-foot garden at the roof-top of the OUE Downtown commercial building in Singapore provides vegetables like salad leaves and herbs, and flowers to the restaurants of the building (Low 2020).

Urbanization is leading to the loss of agricultural lands in Nepal which results in the import of food from outside to meet the food demand (MoUD 2017). With increasing urbanization in developing countries, roof-top farming helps to supply fresh and hygienic food, reduces household expenditure and improves air quality (Safayet *et al.* 2017). However, even in the few available spaces, people have less time for practicing urban agriculture and do not like to do it traditionally (Thapa *et al.* 2020). Hydroponics is a method of doing agriculture without soil and gaining popularity as a hobby (Butler & Oebker 1962). It is a useful technique for growing food with benefits: less time for growing, minimum disease and pest incidents, no weeding and less water consumption (Prakash 2020). In this context, this study is thus aimed to find out the opportunity of roof-top farming using hydroponics in Godawari ward -14.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Godawari Municipality ward-14 of Lalitpur district in Nepal (Figure 1), that had a population of 8261 in 2011, and the total household was 1982 (CBS 2017). This study area has a combination of a high density built-up area with the existence of roof-top farming practitioners and scattered areas with non-practitioners. So, this area was selected for study by dividing it into four urban zones (Figure 2).

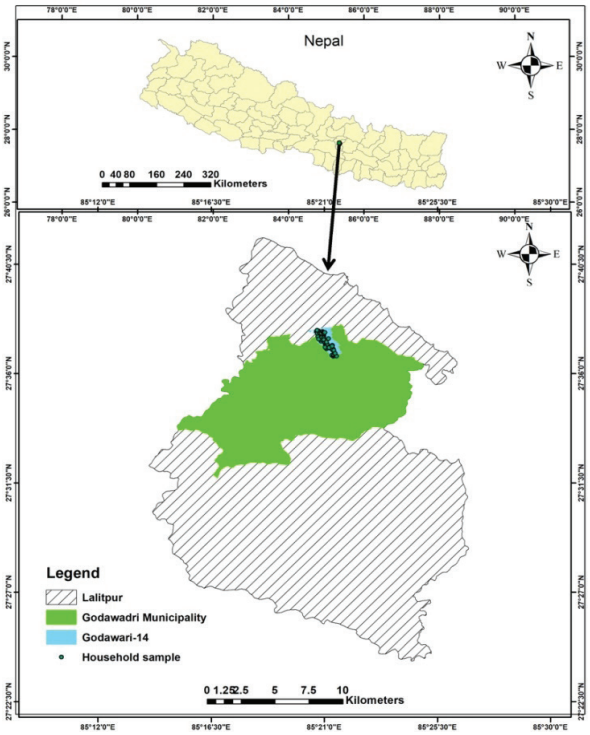

Fig. 1. Location of Study area (Godawari-14) in Nepal

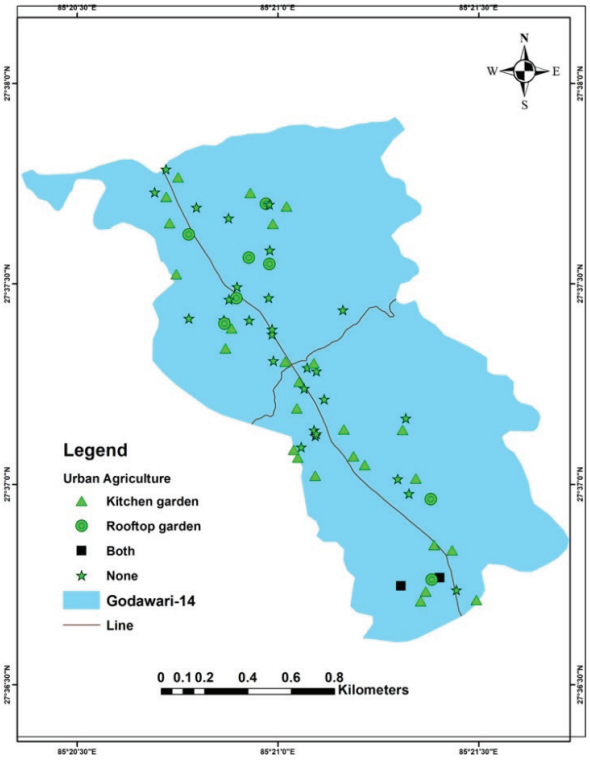

Fig.2. Status of Urban Agriculture in Study Area

2.2 Sample size and Target Population

A cross-sectional study was conducted from Nov. 2018 to Dec. 2018.

To calculate the sample size, the following equation was used from Watson (2001).

$$n = \left(\frac{p[1-p]}{\frac{A^2}{Z^2} + \frac{p[1-p]}{N}} \right) R$$

Where :
n = Sample size required,
N =Target population (1982 urban households)

p = 50% estimated variance in population as a decimal (0.5)

A = 88% precision desired (marginal error 0.12)

Z = 95% confidence level, (z -scores=1.96)

R = 100% estimated response rate as a decimal (1)

n = 64.52

A sample size of 64 Households (HH) was selected, representing 14 percent of the target population by using the above formula. Stratified random sampling was adopted to give the appropriate and representative sample for each urban zone. Each urban zone was used as strata for sampling for 16 households.

2.3 Data Collection Methods

Data was collected using KoBo Toolbox. To collect information from the respondents, an open-ended and closed-ended pretested questionnaire was used. The questionnaire covered general and technical information. The technical information included the total land area, space covered by building/roof-top area and potential space for roof-top farming. The total land space was recorded using a questionnaire; the area of the building was calculated using Google Earth. The potential space (length x breadth) of the roof-top was measured by using Measuring Tape. The location of the sample households were traced through the SW maps. The questionnaire seeked information exploring the opportunity and perceptions of practicing roof-top farming with hydroponics. Trained research associate took a minimum of 20 minutes to an hour for data collection for a household.

Rooftop farming practitioners were interviewed to explore their present conditions and perception towards hydroponics. Non-practitioners were asked about their perception of urban agriculture and roof-top hydroponics. The most important part of the questionnaire was to calculate the opportunity scores in that area. The eight factors, namely Space, Willingness, Affordability, Manpower, Time, Knowledge, Technology, and Acceptance with incentives were considered for the determination of the opportunity scores. The maximum scores were eight by summing up all variables. Space, Willingness, Affordability, Manpower and Time were taken as a minimum requirement for seeking the opportunity of hydroponics roof-top farming. Each factor was given one score. So, these five factors altogether carried total scores of five, which was taken as the minimum score in exploring the high opportunity of roof-top hydroponics. Otherwise, households obtaining less than five opportunity scores were considered having low opportunity to practice roof-top hydroponics.

2.4 Data Analysis

Raw data from KoBo toolbox were downloaded in the excel sheet format. The data analysis was done from SPSS v21.0, and the map was presented using ArcGIS. Frequency, percentage, mean and standard deviation were calculated.

2.5 Ethical considerations

Written consent was obtained from all respondents before the interview, and permission was taken from the local authority for conducting the field survey.

3. RESULTS

Table1 provides an overview of the socio-demographic characteristics of the households surveyed. The majority (89.06%) of the respondents, were in the age group of 15-64 years, and only 10.94% belonged to >65 years. Among the respondents, 56.25% of the people were male, while 43.75% were female. Regarding formal education of the respondents, 53.13 % had primary education and below, 29.69 % people had completed secondary education, 15.62 % of people were graduated and 1.56% had post-graduated. The average sample population size in a family was 5.23, the mean sample population of male was 2.63, and the mean sample population of female was 2.64. The main occupation of respondents was agriculture i.e.37.5% and 32.82% had own business.

Table 1. Socio-Demographic Variables of HH respondents

Socio-Demographic variables	n (%)
Age	
15-65	57(89.06)
>65	7 (10.94)
Gender	
Male	36(56.25)
Female	28(43.75)

Ethnicity	
Janajati	52(81.25)
Brahmin/Chettri	11(17.19)
Dalit	1(1.56)
Religion	
Hindu	59(92.18)
Christian	3(4.69)
Buddhist	2(3.13)
Education	
Primary education and below	34(53.13)
Secondary and higher secondary	19(29.69)
Graduate	10(15.62)
Post graduate	1(1.56)
Occupation	
Agriculture	24(37.50)
Business	21(32.82)
Government service	9(14.07)
Private service	6(9.36)
Others	4(6.25)

The practice of roof-top hydroponics was directly linked with house type and roof-type. This study thus investigated the status of ownership of houses, house structures, and roof-top of the respondents in the study area (Table 2).

Table 2. Housing condition Respondents

Descriptions	**n (%)**
House ownership	
House owner	
Tenant	2(3.12)
House type	
RCC	58(90.62)
Load bearing	4(6.25)
Temporary	2(3.13)
Roof type	
Flat	58(90.62)
Slope	6(9.38)
Space available status	Mean± SD
Average Land Area (sq. m.)	255.56±233.28
Average Total space of Roof (sq. m.)	109.77±34.13
Average Open space at the Roof-top (sq. m.)	91.03±33.99
Average Potential space for Roof-top hydroponics (sq. m.)	84.38±33.79

OPPORTUNITIES OF ROOF-TOP HYDROPONICS

In this study, 96.88% respondents had ownership of the houses. Houses having RCC structure with flat roof-type were 90.63% and potential average open space at roof-top available was 84.38 sq. m., indicating the high opportunity for roof-top farming / hydroponics. Among the total HH respondents, 78.13 % showed willingness for urban agriculture. Among interested people who were asked to choose roof-top farming, kitchen garden or both, 84% of respondents had chosen roof-top gardening whereas 10% had chosen kitchen gardening and both by 6 % respondents.

Out of total respondents, only 6.25 % had knowledge of roof-top hydroponics through the Internet, TV and Newspaper etc. The reason might be hydroponics, being a new technology introduced recently in the country. However, 81.25 % of respondents showed their interest in knowing about hydroponics. Majority of respondents 44 (68.75 %) said they have enough manpower to practice hydroponics, and 89.06 % responded that they could give time for roof-top- hydroponics.

The respondents who could afford roof-top hydroponics were 82.81 %. They were willing to bear minimum to moderate costs of NRS. 20,000–60,000 i.e. US$ 178.24 US$ 534.71 (1US$=NRS 112.21 as per December 2019) to practice roof-top hydroponics farming. About 79.69 % of respondents said that they want to take financial or other types of incentives for practicing hydroponics showing positive attitude towards roof-top hydroponics.

As mentioned in Table 3, majority of the respondents 45 (71.31 %) were found to have opportunities scores >5 and remaining of respondents 19 (29.69 %) had low opportunity scores (1- 4). It showed that there was a high opportunity of roof-top hydroponics in the study area.

Table 3. Opportunity scores

Opportunity Scores	**Remarks**	**Frequency**	**Percentage**
1-4	Low	19	29.69
>5	High	45	71.31
Total		64	100.00

DISCUSSION

Looking at the respondents' age group, most of them can do roof-top hydroponics if they were motivated and provided training. In Nepal, the average family size is 4.6 person, whereas 4.8 in rural areas and 4.2 in urban areas (CBS 2016). The average family size of study population

was 5.23, which was higher than the national family size in urban areas. A higher number of people in the family mean higher human resources available to practice roof-top hydroponics. In this study, 96.88 % of respondents had house ownership, and 3.13 % were tenants. Being the owner of the houses, most of the respondents could take decisions comfortably for practicing roof-top hydroponics farming.

It is important to look at the structural composition of the buildings for exploring the opportunity of roof-top hydroponics. In this study, 90.63 % of respondents had flat roof-type, and 9.38 % had slope roof-type. Roof-type plays an important role in space management and weight-bearing capacity. The flat roof-type had easy access and comparatively much roof-top spaces for farming. Most (90.63%) of the houses were made of RCC with flat roofs showing the suitability for roof-top hydroponics.

The roof weight will increase by 30–950 kg per square meter during heavy rainfall depending on soil depth, so roofs must be strengthen to take that increased weight too (Dixon 2016). It is therefore better to have a technical assessment of the building before doing rooftop farming (Hui 2011). As roof-top soils are different from normal ground soils, keeping the soils healthy and productive may also be challenging (Green 2011). So, roof-top hydroponics can be another option for people, as it exhibits comparatively lightweight to the roof and can also be adopted in load-bearing houses.

We found that hydroponics was not in common practice in the study area. Hence, we could not capture their real perception of hydroponics technology based on their experiences. However, 81.25 % of respondents showed their interest in knowing about hydroponics and 79.69 % wanted to take financial incentives for practicing hydroponics. This reflects that if the government will launch the programs related to roof-top hydroponics, people will easily adapt it. Safayet *et al.* (2017) in their study also mentioned that most of the people do not have proper technical or farming knowledge on roof-top farming in Dhaka city and recommended initiating proper training and awareness program from the government to spread roof-top farming techniques. Thapa *et al.* (2020) highlighted promoting green roofs as an effective strategy in a dense urban area for sustainability. They have recommended the government to focus on urban agriculture by promoting roof-top gardening and farming. This study has a recommendation for the government to consider roof-top farming in their plans to convert unutilized roof-tops into edible by providing support for hydroponics with trainings and subsidy or incentives in tool kits for the beginners.

Our study has also identified one of the most prominent challenges of roof-top hydroponics. In the present situation, the buildings have not been designed with the consideration of roof-top farming. So, before practicing roof-top hydroponics, a building technical assessment needs to be done. Whereas for new construction buildings, Municipality office should encourage in design (structural & architectural design etc.) to incorporate edible roof-tops. Similarly, Safayet *et al.* (2017) mentioned that in Bangladesh, structural modifications are required to make existing houses more suitable for roof-top farming and recommended to consider it during construction of house from the inception phase.

4. CONCLUSION

This study revealed that there was a high opportunity for roof-top hydroponics based urban agriculture system in the Godawari Municipality. However, people were not much aware of its possibility, benefits and opportunity though they showed their keen interest for it. If the municipality provides incentives and technical support to the house owners, there is the high possibility of converting unutilized / underutilized roof-tops into edible green roofs. This will be an opportunity for Godawari Municipality to have more greenery to improve the urban environment and food production locally to realize the concept of Food Green City.

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