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Prospect of Rooftop Gardening: Through the Calculation of Monetary Value of the Soft Benefits

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ABSTRACT

Rooftop Gardening can offer a tangible solution to many challenges faced by communities across Dhaka today. Articulating the esteem of those benefits in financial terms gives an appraise of their commitment to the neighbourhood and territorial economies and licenses governments, arrive designers and building owners to assess short- and long-term public and private gains. Whereas a few benefits are straightforwardly quantifiable and have 'hard' values, numerous benefits are not promptly quantifiable and their values are troublesome to appraise (such as the wellbeing benefits of a rooftop garden). For the reason of this think about, those benefits that are not clearly quantifiable (or calculated based on any line thing on the buildings budget) will be characterized as 'soft' benefits. The purpose of this study is to calculate soft benefits of green roofs of different buildings in Dhaka and Rangpur city. One already densely populated, another one facing rapid urbanization. It will be observed at the end that, if rooftop gardening could support the environment by improving air quality, reducing carbon within the environment and benefit society by diminishing the cost of storm water management or not. Finally, some suggestions will be made to improve and encourage the current practice of rooftop gardening by sharing the soft benefits with them.

1. Introduction

Urban agriculture is now considered to be the solution for quick diminishing green space, food problems, heat island effects due to rapid urbanization, specially in Dhaka which is one of the world's fastest-growing mega cities. Rooftop gardening may reduce travel cost, use of fuel as food would be produced locally. The purpose of this paper would be to encourage people for rooftop gardening through calculating the soft benefits.

The aim of this study is to explore the practice and challenges of rooftop farming and to check the prospect of rooftop gardening through the price of the Soft Benefits of Rooftop Gardening. The objective is to calculate Monetary Value of the Soft Benefits of Rooftop Gardening.

2. Literature Review

Green roof exists since 3000 years; Turf roof seems to be the earliest green roof that is still found in Norway and Iceland. Green roof was first found in the ruins of Pompeii as roof garden. Also Hanging Garden of Babylon, constructed around 500 B.C. During Middle Ages green roof was also found in Guinigi Tower, Lucca, Italy (Stater, 2008).

In the land of Germany and Switzerland, in 1960s after vigorous researches, emerged modern green roof. Now it's also common in many parts of the world.

Green roof contains plant or vegetation and it may cover the roof fully or partially. Green roof has several layers The top layer consists of the vegetation stratum then growing medium, irrigation layer, filter fabric layer, drainage layer, waterproofing membrane layer, and then the roof deck (Dunnet & Kinngsbury, 2004,

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Ouldboukhitine et al, 2011). Green roofs cost more than the normal traditional roof but it has its own advantages and benefits on the long run which will counter the initial cost of installation (Dunnet & Kingsbury, 2004). According to Mentenser et al. (2006) depth of green roof substrate layer defines green roof into two types which are the intensive and extensive green roof.

An intensive green roof consists of vegetation from grasses, shrubs to small trees. It's mostly roof garden and may have walkways, seating arrangements, etc. on the roof. The depth of intensive green roof is greater than 150mm. Their weight is much and requires high maintenance (Magill et al., 2011). The slope of an extensive green roof is less than 10^0 (Kolb and Schwarz, 1999, Krupka, 1992) Intensive green roof can weigh from $171 - 391 kg/m^2$ (Breuning, 2015)

The extensive green roof requires low-maintenance thus is simpler. It doesn't weight much and and drought resistant plants are used. The thickness is less 150 mm. According to Breuning (2015) extensive green roof can weigh from $73 kg/m^2$ to $122 kg/m^2$.

3. Methodology

To perform this research,

- 2 study areas (Ganeshpur at Rangpur which is already densely populated, another one- Bosila at Mohammadpur in Dhaka which is facing rapid urbanization) were selected that have existence of rooftop farming practitioners in common.
- Property value, monetary value of soft benefits of Food Production, Storm water retention, Air quality, Carbon sequestration would be calculated.

Bosila form Dhaka has been selected as study area. Because the prospect of rooftop Gardening would be calculated, a study area was needed that's growing recently and lots of people already started rooftop gardening. A study of this area could also be helpful for the community people to urge motivated. Ganeshpur of Rangpur is because it's getting dense recently and ½ storied buildings with gardens are becoming replaced by 5/6 storey buildings.

Two practicing rooftop gardener were met to investigate their inspiration, show condition, benefits and issues confronted and other encounters. Non-practitioners were inquired approximately their recognition towards housetop cultivating, readiness to do it, etc. Esteem of the arrive cost/ katha and building/ loft/ square feet have been collected from the specialists.

4. Soft Benefit Calculation of rooftop farming

Financial values have been calculated for the delicate benefits of housetop cultivating from five points of view- Property Value Increase; Food production; Storm water retention, Improvement of Air Quality; Carbon Sequestration. The standard values to calculate the benefits are taken from Tomalty and Komorowski (2010) because there is absence of study/ research to evaluate the benefits of rooftop gardening in Bangladesh.

Table 1- List of benefits, input variables, notations, and units

Benefit	Input variable	Notation	Unit
property value (recreational garden)	property value	v	dollars
property value (productive garden)	neighbouring property value	v_n	dollars
	neighbouring property distance	d_n	meters
property value (property with view)	property with view value	v_v	dollars
	property with view height	h_v	meters
	green roof height	h	stories
food production	growing season	g	months
	food production area	a_f	square meters
	actual value of food production	v	dollars
sound attenuation	property value	v	dollars
	building height	h	stories
stormwater retention	vegetative roof area	a	square meters
air quality	growing season	g	Months

	vegetative roof area (total)	a	square meters
	short grass area	a_{sg}	square meters
	tall grass area	a_{tg}	square meters
	deciduous plant area	a_d	square meters
GHG sequestration	vegetative roof area (total)	a	square meters
	food production area	a_f	square meters
	grass area (short + tall)	$a_{sg}+a_{tg}$	square meters
	deciduous area	a_d	square meters

Figure 01- Single Residence, Aram Housing, Bosila

Table 2- Key Features

location	Aram Housing, Bosila
Building type	residential building
number of storeys	2
type of green roof	semi intensive
Plot Area	3 katha
Roof Area	93 m^2 (1000 sft)
Gardening Area	30 m^2 (320 sq ft)
completion date	2016
designer	Md. Afif Ibne Mahmud
type of vegetation	Fruit trees, Flowers

5. Case Study 1 – Single Residence, Aram Housing, Bosila

General Information of practitioner

Md. Mahmudul Haque started roof gardening in 2017. The initial cost was Tk. 8000 (USD 94.58). At first, the garden started with flower plants along with Java apple, pomegranate, jackfruit, mango, lime, guava trees. The following is a summary of the practitioners' general information: (Table2).

5.1. Methods for cultivation

Standard soil culture strategy has been utilized for planting. There are bags, tubs and drums for cultivating vegetables, fruits, flowers and other types of plants. Bedding method has been followed for some plants.

Though Md. Mahmudul Haque started with mainly flowers and Java apple, pomegranate trees, now almost $1/3^{rd}$ roof area of the garden is covered with vegetables including Tomato, Brinjal, Bean, Lady's Finger, Chili, Gourd, Spinach etc. and some fruit trees such as jackfruit and mango have been planted (Fig. 1). In the winter,

mainly Tomato, Brinjal, Bean, etc. are grown in the garden. Among them, Tomato has the most production (10–15 kg per year).

There are Chili, pomegranate, Guava plants in the garden which give fruits all the year round. Recently a 7 storied building is under construction beside the building. For the height of the neighbouring building, sunlight won't pass to the plant that may harm the future growth of the plants.

5.2. Maintenance

Md. Mahmudul Haque & his family maintain the garden. So, there is no extra cost for maintenance, i.e. hiring any gardener. Pesticides were used earlier at first but its use stopped as no problem of pests is found in the plants. Milibugs appears sometimes but they are treated with herbal remedy. Mainly kitchen waste and organic fertilizer is used.

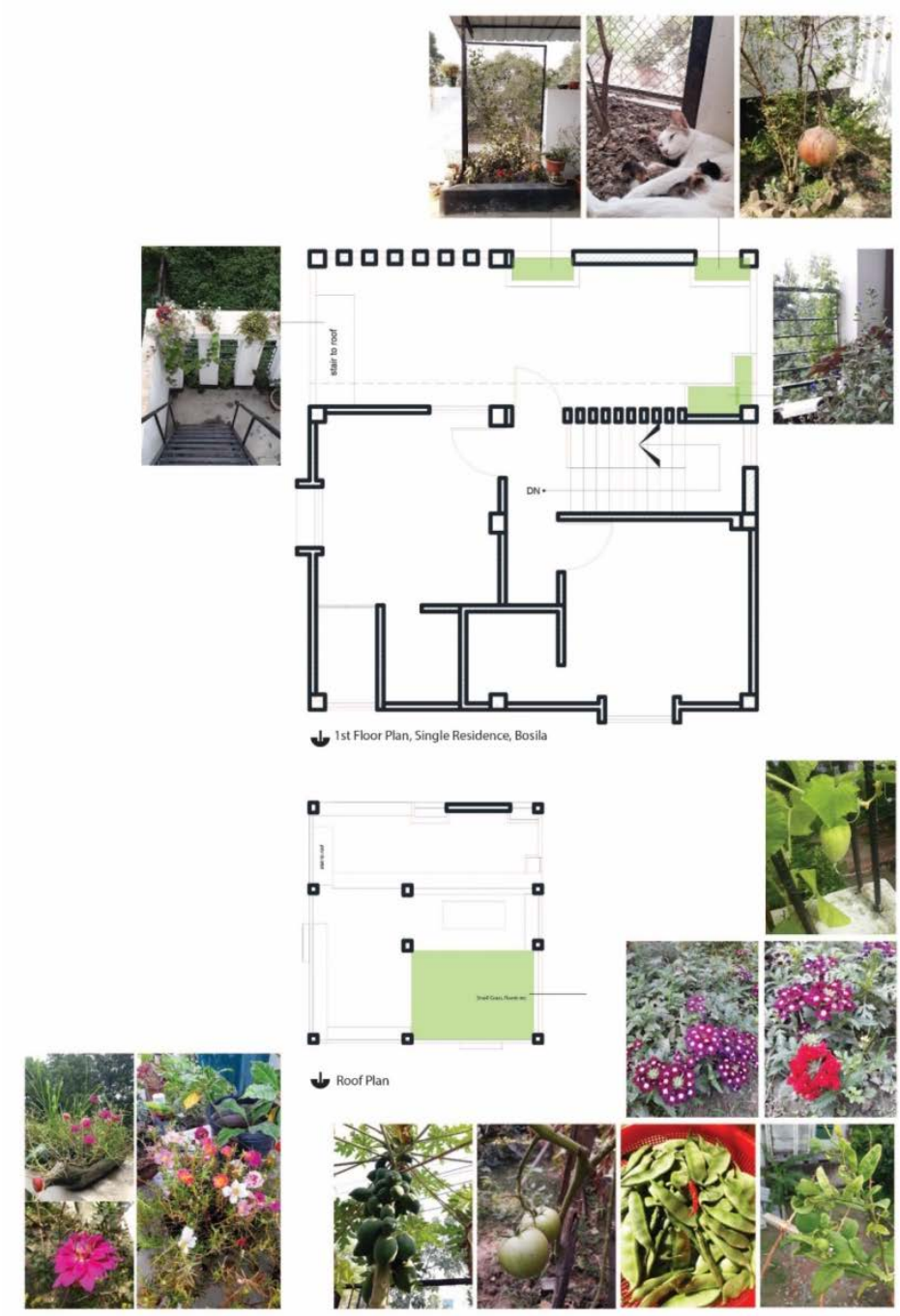

Figure 02- 1st floor plan and roof plan of Single Residence, Aram Housing, Bosila

Table 03- Existing plants and production

Winter	Name of fruit & vegetable	Tomato	Brinjal	Bean	Okra
	Production/year	10-15 kg/year	2-3 kg/year	7-8 kg/year	5-6 kg/ year
All the year	Name of fruit & vegetable	Chili	Guava	pomegrana te	lime	Bitter Gourd
	Production/year	2-3 kg/year	2-3 kg/year	8-10 kg/year	4-5 kg/year	4/5 kg/year
Summer	Name of fruit & vegetable	Spiny Gourd		Jhinga	
	Production/year	7-8 kg/year		10-15 kg/year	

5.3. Benefits from rooftop gardening

Social benefits

- Ensuring quality fresh fruit without chemicals would be the first benefit.
- Besides, spending time at garden gives him and other family members immense pleasure.
- Vegetables and fruits shared among the neighbours create social bonding.

The Economic benefits along with environmental benefits - monetary values of soft benefits

The practitioner in Bosila has approximately an area of 320 square feet (30 m^2) rooftop garden, and the soft benefits obtained from the roof gardens of the buildings are calculated below:

Property value

The formula used in this research to find property value is,

$b = 0.07 \times v$ (*Tomalty* & *Komorowski* 2010)

Where, 'b' stands for value of benefit and 'v' represents value of roof garden host property. In determining 'v', present value of land price and building/ apartment price- both are required. On an average, the present land price/ katha in Bosila area is approximately Tk. 45,00,000 and the building/ apartment price/ square feet is Tk. 4,000.

The building plot area is approximately 3 katha, the building area is approximately 1000 square feet and the building is of 2 storied, so the total price of the land is Tk. 13,500,000 and the building is (Tk. 1000x4000x2) = Tk. 8,000,000.

Thus, the value of the roof garden host property is approximately Tk. 21,500,000. *US*$ 2,541,9.57

Value of benefit, $b = 0.07 \times 21{,}500{,}000 =$ *Tk.* 1,505,000 *i. e. US*$ 17793.48.

Food production

The value can be estimated through the following formula:

$b = P \times g \times a$ (*Tomalty* & *Komorowski* 2010)

In the above mentioned formula, 'b' stands for annual value of benefit and 'a' represents roof garden area in square meter. In Bangladesh crops are cultivated throughout the year. Thus, length of growing season (g) for fruits, vegetables etc. is taken 12 months.

In case of mixed fruit and vegetables (low case), productivity (P) is Tk. 158 or $2 / square meter / month and for lettuces, herbs and flowers (high case scenario), productivity (P) is Tk. 1580 or $20 / square meter / month (Tomalty & Komorowski 2010).

Area of fruit and vegetables=120sft
Area of lettuces, herbs and flowers=200sft

Low Scenario
$b = P \times g \times a$
$= 2x12x\ 11.15$
$=\$\ 287 = 24{,}274.90tk.$

High Scenario
$b = P \times g \times a$
$= 20x\ 12x\ 18.5$
$= \$\ 120 = 10{,}149.79$ tk.

For this research, the food production value from rooftop gardening of the practicing gardener of Bosila area is estimated to be between *24,274.90tk* and 10,149.79 tk. The grown products are mainly mixed fruits and vegetables, so the total value of production remains at the lower end of this range.

Variables

Definitions of the variables are given in the Table 1.

$v =$ *US*$ 21,500,000
$h = 2$ stories
$a = 30\ m^2$
$g = 12$ months

Storm water retention

The value can be estimated through the following equation:

$b = (R + E)$ x C x a (*Tomalty* & *Komorowski* 2010)

Here, 'b' stands for annual value of benefit and 'a' for roof garden area in square meter. The value of erosion mitigation, E is worth $13.66/m3 i.e. Tk. 1075/m3 (Tomalty & Komorowski 2010).

The lowest value for storm water retention services is $20.13/m3 (R) for a retention pond and the highest value is $1059.44/m3 (R) for a retention basin (Cunningham 2001).

An average retention capacity of 42.7 L/m2 roof (C) used by Carter and Keeler (2008) has been used for the calculation.

$b = (R + E)$ x C x a
$= (20.13+13.66)$ x 42.7x 30
= $43285= tk. 3,661,112.20

$b = (R + E)$ x C x a
$= (1059.44+13.66)$ x 42.7x 30
= $1,374,641.1= tk. 116,269,268.73

Therefore, in this research, the storm water management benefit from rooftop gardening of the practicing gardener of Bosila area is estimated to range between Tk. 3,661,112.20 and Tk. 116,269,268.73

i.e. US$ 43285 and US$ 1,374,641.1.

For a dense urban area along with high land values, low cost storm water management won't be an option. Thus, the values of the benefits remain at the upper end of the range. In these case Tk. 116,269,268.73, US$ 1,374,641.1

Thus, the values of the benefits may remain at the upper end of the range in these cases (around Tk. 904,652.59 i.e. US$ 11494 and around Tk. 402,064.73 i.e. US$ 5108).

Air quality

To calcualte air quality benefit, following equation has been used::

$b = (g/12 months)$ x $\lceil H_{sg}$ x $a_{sg} + H_{tg}$ x $a_{tg} + H_d$ x $a_d \rceil$ (*Tomalty* & *Komorowski* 2010)

In the above formula, b stands for the value of benefit; g represents growing season in months; H_{sg}, H_{tg} and H_d for the health benefit for (short grass, tall herbaceous plant, deciduous plant) pollution absorption in $/m^2$ year respectively and a_{sg}, a_{tg} and a_d represent the roof garden area covered by short grass, by tall herbaceous plant and deciduous plants in m^2 respectively.

In Bangladesh crops are grown all the year round. Thus, length of growing season (g) for fruits, vegetables and other plants is taken 12 months.

Value of annual pollutant removal health benefit for different types of rooftop vegetation has been used 0.0521 US$/m2 for short grass, 0.0673 US$/m2 for tall herbaceous plants and 0.0839 US$/m2 for deciduous trees (Tomalty & Komorowski 2010).

Area of short grass- 200sft
Area of short Tall grass- 80sft
Area of short Deciduous- 40 sft

Low scenario (short grass coverage)
$b = (g/12 months)$ x $\lceil H_{sg}$ x $a_{sg} \rceil$
= 1x $\lceil 0.0521$x 18.5$\rceil$
=0.096 = US$ 1 = 84tk.

Mid scenario (tall grass coverage)
$b = (g/12 months)$ x $\lceil H_{tg}$ x $a_{tg} \rceil$
= 1x $\lceil 0.0673$ x7.4$\rceil$
=0.5 = US$ 0.5 = 42.29tk

High scenario (tall grass coverage)
$b = (g/12 months)$ x $\lceil H_d$ x $a_d \rceil$
= 1x $\lceil 0.0839$ x3.7$\rceil$
=0.3 = US$ 0.3 = 25 tk

Thus, in this research, the air quality benefit from rooftop farming for the practitioner of Bosila area is estimated to be worth between Tk. 84 and Tk. 25 i.e. US$ 1 and US$ 0.3. As the roof is semi extensive, with mixed grassy and leafy vegetation and fruits, the value of the benefits is likely to tend towards the middle of the range (around Tk. 42 i.e. US$ 0.5).

Carbon sequestration

To calculate carbon sequestration, following formula has been used

$b = S_d$ x $a_d + S_g$ x $a_g + S_f$ x a_f (*Tomalty* & *Komorowski* 2010)

Here, 'b' means the value of benefit in $/year; S_d, S_g and S_f denote the value of carbon sequestration by deciduous plants, by grasses and by productive agriculture in $/hax year respectively and a_d, a_g and a_f represent the area of roof garden covered by deciduous plants (ha), covered by grasses and covered by productive crops in hectare respectively.

The value of carbon sequestration by deciduous plants, by grasses and by productive agriculture have been found to be worth $39.11/ha, $28.46/ha and $28.59/ha respectively (Tomalty & Komorowski 2010).

Low scenario (short grass coverage)
$b = S_g$ x a_g
$= ($28.46/ha) x 0.002ha
= $0.06= 5tk

Mid scenario (tall grass coverage)
$b = S_f$ x a_f
$= ($28.59/ha) x 0. 0007ha
= $0.02=2tk.

High scenario (tall grass coverage)
$b = S_d$ x a_d
= ($39.11/ha) x 0. 0003ha
= $0.01= 0.85tk.

For this research, the carbon sequestration benefit from rooftop farming of the practitioner of Bosila area is estimated to be worth between Tk. 5 and Tk. 0.85 i.e. US$ 0.06 and US$ 0.01. As the roof is semi-extensive, with mixed grassy and leafy vegetation and fruits, the value of the benefits are likely to lie in the middle of the range (around Tk. 2 i.e. US$ 0.02).

In spite of the fact that the air quality and carbon sequestration benefits are inconsequential for personal roof gardens, both of these benefits would be more important if calculated for various roof gardens of a city or a certain area of a city.

6. Case Study 2 – Single Residence, Ganeshpur, Rangpur city

General Information of practitioner

Mrs. Akhtarun Nahar started roof gardening in 2015. The initial cost was Tk. 200,000 (USD 2364.58). At first, the garden started with various fruits, flowers, vegetables and herbal plants. The following is a summary of the practitioners' general information: (Table 4).

Table 04- Key Features

location	Rangpur City
type of building	residential building
number of storeys	2
type of green roof	semi intensive
Plot Area	22 katha
Roof Area of the Building	278.7091 m² (3000 sft)
Gardening Area	232 m² (2500 sq ft)
completion date	2015
designer	Golam Mosabbir Tawhid
type of vegetation	Fruit trees, Flowers

Table 05- Existing plants and production

Winter	**Name of fruit & vegetable**	**Tomato**		**Brinjal**		**Bean**	**Okra**
	Production/year	25-30 kg/year		8-10 kg/year		15-20 kg/year	9-10 kg/year
All the year	Name of fruit & vegetable	Chili	Guava	Dragon Fruit	lime	Bitter Gourd	
	Production/year	4-5 kg/year	2-3 kg/year	8-10 piece	7-8 kg/year	4-5 kg/year	
Summer	Name of fruit & vegetable	Spiny Gourd				Jhinga	
	Production/year	8-10 kg/year				10-15 kg/year	

6.1. Methods for cultivation

Standard soil culture strategy has been utilized for planting in both cases. There are bags, tubs and drums for cultivating vegetables, fruits, flowers and other types of plants. There are some plants grown in the bedding method.

6.2. Maintenance

Mrs. Akhtarun Nahar & her daughter-in-law maintain the garden. Pesticides are not used. Mainly kitchen waste and organic fertilizer is used.

6.3. Benefits from rooftop gardening

The Economic benefits along with environmental benefits - monetary values of soft benefits

The rooftop garden areas of the practitioner in Rangpur city is approximately 2500 square feet (232 m^2) and the soft benefits obtained from the roof gardens of the buildings are calculated below:

Property value

The formula used in this research to calculate property value is,

b = 0.07 x v (*Tomalty* & *Komorowski* 2010)

Here, 'b' stands for value of benefit and 'v' represents value of roof garden host property. To determine v, present value of land price and building/ apartment price both are required. On an average, the present land price/ katha in Rangpur city area is approximately Tk. 30,00,000 and the building/ apartment price/ square feet is Tk. 5,000.

The plot is approximately 22 katha, the building area is approximately 3000 square feet and the building is of 2 storied, Total price of the land= Tk. 6,60,00,000 and the building is (Tk. 3000x 5000x 2) = Tk. 3,00,00,000.

Thus, value of the property is approximately Tk. 9,60,00,000. *US*$ 1,134,999.36

Value of benefit, b = 0.07 x 9,60,00,000= *Tk.* 67,20,000 *i. e. US*$ 79,449.96.

Food production

The value can be estimated utilizing the following formula:

$b = P$ x g x a (*Tomalty* & *Komorowski* 2010)

In the above mentioned formula, 'b' stands for annual value of benefit and 'a' for the garden area in square meter. The length of growing season (g) of fruits, vegetables etc. is 12 months.

In case of mixed fruit and vegetables (low case), productivity (P) is found Tk. 158 or $2 / square meter/ month and for lettuces, herbs, flowers (high case scenario), productivity (P) is Tk. 1580 or $20/ square meter/ month (Tomalty & Komorowski 2010).

Area of fruit and vegetables= 1200sft
Area of lettuces, herbs and flowers=1800sft

Low Scenario
$b = P$ x g x a
= 2x12x 1200
=$ 28,800= 24, 35, 948.51 tk.

High Scenario
$b = P$ x g x a
= 20x 12x 1800
= $ 432,000= 36,539,227.65 tk.

For this research, the food production value of practising gardener from his garden of Rangpur city area is estimated to be between *24,35,948.51 tk.* and 36,539,227.65 tk. The grown products are mainly mixed fruits and vegetables.

Total value of production would remain at the lower end of this range.

Variables

Definitions of the variables are given in Table 1.

v = *US*$ 1,134,999.36
h = 2 stories
a = 232 m^2
g = 12 months

Storm water retention

The value can be estimated utilizing the following formula:

$b = (R + E)$ x C x a (*Tomalty* & *Komorowski* 2010)

Here,'b' stands for annual value of benefit and 'a' for roof garden area in square meter. The value of erosion

Mitigation, E is worth $13.66/m3 i.e. Tk. 1075/m3 (Tomalty & Komorowski 2010).

The lowest value for storm water retention services is $20.13/m3 (R) for a retention pond and the highest value is $1059.44/m3 (R) for a retention basin (Cunningham 2001).

An average retention capacity of 42.7 L/m2 roof (C) as used by Carter and Keeler (2008) has been used for the purpose of the calculation.

$b = (R + E)$ x C x a
= (20.13+13.66) x 42.7x 232
= $334,737.26= tk. 28312594.78

$b = (R + E)$ x C x a
= (1059.44+13.66) x 42.7x 232
= $10,630,557.84= tk. 89,91,49,011.54

Therefore, in this research, the storm water management benefit from rooftop farming of the practitioner of Rangpur area is estimated to range between tk. 28312594.78 and tk. 89, 91, 49, 011.54.

Low cost storm water management solutions can't be an option for a dense urban environment with very high land values. For this reason, the values of the benefits are likely to be at the upper end of the range in this case $334,737.26, i.e. 28312594.78tk.

Air quality

To calculate air quality benefit, following equation has been used:

$b = (g/12 months)$ x $[H_{sg}$ x $a_{sg} + H_{tg}$ x $a_{tg} + H_d$ x $a_d]$ (*Tomalty* & *Komorowski* 2010)

In the above formula, b represents the value of benefit;

'g', growing season in months; H_{sg}, H_{tg} and H_d for the health benefit for short grass pollution absorption, for tall herbaceous plant pollution absorption and for deciduous plant pollution absorption in $/m2xyear respectively and a_{sg}, a_{tg} and a_d represent the roof garden area covered by short grass, by tall herbaceous plant and

Deciduous plants in m^2 respectively.

In Bangladesh crops are grown all the year round. Thus, length of growing season (g) for fruits, vegetables and other plants is taken 12 months.

Value of annual pollutant removal health benefit for different types of rooftop vegetation has been used 0.0521 US$/m2 for short grass, 0.0673 US$/m2 for tall herbaceous plants and 0.0839 US$/m2 for deciduous trees (Tomalty & Komorowski 2010).

Area of short grass 400 sft= 37 m^2
Tall grass 900= 84 m^2
Deciduous 1200= 111 m^2

Low scenario (short grass coverage)
$b = (g/12 months) \times [H_{sg} \times a_{sg}]$
= 1x [0.0521x 37]
=1.9277 US$ = 163.05tk.

Mid scenario (tall grass coverage)
$b = (g/12 months) \times [H_{tg} \times a_{tg}]$
= 1x [0.0673 x84]
= 5.6532US$ = 478.16tk.

High scenario (tall grass coverage)
$b = (g/12 months) \times [H_d \times a_d]$
= 1x [0.0839 x111]
=9.3129 US$= 787.70 tk.

Thus, in this research, the air quality benefit from rooftop farming for the practitioner of Rangpur city area is estimated to be worth between 163.05tk.and 787.70 tk. i.e. US$ 1.9277 and US$ 787.70. As the roof is semi extensive, with mixed grassy and leafy vegetation and fruits, the value of the benefits is likely to tend towards the middle of the range (around 478.16tk i.e. US$ 5.6532).

Carbon sequestration

To calculate carbon sequestration, following formula has been used

$b = S_d \times a_d + S_g \times a_g + S_f \times a_f$ (*Tomalty & Komorowski* 2010)

Here,b stands for the value of benefit in $/year; S_d, S_g and S_f for the value of carbon sequestration by deciduous plants, by grasses and by productive agriculture in $/hax year respectively and a_d, a_g and a_f represent the area of roof garden covered by deciduous plants (ha), covered by grasses and covered by productive crops in hectare respectively.

The value of carbon sequestration by deciduous plants, by grasses and by productive agriculture have been found to be worth $39.11/ha, $28.46/ha and $28.59/ha respectively (Tomalty & Komorowski 2010).

Low scenario (short grass coverage)
$b = S_g \times a_g$
= ($28.46/ha) x 0.0037 ha
= $0.105302= 8.91tk

Mid scenario (tall grass coverage)
$b = S_f \times a_f$
= ($28.59/ha) x *0.0084ha*
= $0.240156=20.31tk.

High scenario (tall grass coverage)
$b = S_d \times a_d$
= ($39.11/ha) x *0.0111ha*
= *$0.434121= 36.72tk.*

Hence, the carbon sequestration benefit from rooftop farming of the practitioner of Bosila area is estimated to be worth between 8.91tk and *36.72tk.* As the roof is semi-extensive, with mixed grassy and leafy vegetation and fruits, the value of the benefits are likely to lie in the middle of the range (around 20.31tk. i.e. US$0.240156).

In spite of the fact that the air quality and carbon sequestration benefits are inconsequential for personal roof gardens, both of these benefits would be more important if calculated for various roof gardens of a city or a certain area of a city.

Problems faced by the practitioners

It has been found that in some cases birds make unsettling influence by eating the little vegetable and plants.

The leaves of the plants make the roof unclean and may close the outlet for water draining. So, it is necessary to clean the roof in a regular basis.

Another problem is to find good quality plants. The local nurseries deceive them by selling lower quality plants that don't give them desirable result.

Another issue that has been found in case of Mr. Mahmudul is that, shadow of neighbouring building hampers production in his garden.

7. Recommendations

- The government or any other organizations most of the time fails to provide incentives or there are lack of initiatives to boost up the practitioners. The arrangement can be made in BNBC and can be sanctioned to form housetop cultivating required. In addition, FAR (Floor Area Ratio) or density bonus can be awarded for practising gardening at rooftop.
- The people still do not get the idea about the benefits of rooftop farming. Govt, NGO etc, may work for it. Again,

lack of proper technical knowledge is also the cause of their unwillingness. Govt. and private sectors should work together to overcome these problems.
- Most of the building roofs are more or less structurally able to allow rooftop gardening, still extensive gardening always require extra caution. If the roofs are treated for gardening during construction, then extra cost would be minimised.
- To protect roof from dampness is a bigger challenge. Drums, tubs, bed systems would be helpful to protect roof from further damage from dampness.

8. Conclusion

This study has shown that soft benefits generate economic advantages for individuals, municipalities, and society at large. With the increasing population, food demand and expenditure on food are increasing. Agricultural land is converting to other land uses limiting the resources. To solve these problems, initiation of rooftop gardening would be a potential solution. With the help of government and private organizations, the practise of rooftop gardening may flourish, that would ensure a sustainable city with food supply as well as lush greenery. This study concentrates on calculating the soft benefits of rooftop gardening in Dhaka and Rangpur but other cities can also practice and may get similar benefit.

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