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Vertical Gardening Practices for Environmental and Socio-economic Wellbeing: A Study on Mirpur DOHS of Dhaka City

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Abstract: The capital city of Bangladesh, Dhaka is losing its green facade day by day and it is affecting our urban eco-systems. It produces multi-dimensional socio economic, cultural and environmental problems. To mitigate these urban problems, vertical garden could be a solution. Vertical garden and/or rooftop garden has its diverse uses like reducing the hostile ecological effect of the buildings, greenhouse gas emission and to some extent regulating the temperature. Therefore, the present study aims in evaluating the contemporary practices of vertical gardening and its contribution in disaster risk reduction in the context of the Mirpur DOHS of Dhaka city. The study followed both quantitative and qualitative approach using questionnaire survey, in-depth interviews, observation and visual documentation as data collection tools for identifying the contemporary practicing types of vertical gardening. Research shows the most common types of plants in Mirpur DOHS area which are cultivating throughout the year. This study attempts to review the way vertical gardening reduce urban disaster risk. The preliminary findings suggest that vertical gardening can be the source of urban food security and improving the quality of the living environment. Practicing sustainable farming, urban territory can be benefited environmentally, socially and economically. Finally, some suggestions are addressed to improve practice of vertical gardening in the near future.

Keywords: Vertical Gardening, Contemporary practices, Eco-system services, Disaster Risk Reduction, Mirpur DOHS

Introduction

In the face of swift urban expansion, cities will encounter both emerging and persistent challenges related to the environment, economy, education, health, and food. Urban areas play a pivotal role in pursuing economic growth that is carbon-free, simultaneously aiding their populations in navigating climate uncertainties and coping with natural disasters. Optical and thermal properties of materials (Albedo, emissivity, heat capacity) of different magnitudes are altered factors that steer the main difference between a rural and an urban environment and these factors affect heat exchanges locally (Specht et al., 2014). Materials of low porosity and deficiency of evapo-transpiring surfaces (vegetation) are characteristics of urban areas. Moreover, anthropogenic heat releases are also caused by human activities. The intricate and sophisticated nature, coupled with higher population density, renders urban areas more susceptible to risks compared to rural areas in the event of hazards. All governments are obligated to protect their city

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dwellers and in this aspect, resilience represents a collective public good (Lall et al., 2009). At present, Dhaka North City Corporation (DNCC) confronts challenges in effectively managing urban biodiversity, soil quality, air pollution, and water contamination. Over the past two decades, approximately 40% of Dhaka city's wetlands have vanished due to indiscriminate filling of lowlands (Kabir et al. 2018). Over the past 50 years, more than 40% of green spaces have been lost due to infrastructure development, housing expansion, and related activities (Kabir et al. 2018). DNCC has launched the Clean-Green Dhaka campaign, envisioning a cleaner and greener city through a comprehensive approach. As a component of this initiative, rooftop gardening has become a prevalent practice in numerous buildings (Kabir et al. 2018). A vertical garden is a garden that grows upward or vertically rather than on the ground or horizontally. Though vertical garden is not a new concept in the context of Dhaka residential area, the way this concept is applied is not satisfactory enough (Hossain, 2009). Vertical gardening has enormous potentials in solving environmental problems of Bangladesh. In a high density urban context of Dhaka, vertical gardening is a great incentive to ensure balanced urban ecosystem.

Urbanization significantly contributes to the socio-cultural and political development of a country. In Bangladesh, since gaining independence, the average urbanization rate has been 5% (World Bank 2012). Over this period, the urban population percentage has doubled, rising from 15% in 1974 to 39% in 2021 according to the Population Census-2021. The rapid urbanization in Dhaka City is occurring at an alarming pace, giving rise to various issues that negatively impact the fundamental rights of its citizens. While urbanization brings about economic and social advantages, it also entails adverse effects, as noted by Abel (2010). A particularly severe consequence of swift urbanization is the extensive degradation of the urban environment, a situation currently witnessed in Dhaka (Mowla, 2005). The air, water, and soil in the city have reached hazardous pollution levels, posing significant threats. The accelerated urbanization has led to a shortage of ecosystem services, exacerbating environmental problems in Dhaka. Reduction of green spaces in the urban areas are responsible for creating water logging, air pollution, sound pollution and global warming, occurring diseases and food insecurity (Bolund and Hunhammar, 1999). Green spaces in Dhaka city is reducing day by day and we do not have enough surface area for gardening (Islam, 2004). Addressing this issue, the study aims to assess the efficacy of vertical gardening in the residential areas of Dhaka City. Given the limited access to garden space for many Dhaka residents, a potential solution lies in the implementation of vertical gardening, allowing for green spaces without compromising work surfaces or floor space. The research will delve into the services offered by vertical gardens and their potential contribution to mitigating urban challenges, including environmental pollution, noise pollution, carbon footprint, and the impact of heat waves. An in-depth investigation on the implications of vertical gardening bas been carried out in Mirpur DOHS area of Dhaka city to identify the opportunities and associated challenges. However, the objectives of this study are…

- To identify the practicing and most common types of plants of vertical gardening in Mirpur DOHS.
- To investigate the way vertical gardening can contribute socio-economic wellbeing in urban areas.

- To understand the way vertical gardening is reducing urban disaster risk.

Vertical Gardening

Vertical gardening is an agricultural technique employed in high-rise buildings, facilitating large-scale food production by leveraging technology, hydroponics, and advanced greenhouse methods. This approach allows for controlled or uncontrolled environmental conditions, providing an innovative means of cultivating crops in a vertical, space-efficient manner (Abel, 2010; Banerjee & Adenaeuer, 2014; Despommier, 2010, 2011). Vertical farming covers both engineering and natural science disciplines and that has various applications in economic, social and environmental issues (Perez, 2014). Producing sustainable food in the city areas, vertical farming is attaining enough attention in practical and academic fields (Despommier, 2013; Specht et al., 2014). Countries such as China, Japan, Holland, South Korea, Italy, Canada, the USA, and Singapore have already embraced vertical gardening methods to enhance crop production and bolster environmental sustainability (Sivamani, Bae, & Cho, 2013).

Vertical gardening finds it's most widespread and efficient application in the form of rooftop gardening. The word 'Roof' means any continuous surface design in the building which can protect the inhabitants from any climatic events or elements. On the other hand 'Sky garden' refers the vegetated space which is planted in the top floor of the building. But all the plants are not planted in the rooftop rather it depends on its capacity (Hossain, 2009). The practice of rooftop gardening had started a thousand years ago. Ornamental rooftop gardening was first developed in the Mesopotamian civilizations near the Tigris and Euphrates River valleys which is known the Hanging Garden of Babylon (Barthel and Isendahl, 2013). Then mid-20th century it became more popular in the Scandinavia and Kurdistan region. Scandinavian people used this idea to reduce the heat in the summer and keep the heat in the winter in their residents. On that time they only used mud and grass on their rooftop, today which is known as rooftop gardening (Lawson, 2005). In the 1960s when green spaces were decreasing rapidly in the urban areas, green roof was practiced as a "green solution" in the Northern Europe. Within 1980s green roof market was rapidly extended in the Germany. On that time two modern green roof technology architects were Le Corbusierand and Frank Lloyd Wright. In 1920s Le Corbusier first used green roof technology only for elite buildings. Then in 1914 Frank Lloyd Wright first designed a restaurant with a green roof (Mowla, 2010).

Vertical garden can conserve animal habitats and vegetation types. Different types of vegetation can support a greater diversity of animal species. It can create a new ecological system on its surrounding environment. When plants are being planted it can manage a habitant for indigenous birds and insects (Mowla, 2005). Green roof can improve human health also. Various kinds of smell, colors and movement which are provided by plants can play a vital role for the improvement of human physical and mental health. Studies prove that patient's eye sight remain better in the green view (Safikhani et al., 2014). Mental health and physical stability are influenced by green view and natural elements of the environment. Green view can reduce stress, mental pressure, blood pressure and increase positive thinking (Kaplan, 1993).Vertical gardening can reduce food insecurity. Through rooftop gardening we can get fresh food in every day which is good for our health (Lam, 2007; Sauerborn, 2011). Though there are lots of benefits of vertical farming, it has some challenges too. Loading capacity of the building

as well as roof and slope of the roof are the main challenges issued in the context of Dhaka city. So concentration should be given in building structures and retrofitting them accordingly from the very first time (Hui, 2011). Vertical farming in the roof top can increase the weight depending on the types of garden, soil structure and heavy rainfall (Green, 2011). High wind and high temperature in the Dhaka city may create a new problem. Pesticide use in the vertical garden could be a health issue or problem; while many gardeners engage themselves only with organic farming (Tiller, 2008). Sometimes it may costly for maintenance (Dixon n.d.). In most of the cases, city residents have not proper training regarding this field. In the very first time if outcomes are not satisfactory, they will be frustrated (Islam, 2004). Tokyo is one of the model cities in the world that mandates building vegetation of about 20% of its total rooftop as mandatory (Torstar News Service, 2015). Bangladesh should go for the same process to reduce the urban disaster through the vertical gardening.

Eco-system Services and Urban Disaster Risk Management

Since the inception of human existence, humans have relied on goods and services provided by nature for survival. Nature's ecosystem plays a crucial role in delivering ecosystem services, categorized into two types: natural and artificial ecosystems. These services include climate regulation, water supply and purification, as well as the cycling of water and nutrients (Millennium Ecosystem Assessment, 2005). They are collectively referred to as ecosystem services, which can be broadly classified into four types: provisioning services (e.g., food, fresh water), supporting services (e.g., nutrient cycle, water cycle), regulating services (e.g., climate regulation, erosion regulation), and cultural services (e.g., spiritual and religious values, knowledge, sense of place) (Millennium Ecosystem Assessment, 2005).

Plants, irrespective of their type or location, possess the ability to capture, utilize, and retain substantial amounts of rainwater. Following capture, they release water into the atmosphere through processes like evaporation and evapotranspiration (Banerjee and Adenaeuer, 2014; Besthorn, 2013; Cicekli & Barlas, 2014; Despommier, 2009, 2010; Sauerborn, 2011; Thomaier et al., 2015; Voss, 2013). In vertical farming, plants can retain approximately 70-90% of summer precipitation and 25-40% during winter (Hossain, 2009). Throughout the entire year, rooftop garden plants retain an impressive 50-90% of the precipitation (Mowla, 2005). Additionally, plants in vertical gardens serve the purpose of shading buildings from solar radiation. Plants are cooling down the surrounding environment through using their evapo-transpiration process. These cools down the air and reduce the temperature (Afrin, 2009; Thomaier et al., 2015). The implementation of rooftop gardening has the potential to cut cooling costs by up to 50%, concurrently lowering the surrounding temperature by approximately 25% (Specht et al., 2014). However, the effectiveness of these processes depends on factors such as building size and location, climatic conditions in the area, and the type of rooftop garden in place (Mowla, 2005). Vertical gardening can reduce sound pollution. We can use green roof as an insulator for sound. Growing medium of the rooftop gardening can block lower sound frequencies and plants can block higher frequencies of sound (Safikhani et al., 2014). Rooftop garden which has 12cm (4.7 in) substrate layer that can reduce 40 decibels and which has 20cm (7.9in) substrate layer can reduce sound by 46-50 decibels (Afrin, 2009). So we can practice this process not only in our residential area but also in educational institutions, hospitals and offices to keep our life free from the sound pollution. Vertical

gardening can improve air quality of the urban area. When air passes over the green roof, it can filter dust, fine and airborne particulates (Afrin, 2009). It can reduce about 85% of airborne particles from the surrounding environment. Using their photosynthesis process they can absorb gaseous pollutants (Kalantari et al., 2015). Vertical gardening can reduce green-house gas emission. Buildings are the main responsible for green-house gas emission and consumption of about 48% of all energy (Besthorn, 2013). Buildings are consuming all power plant-generated electricity, which amounts in nearly 76%. Garden in the roof top cool down the building and reduce the buildings heat consumption. It has been shown that rooftop gardening can reduce green-house effect in many ways (Miller, 2011) Vertical gardening can resist the spread of the fire from one building to another building. On the other hand dry plants can spread the fire. When fire is our main concern we can use gravel or concrete pavers in the regular interval on the garden. We can cultivate high water content plants in our roof top garden (Peck et al, 1999).

Data and Methods

To conduct this research Mirpur DOHS has been selected as the study area. Mirpur DOHS is an area of Dhaka North, located in Mirpur Thana of Dhaka City. The area is under the authority of Pallabi Thana Police Station. The area is located close to Mirpur Cantonment. The area is governed by Mirpur DOHS parishad. It is the largest DOHS in the country with a total of 1290 individual lots. Mirpur DOHS has been chosen as the study area due to the presence of vertical farming practitioners. Being an urbanized area, there is a substantial availability of roof space in this location. And before doing our research very few studies have been conducted regarding vertical gardening and its impact on urban eco-system in this area.

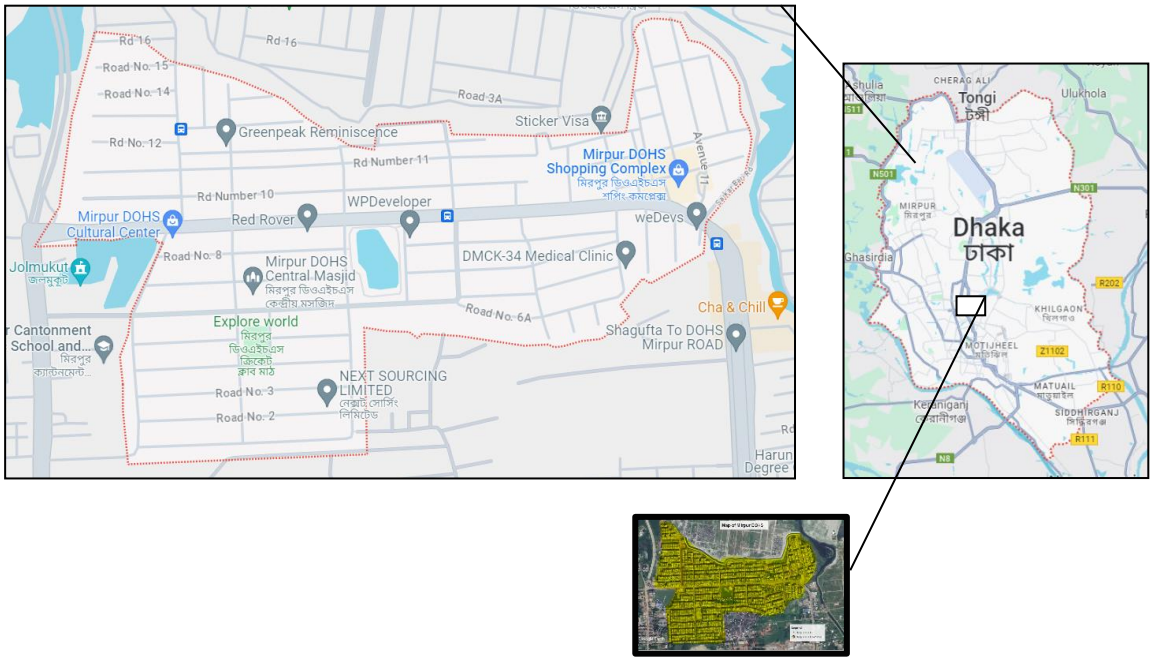


Figure 1: Geographic location of Mirpur DOHS in Dhaka City

Source: Google Maps 2023

For sampling, this research follows purposeful and Convenience sampling, which made it possible to conduct and completed this research on time. The research site for this study is the showing contemporary vertical gardening practices for environmental and socio-economic wellbeing. Considering the difficulties to access the relevant private properties within this very secured residential neighbourhood and on the basis of convenience this study considers only 15 samples to conduct this research based on a convenient sampling design. Moreover, this study has taken all the samples depending on the types of vertical gardening and different types of plants. There are three types of vertical gardening exist in Mirpur DOHS area. So in every type we took 5 respondents So that we can get better information in individual type of vertical gardening in Mirpur DOHS area.

The study encompasses both primary and secondary data collection. Three primary data collection methods have been employed: 1) Questionnaires, 2) Interviews, 3) Observation, together-with visual documentation. For the interview component, 15 practitioners were interviewed to investigate aspects such as their motivations, types of plants cultivated, maintenance costs, perceived benefits and challenges, and other relevant experiences. A questionnaire survey has been conducted with mostly open ended questions. The questionnaire had the following content shown in the following Table.

Table 1: Content of the Questionnaire

Basic Information of the respondents	Address, sex, age, occupation, floor space, size of the building, Motivation for the gardening.
Exploring the present state of the gardens	For how long they are practicing, types of plants grown, seasonal variation of plants.
Identifying opportunities and challenges	Measures for starting up and maintenance, benefits and barriers faced while practicing vertical gardening.

The responses were recorded by using a digital recording device with the informed consent of the interviewee. Few respondents agree to be interviewed but decline to be recorded although the interview conducted by writing down key points. After completion of interview process, we transcribed our notes by copying what was said into a word processing document. Observation is another data collection method that has been applied in this research. This study not only observed the research participants but also actively observed different activities of the research participants. We tried to become integrated into the participants' environment while taking down notes and recordings. This method helped to decide which questions are relevant and what language to use. Through participant observation an attempt has been made to access to different types of information that might not be easily accessible. As part of the observation process during field visits, we noted three general types of vertical gardening methods: 1) intensive, 2) extensive, and 3) semi-intensive. Additionally, we observed four predominant types of plants, comprising various species of 1) fruits, 2) flowers, 3) vegetables, and 4) ornamental plants. An exception was noted in the cultivation of various species of spices.

Respondents' mental satisfaction, natural beauty of green façade and feel of soothing ambient which could not be captured by any means were felt through observation of the participants.

The last method conducted was visual documentation through still photography and video. This form of documentation encompassed digital camera. It fulfilled the accuracy and transparency of our field survey. Visual documentation was needed as a powerful evidence of study area visit, making it an integral component to present the paper. It captured the existing practices and scenario of vertical gardening of the study area. It helped in visual representations of our analysis and findings. Apart from the above data collection techniques, different research journals, articles, books, websites were accessed to collect secondary data. A thorough review of these literally works helps us to acquire an understanding on the practice of vertical gardening in different countries. We got to know associated advantages, requirements for implementation and its contribution in serving urban areas as a means of resilience.

In this study thematic analysis method has been applied. Thematic method of analysis in qualitative research helped to explain the data in an easier way. While analyzing data, quantitative data has been turned into qualitative form. Using coding we can easily identify same kind of information. As we have three specific objectives, we took three themes. That's helped us to get our expected result. Under these themes we have found, how vertical gardening reduce urban disaster risk, challenges and opportunities from vertical gardening and have shown what types of vertical gardening are practiced and what types of plants are cultivated there.

Types of Vertical Gardening

There are three types of vertical gardening practices observed in Mirpur DOHS area. They are based on the soil depth in which the plants grow on the rooftops. The types of gardens are-

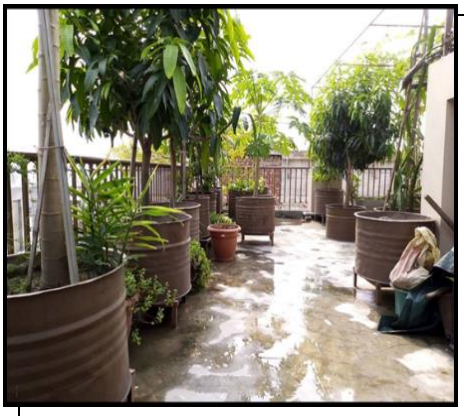
i) Intensive vertical gardening

ii) Semi-intensive vertical gardening

iii) Extensive vertical gardening.

In the context of the Dhaka city intensive vertical gardening is not common. But in Mirpur DOHS area, all three types are available including intensive one. Because they did special treatment on their building rooftops, as a result the residents of those buildings can practice the intensive one as well as other types.

Table 2: Types of vertical gardening

		
Photograph 1: Intensive vertical gardening.	Photograph 2: Semi-intensive vertical gardening	Photograph 3: Extensive vertical gardening
Characteristics I. Soil depth ranging from 20-60 cm (8-24 inch). II. Can increase the load of 60-200 lb/sq.ft.in the rooftop. III. Plants: Banana, Mango, Coconut, Jackfruit and Papaya etc.	**Characteristics** I. Soil depth ranging from 5-15cm (5-7 inch). II. Can increase the load of 25-35lb/sq.ft.in the rooftop III. Plants: hyacinth bean, cucumber, bottle gourd, ribbed gourd, sponge gourd, wax gourd and bitter gourd etc.	**Characteristics** I. Soil depth ranging from 2-5 inch. II. Can increase the load of 14-35lb/sq.ft.in the rooftop III. Plants: Different types of vegetables and flowers

Source: Field Survey, 2021

During our field visits, we observed three broad categories of vertical gardening methods: 1) intensive, 2) extensive, and 3) semi-intensive. Alongside this, we identified four primary types of plants, encompassing different species of 1) fruits, 2) flowers, 3) vegetables, and 4) ornamental plants. Notably, we found an exception in the cultivation of various species of spices in Mirpur DOHS.

Table 3: Practicing mixed types of vertical gardening

Practicing Type	Percentage (%)
Intensive + Semi-intensive	40
Semi-intensive + extensive	27
Intensive + Extensive	13
Intensive + Semi-intensive + Extensive	20

Source: Field Survey, 2021

From the Table 3 we can see, about 40 percent people are practicing intensive and semi-intensive type to produce vegetables and fruits. Because they try to reduce their dependency on fruits and vegetables of the market which are containing poisonous chemical in a huge extend. About 27 percent people practicing semi-intensive and extensive type to produce vegetables and flowers. People cultivate flowers for mental satisfaction and aesthetic purpose. About 13 percent people practicing intensive and extensive type in their rooftop. On the other hand about 20 percent people who are practicing all types of vertical for producing vegetable, fruits, flowers, ornamentals and spices at a time in one rooftop. For doing that they did special treatment in their rooftop so that new hazardous situation will not occur in the future because of over loading. The fact is, no gardeners were found those are practicing only one methods i.e. intensive, extensive or semi-intensive gardening as the above table 3 shows the mixed nature of gardening practice in Mirpur DOHS area.

Most Common Types of Plants

From Table 4 to Table 8, we include most common types of vegetables, fruits, flowers, ornamentals and spices respectively. These kinds of plants are planted on most of the rooftop in Mirpur DOHS area. We ignored some rare types of species.

Table 4: Available vegetables in the study area's vertical garden.

Local name	English name	Scientific name
Phulkopi	Cauliflower	*Brassica oleracea var botrytis*
Mula	Radish	*Raphanussativus*
Sheem	Hyacinth bean	*Lablab niger*
Shasa	Cucumber	*Cucumissativus*
Lau	Bottle gourd	*Lagenariasiceraria*
Jhingga	Ribbed gourd	*Luffa acutagula*
Dhundul	Sponge gourd	*Luffa cylindrica*
Chalkumda	Wax gourd	*Benincasahispida*
Ucche/Karala	Bitter gourd	*Momordicacharantia*
Patal	Parwal	*Trichosanthesdioica*
Alu	Potato	*Solanum tuberosum*
Begoon	Brinjal	*Solanum melongena*
Tomato	Tomato	*Lycopersiconesculentum*
Jhalmarich	Chilli	*Capsicum species*
Dhedosh	Okra	*Abelmoschusesculentus*
Lalshak	Red amaranth	*Amaranthusgangeticus*
Shalgom	Turnip	*Brassica rapa*

Source: Field Survey, 2021

Table 5: Available fruit plants in the study area's vertical garden.

Local name	English name	Scientific name
Kola	Banana	*Musa sapientum*
Kathal	Jackfruit	*Artocarpusheterophyllus*
Am	Mango	*Mangiferaindica*
Lichu	Litchi	*Litchi chinensis*
Pepe	Papaya	*Carica papaya*
Narikel	Coconut	*Cocos nucifera*
Peyara	Guava	*Psidiumguajava*
Komola	Orange	*Citrus chrysocarpa*
Apel	Apple	*Aegle marmelos*
Lebu	Lemon	*Citrus limon*
Boroi	Jujube	*Ziziphusmauritiana*
Sofeda	Sapodilla plum	*Manilkarazapota*
Kamranga	Carambola or star fruit	*Averrhoa carambola*

Source: Field Survey, 2021

Table 6: Available floral plants in the study area's vertical garden.

Local name	English name	Scientific name
Golap	Rose	*Rosa spp.*
Gadha	Marigold	*Tagetes spp.*
Rojonigondha	Tuber rose	*Polianthestuberosa*
Chondromollika	Chrysanthemum	*Chrysanthemum sinense*
Joba	China rose	*Hibiscus rosasinensis*
Paddo	Lotus	*Nelumbiumspeciosum*
Shadashapla	Water lily	*Nymphaea nouchali*
Hasnahena	Night queen	*Cestrum nocturnum*
Daliya	Dahlia	*Dahlia variabilis*
Beli	Belly	*Jasminum duplex*
Patabahar	Croton	*Codiaeum spp.*
Sondha Maloti	Four o clock flower	*Mirabilasjalapa*
Aloknonda	Allamanda	*Allamandacathertica*
Gondhoraj	Cape jasmine	*Garderniaflorida*
9 o'clock flower	9 o'clock flower	*Portulaca grandiflora*

Source: Field Survey, 2021

Table 7: Available ornamentals plants in the study area's vertical garden

Local name	English name	Scientific name
Supari	Areca	*Areca catechu*
Serius	Torch cactus	*Cereus spp.*
Orchid cactus	Orchid cactus	*Epiphyllum spp.*
Vanda	Vanda	*Vanda teres*
Npple cactus	Apple cactus	*Mammillariaspp.*
Areca palm	Areca palm	*Areca lutescens*
Bilati Jhaow	Casuarina	*Casuarianaequisetifolia*

Source: Field Survey, 2021

Table 8: Available Spices plants in the study area's vertical garden.

Local name	English name	Scientific name
Ada	Ginger	*Zingiberofficinale*
Elaach	Green cardamom	*Elettariacardamomum*
Kapsicum	Bell pepper	*Capsicum annuum*
TezPata	Indian bay leaf	*Syzygiumpolyanthum*

Source: Field Survey, 2021

How Vertical Gardening Can Contribute Socio-economic Wellbeing in Urban Area

More Productivity per Unit of Area

Traditional farming typically allows for the cultivation of only one crop at a time, whereas vertical gardening enables the simultaneous production of various products. This distinction represents a key difference between vertical gardening and traditional farming. Given the ongoing reduction in horizontal space, embracing vertical expansion becomes imperative for sustainable agricultural practices. Respondents are producing different types of foods in one roof. In our field survey we have found about 20 percent garden owners who are cultivating fruits, vegetables, flowers, ornamentals and spices at the same time. Most of the respondents are practicing multiple-culture instead of practicing monoculture. They have changed their cropping pattern with the change of season. So vertical gardening creates the opportunity for urban dwellers to cultivate more food in a small area.

Recycling of organic waste

Household-generated organic waste can serve as a valuable fertilizer for vertical gardens. Our research indicates that numerous individuals are incorporating their organic waste into their gardens. This approach proves to be environmentally friendly and avoids water contamination issues associated with chemical fertilizers. Moreover, it involves recycling organic waste into garden fertilizer, eliminating the necessity to spend additional funds on chemical alternatives.

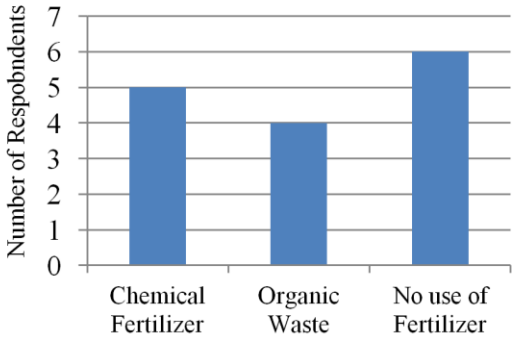


Figure 2: Types of fertilizer which are used in vertical gardening

From Figure 2, we see 4 respondents are using their organic wastes in their garden as a fertilizer. This is almost one third of the total respondents. If other respondents who are using chemical fertilizer and start using organic waste then vertical gardening concept can be exemplified as reusing organic wastes platform.

Local job opportunities

Vertical gardening offers employment prospects in major urban centers such as Dhaka. It has the potential to generate both direct and indirect job opportunities for unemployed individuals in these cities. In the Mirpur DOHS area, some people are employed on a permanent basis, while others work on a temporary basis in the vertical gardens maintained by respondents. Other potential job opportunities in this gardening sector can be created which may include managing seed production, harvesting, quality control of the plants and supervising the growth of plants, etc.

Table 9: Types of employment and number of employee

Types of employment	Number of employee	Salary (BDT)	No. of respondents
Permanent employee	01	(9-12 thousand) per month/person	4
Temporary employee	01	500 per day	7
No employee	none	None	4

Source: Field Survey, 2021

Table 9 reveals that among the respondents, four have a single permanent employee earning a salary in the range of 9-12 thousand BDT. Conversely, temporary employees are engaged on a daily basis, receiving compensation of 500 BDT per day. The remaining four respondents do not have any employees and personally tend to their gardens. This illustrates how vertical gardening serves as a means of job creation for the local population.

Improved food security

In Dhaka city, the availability of fresh food is constrained. It's crucial to distinguish between access to available food and access to fresh food. To ensure the production of readily available fresh food, individuals are establishing vertical gardens on their rooftops. Respondents engage in cultivating vegetables, fruits, and flowers on their rooftops to decrease reliance on market-supplied fruits and vegetables, which may be tainted with harmful substances. The influence of price is another significant factor motivating them to embrace vertical gardening. Cost of producing food is much less than cost of buying that foods from the market. So aim and objective of the vertical gardening is to produce available fresh food for the city dwellers and reduce the urban food insecurity.

How Vertical Gardening Reduce Urban Disaster Risk

Over the past few decades, urban areas have faced escalating threats from air pollution, sound pollution, carbon emissions, urban heat islands, and waterlogging. Addressing these urban disaster risks has become increasingly critical. Vertical gardening emerges as a supportive solution to mitigate these risks. In Dhaka city, waterlogging has become a significant source of distress for urban residents. Vertical gardening plays a role in reducing this issue by absorbing and releasing water into the atmosphere through evaporation and evapotranspiration. During the summer, it can retain approximately 70-90% of precipitation, and throughout the year, it holds onto 50-90% of rainwater (Mowla, 2005).

Apart from the above, Vertical gardening serves as an effective measure to alleviate the impact of the urban heat island phenomenon. Vegetation acts as a natural shade for buildings, cooling the surrounding environment through its evapotranspiration process. The cooling cost can be significantly reduced, up to 50%, leading to a 25% decrease in the surrounding temperature, contingent on factors such as building size, location, climatic conditions, and the type of rooftop garden (Specht et al., 2014). Additionally, vertical gardening contributes to reducing sound pollution by acting as a sound insulator. The growing medium in vertical gardens can mitigate lower frequency sounds, while the plants themselves can attenuate higher frequency sounds. Depending on the specific type of vertical garden, it has the potential to reduce sound levels by 46-50 decibels (Afrin, 2009). During the fieldwork, nearly all respondents highlighted the positive aspects of rooftop gardens, emphasizing their role in diminishing heat, minimizing noise, and creating a more pleasant living environment.

The influence of trees, shrubs, and natural vegetation on urban air quality is widely acknowledged, with direct implications for the health and well-being of individuals residing in urban areas. Authors have delved into the impact of vegetation, particularly trees, on cooling the ambient urban air, providing shade to buildings, and absorbing gaseous air pollutants in response to environmental challenges in urban settings. In densely populated areas such as Mirpur DOHS, where space for traditional trees is limited, the most cost-effective solution lies in utilizing shrubs and intensive green roofs. Shrubs, along with green walls and roofs, complement existing trees in mitigating air

pollution. The incorporation of shrubs on roofs, known as intensive green roofs, can significantly reduce airborne contaminants. The introduction of greenhouse gas emissions has added a new dimension to the understanding of urban disaster risks. In city areas like Dhaka, buildings account for approximately 48% of total energy consumption (Besthorn, 2013), making them significant contributors to urban greenhouse gas emissions. Vertical gardening on rooftops emerges as an effective strategy to cool down buildings and decrease their energy consumption.

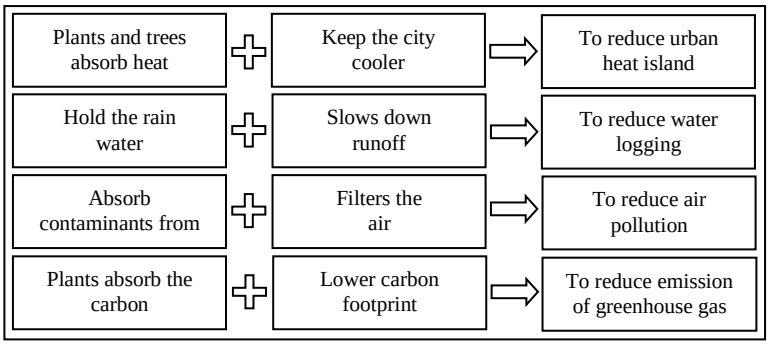


Figure 3: How vertical gardening reduce urban disaster risk

Vertical Gardening and Urban Resilience

Urban resilience refers not only the ability to maintain basic functions but also to return to a steady condition after the disturbance (Campanella, 2006; Coaffee, 2013; Lhomme et al., 2013). When assessing urban resilience, four key parameters are taken into consideration: economic, social, infrastructural, and environmental (Merrow et al., 2016). Concurrently, urban ecosystems provide various services, falling into four categories: provisioning, cultural, supporting, and regulating (Bolund and Hunhammar, 1999). In this context, we elucidate how ecosystem services derived from vertical gardening can enhance urban resilience.

To begin, firstly, provisioning services, encompassing food, fuel, genetic resources, and fresh water, are crucial components derived from urban agriculture (Bolund and Hunhammar, 1999). Vertical gardening contributes to the production of seasonal and non-seasonal foods, thereby mitigating urban food insecurity. It ensures readily available access to fresh produce for urban residents. Additionally, by creating local job opportunities, vertical gardening plays a role in supporting the local economy. So provisioning ecosystem services that provide foods, green environment and local job opportunity which can resilient our society financially. One of the respondents during an interview session mentioned that,

> *"The fruits I get from my garden is simply heavenly and I cannot compare it with the fruit that are available in markets. These are fresh, safe and simply it can satisfy and refresh our body and mind."*

From this quotation it can be understood that people are considering their grown products not only as a feeding materials but it can also energize their mind.

Cultural services, encompassing spiritual and religious values, recreation, and aesthetic values, play a pivotal role in fostering mental health and enhancing social cohesion (Bolund and Hunhammar, 1999). These services contribute to the development of strong social bonds among individuals, creating a sense of community and connection. In the realm of social resilience, key factors such as the quality of education and information, access to healthcare, and the emphasis on social relationships are of paramount importance. The cultural services provided by activities like vertical gardening can positively impact these factors, contributing to the overall social resilience of urban communities. Cultural ecosystem services fulfill all of the criteria by giving opportunity to share the knowledge, providing recreation facilities and improving health condition by providing aesthetic values. During an interview session, an aged garden owner who has been managing this garden more than 10 years mentioned that,

> *"I have motivated many persons to create a garden in their own rooftops and I became successful in creating such a nice neighourhood in this Mirpur DOHS area. Many interested person took some guidance from me about the management of the gardens. I am happy to disseminate my experience with others."*

From this quotation, it can be said that this concept may bring popularity if proper information and guidance are available that can create a nice greener environment within a concrete residential areas.

Ecosystem services contribute to the enhancement of social infrastructure. Engaging in vertical gardening allows us to alleviate the impacts of urban deforestation, as highlighted by Lovell and Taylor in 2013. This practice serves as a means of conserving our forests. By incorporating organic waste as fertilizer in vertical gardens, we can effectively address waste management challenges, both locally and globally. The proper management of waste remains a significant issue in our country and worldwide. Urban heat island in Dhaka city is becoming a big issue in last few years. Practicing vertical gardening we can solve the problem. These are the way how vertical gardening resilient our social infrastructure. In this regard, a female garden owner during an interview session mentioned that,

> *"Now we feel fortunate that we can open our eyes in the morning with birds tweeting sound which was not the case few years ago. After creating this garden we got this kind of satisfactory and mind blowing sound which is not very common in urban setting. We are now enjoying tweeting sound not the hazardous sound of horns."*

This comment from the garden owner sheds light to the necessity of this type of natural setting where we can live closely with the essence of the nature.

Last but not least, among the ecosystem services regulating services are paramount in controlling and mitigating urban disaster risks, as highlighted by Bolund and Hunhammar (1999). Vertical gardening plays a crucial role in this regard by effectively managing rainwater, thereby reducing the likelihood of waterlogging in urban areas. Additionally, it acts as a natural filter, absorbing dust particles and purifying polluted air. Serving as an

insulator, vertical gardening also diminishes the impact of sound pollution. Although during the data collection nobody has highlighted this fact but theoretically and practically the existence of rooftop gardens can reduce some of the urban problems such as reducing dusts from the air, increasing oxygen supplies, reducing the effect of sound pollution, reducing heat, increasing satisfactory urban living atmosphere, to some extent. However, it is also a matter of fact that the lack of maintenance, proper care and regular observation in those gardens can create a deadly surrounding as these kinds of areas are potentially remarked as a breeding ground of Aedes mosquitoes which cause deadly Dengue fever.

Conclusion

There is a growing concern for enhancing urban resilience in the face of unprecedented climate change and urbanization. Vertical gardening and/or rooftop gardening practice emerged due to the lack of horizontal spaces in urban areas. Vertical gardening is suitable in urban places because plants can be grown on, up, or against internal or external walls of buildings. As there is insufficient urban green space, vertical gardening can be implemented to improve urban life quality and ecosystems. Practice of vertical gardening can help to upgrade urban realm and it serves numerous advantage towards a city. Exploration of ways to implement vertical green in urban environment is needed for city's betterment. A sustainable city model comprises of strong urban ecosystem and improved balance of socio-economic systems. Vertical gardening allows for ecosystem continuity and renewable production. Yet provision of required water, nutrients and lights from outside is inconsistent with maintenance. Attention should be given in minimizing dependency on outside and use of rainwater for plantation, provision of light naturally in the design and implementation of vertical gardens.

However, for the substantial implementation of vertical gardening, additional steps are advisable. The practice of vertical gardening necessitates more rigorous adherence to structural standards. It is crucial to examine the building codes of existing structures to ensure their capacity to bear the load of vegetation before adopting vertical gardening. Therefore, structural consultant is required to examine the loading capacity of the existing roof. An architect can assist in this regard to co-ordinate the project as well as to look after the design and detailing of the building and roof for gardening. Besides Installation of adequate water proofing systems and root barriers must be cost effective. If necessary, additional support can be obtained while working with existing roofs. Placing additional structural elements like columns, beams and braces to strengthen the roof and heavy planters strategically located over bearing walls or columns may be contemplate. In developing vertical gardening, landscape architect can help to layout planting trees and selection of the plants. Besides roofing consultants, planners, ecologists and marketing professionals may also include in the team to develop vertical vegetation. Climatic features are important factors in selection of plants for vertical gardening. Root size and depth should also be considered during plantation in order to determine the depth of growing medium. Designers and managers must have a greater knowledge on plant growth. They should know about the technical sides of associated support systems such as drainage and irrigation, water movement in soil media. This knowledge is needed to establish a successful vertical gardening.

References

Abel, C. (2010). The vertical garden city: towards a new urban topology. CTBUH Journal, (2), 20–30. Available at: http://www.et2050.eu/et2050_library/docs/tech/land uses/Verticalgarden.pdf [Accessed September 5, 2022].

Afrin, S. (2009). Green Skyscraper: Integration of Plants into Skyscrapers. (Master's Thesis). Kungligatekni skahögskolan (KTH), Stockholm. Available at: www.infra.kth.se/sb/sp. [Accessed January 15, 2022].

BBS. (2021). Population Census. Bangladesh Bureau of Statistics.

Banerjee, C., & Adenaeuer, L. (2014). Up, Up and Away! The Economics of Vertical Farming. Journal of Agricultural Studies, 2(1), 40. Available at: http://doi.org/10.5296/jas.v2i1.4526 [Accessed January 15, 2022]

Barthel, S., &Isendahl, C. (2013). Urban Gardens, Agriculture, and Water Management Sources of Resilience for Long-Term Food Security in Cities. Ecological Economics, 86, 224-234.

Besthorn, F. H. (2013). Vertical Farming: Social Work and Sustainable Urban Agriculture in an Age of Global Food Crises. Australian Social Work, 66(2), 187–203. Available at: http://doi.org/10.1080/03124 07X.2012.716448. [Accessed December 5, 2022].

Bolund, P. and Hunhammar, S., (1999). Ecosystem services in urban areas. Ecological economics, 29(2), pp.293-301.

Boyce, C. & Neale, P. (2006) "Conducting in-depth Interviews: A Guide for Designing and Conducting In-Depth Interviews", Pathfinder International Tool Series.

Butkovich K, Graves J, Mckay J, and Slopack M (2008). An Investigation into the Feasibility of bio wall technology. George Brown College Applied Research & Innovation.

Campanella, T. J. (2006). Urban resilience and the recovery of New Orleans. Journal of the American Planning Association, 72(2), 141–146. Available at: http://dx.doi.org/10.1080/01944360608976734.

Cicekli, M., &Barlas, N. T. (2014). Transformation of today greenhouses into high technology vertical farming systems for metropolitan regions. Journal of Environmental Protection and Ecology, 15(4), 1779–1785.

Coaffee, J. (2013). Towards next-generation urban resilience in planning practice: From securitization to integrated place making. Planning Practice and Research 28(3), 323–339. Available at: http://dx.doi.org/ 10.1080/ 02697459.2013.787693.

Despommier, D. (2009). The rise of vertical farms. Scientific American, 301(5), 80–87.

Despommier, D. (2010). The vertical farm: feeding the world in the 21st century. Macmillan.

Despommier, D. (2011). The vertical farm: controlled environment agriculture carried out in tall buildings would create greater food safety and security for large urban populations. Journal fürverbraucherschutz Und Lebensmittelsicherheit, 6(2), 233–236. Available at: http://doi.org/10.1007/s00003-010-0654-3. [Accessed March 15, 2022].

Despommier, D. (2013). Farming up the city: The rise of urban vertical farms. Trends in Biotechnology, 31(7), 388–389. Available at: http://doi.org/ 10.1016/j.tibtech.2013.03.008. [Accessed December 7, 2022]

Dewan, A.M., Kabir, M.H., Islam, M.M., Kumamoto, T. And Nishigaki, M. (2007) Delineating Flood Risks in Greater Dhaka of Bangladesh Using Geoinformatics, Georisk, and [Online] vol 1(4), p. 190-201. Available at: https://www.tandfonline.com/doi/abs/10.1080/17499510701772097. [Accessed September 13, 2022].

Dixon, P. Roof Gardens Impact on Energy Saving. Available at: globalchange.com: http://www.globalchange. com/ roof-gardensimpact- on-energy-saving.htm. [Accessed February 9, 2022]

Elinç, z., kaya, l. And Elinç, h. (2013). Analysis of Contribution 0f Vertical Gardens to Urban Sustainability: The Case Study of Antalya City, Turkey. İnönü University Journal of Art and Design, [Online] 3(7), pp.55-59. Available at: https://www.researchgate.net/publication/271208817_Analysis_of_ Contribution_of_Vertical_Gardens_to_urban_Sustainability_The_Case_Study_of_ Antalya_City_Turkey [Accessed September 28, 2022].

Fabrice G, R., Karen, S. R. And Marisol, E. (2013). The role of ecosystems in disaster risk reduction. Tokyo: United Nations University Press, pp. 486.

Gawad, I.O., (2014). The rise of rooftop gardens in informally developed areas in Egypt: exploring the abilities and boundaries. مؤتمراتكليةالهندسة.

Green Roofs for Healthy Cities. (2005). About Green Roofs. Available at: Http://www.greenroofs.org/index.php? Option =com_content&task=view&id=26&Itemid=40. [Accessed November 20, 2022].

Green, J. (2011). December 16. Farm the Rooftops. Available at: dirt.asla.org: (http://dirt.asla.org/2011/12/ 16/farm-the-rooftops/) [Accessed February 9, 2022]

Greenstone, C., (2009). Rooftop Gardens and the Greening of Cities–A Case Study of University of Kwazulu-Natal. School of Architecture, Housing and Planning, University of Kwazulu–Natal, Durban.

Hossain, M. M. (2009), Effects of Green Roof Concept on Residential Apartment Buildings in the Context of Dhaka City, unpublished M.Arch term paper under the supervision of Prof. Dr. Qazimowla (the author of this paper) of Bangladesh University of Engineering and Technology, Dhaka.

Hui, D., (2006). Benefits and potential applications of green roof systems in Hong Kong. Evaluation, 11, p.12.

Hui, D.C. (2011). Green roof urban farming for buildings in high-density urban cities. The Hainan China World Green Roof Conference, pp. 1–9. China.

Islam, K.M. (2004). Rooftop Gardening as a Strategy of Urban Agriculture for Food Security: The Case of Dhaka City, Bangladesh. Available at: teiep.gr: ⟨http:// wwwlib.teiep.gr/images/stories/acta/Acta %20643/643_31.pdf⟩.

Jafari, N. And Utaberta, N., (2015). Evaluating the Urban Agriculture of Roof Garden at High-Rise Building in Malaysia. Advances in Environmental Biology, 9(23), pp.98-105.

Jha, A.K. Miner, T.W. and Geddes, Z.S. (end): (2013), Building Urban Resilience: Principles, tools and practice, The World Bank, Washington, D.C.

Kabir, M. H., Sato, M., Habbiba, U. And Yousuf, T.B. (2018) Assessment of Urban Disaster Resilience in Dhaka North City Corporation (DNCC), Bangladesh. Procedia Engineering, [Online] vol 212, p. 1107-1114. Available at: https://www.sciencedirect.com/science/article/pii/S1877705818301693. [Accessed September 12, 2022]

Kalantari, F., Mohdtahir, O., Golkar, N., &Kalantari, S. (2015). Restoration of Tajan River through Ecological Design Approach. ALAM CIPTA, International Journal on Sustainable Tropical Design Research & Practice, 8(spec. 1), 52–59. Available at: http://psasir.upm.edu.my/42296/. [Accessed April 2, 2015]

Kaplan, R. (1993). The role of nature in the Context of the workplace. Landscape and Urban Planning, 26(1), 193–201. Available at: http://search.ebscohost.com/login.aspx?Direct=true&db=psyh&AN=1985-16132-001&site=eds-live&scope=site. [Accessed September 16, 2022]

Kathiresan, K., and Rajendran, N. (2005). Coastal mangrove forests mitigated tsunami. Estuarine, Coastal and Shelf Science, vol 65(3), pp. 601-606. Available at: https://www.sciencedirect.com/journal/estuarine-coastal-and-shelf-science/vol/65/issue/3. [Accessed September 11, 2022]

Kumar, A. (2017). Vertical Gardens for India Social, Architecture Acceptance & Practice. International Journal on Emerging Technologies, [Online] 8(1), pp.18-24. Available at: https://www.researchtrend.net /ijet/pdf/ 4%20 ANKIT %20KUMAR.pdf [Accessed September 28, 2022].

Lakhsmi, A., Schiavina, A., Banerjee, P., Reddy, A., Mandeen, S., Rodriguez, S. And Apte, D. (2012). The Challenged Coast of India: A Report. [Online] BNHS, NCPC, Pondy CAN and TISS. Available at: http://www.indiawater portal.org/articles/challenged-coasts-india-report. [Accessed September 13, 2018]

Lall, S.V. and Diechmann, U. (2009) Density and Disasters: Economics of Urban Hazard Risk, Policy research working paper 5161, World Bank, Washington, D.C.

Lawson, L. (2005). City Bountiful: A Century of Community Gardening in America. Berkeley, CA: University of California Press.

Lhomme, S., Serre, D., Diab, Y., &Laganier, R. (2013). Urban technical networks resilience assessment. In R. Laganier (Ed.), Resilience and urban risk management. (pp. 109–117). London: CRC Press. Available at: http://dx.doi.org/10.1201/b12994-13.

Lovell, S.T. and Taylor, J.R., (2013). Supplying urban ecosystem services through multifunctional green infrastructure in the United States. Landscape ecology, 28(8), pp.1447-1463.

Meerow, S., Newell, J.P. and Stults, M., (2016). Defining urban resilience: A review. Landscape and urban planning, 147, pp.38-49. Metronews.ca/news/toronto/2015/06/08/rooftop-farming-could-be-the-next-step-in-toronto-archit ecture.html⟩.

Millennium Ecosystem Assessment. (2005). Ecosystems and Human Well-Beings: Current State and Trends, Volume 1. Washington: Island Press.

Miller, A. (2011). Scaling Up or Selling Out? A Critical Appraisal of Current Development in Vertical Farming. (Unpublished Master's Thesis).Carleton University, Ottawa, Ontario, Canada.

Mowla, Q.A. (2005a), "Ecological Imperatives for Sustainable Environment", in International Conference on Geography and Environment – Issues and Challenges, Dec 9-11, 2005, Dhaka.

Mowla, Q.A., (2010), October. Green Roof Concept for Eco-Sustainability in the Context of Urban Dhaka. '. In International seminar on 'GO GREEN: the Architecture of the New Order 'on the occasion of ARCASIA, 0rganized by ACA, Lahore, Pakistan (pp. 25-30).

Nel, J.L., Le Maitre, D.C., Nel, D.C., Reyers, B., Archibald, S., Van Wilgen, B.W., Forsyth, G.G., Theron, A.K., O'Farrell, P.J., Kahinda, J.M.M. and Engelbrecht, F.A. (2014). Natural hazards in a changing world: a case for ecosystem-based management. Plos one, vol 9(5), p.e95942.

Peck, S.P., C. Callaghan, M.E.Kuhn, B.Bass. (1999), "Greenbacks Available at: Green roofs: forging a New Industry in Canada. Toronto: Canada Mortgage and Housing Corp.

Perez, V. M. (2014). Study of the Sustainability Issue of Food Production Using Vertical Farm Methods in an Urban Environment within the State of Indiana. (Master's Thesis). Available at: ProQuest Dissertations and Theses database. (UMI No.1565090).

Rieux, K. S., Ash, N. And Murti, R. (2009) Environmental guidance note for disaster risk reduction: healthy ecosystems for human security, 1st ed. (pdf) Gland, Switzerland: IUCN. Available at: https://www.iucn.org/content/environ mental-guidance-note-disaster-risk-reduction-healthy-ecosystems-human-security-and-climate-change-adaptation. [Accessed September 13, 2022]

Rieux, K. S., Masundire, H., Rizvi, A. And Rietbergen, S. (2006). Ecosystems, Livelihoods and Disasters: An integrated approach to disaster risk management. 1st ed. (pdf) Gland, Switzerland and Cambridge, UK: IUCN. Available at: https://www.preventionweb.net/publications/view/568. [Accessed September 12, 2022]

Safayet, M., Arefin, M.F. and Hasan, M.M.U., (2017). Present practice and future prospect of rooftop farming in Dhaka city: A step towards urban sustainability. Journal of Urban Management, 6(2), pp.56-65.

Safikhani, T., Abdullah, A. M., Ossen, D. R., &Baharvand, M. (2014). A review of energy characteristic of vertical greenery systems. Renewable and Sustainable Energy Reviews, 40, 450–462. Available at: http://doi.org/10.1016/j.rser.2014.07.166. [Accessed August 25, 2022]

Sam M. And Hui S. C. (2011) "Green roof urban farming for buildings in high-density urban cities", In World Green Roof Conference, March 18-21, 2011, Hainan, China.

Sauerborn, J. (2011). Skyfarming: an alternative to horizontal croplands. Resource: Engineering & Technology for a Sustainable World, 18(1), 19. Available at: http://www.highbeam.com/doc/1G1-247226253.html [Accessed December 15, 2022]

Shaw, R., Mallick, F. And Islam, A. (2013) Disaster Risk Reduction Approaches in Bangladesh. Tokyo: Springer Dordrecht Heidelberg London New York, pp. 235-257.

Singapore Magazine. (2015) Farming in the Sky. [Online] Available at: http://singaporemagazine.sif.org.sg /farming-in-the-sky [Accessed September 27, 2022].

Sivamani, S., Bae, N., & Cho, Y. (2013). A Smart Service Model Based on Ubiquitous Sensor Networks Using Vertical Farm Ontology. International Journal of Distributed Sensor Networks, 9(12), 161495. Available at: http://doi.org/10.1155/2013/161495 [Accessed April 20, 2022]

Spalding, M. D., mcivor, A. L., Beck, M. W., Koch, E. W., Möller, I., Reed, D. J., Rubnioof P., Spencer, T., Tolhurst T. J., Wamsley T.V., Wesenbeeck, B. K., Wolanski, E., and Woodroffe C.D. (2014). Coastal ecosystems: a critical element of risk reduction. Conservation Letters, vol 7(3), pp. 293- 301. Available at: https://onlinelibrary.wiley.com/doi/full/10.1111/conl.12074. [Accessed September 11, 2022]

Specht, K., Siebert, R., Hartmann, I., Freisinger, U. B., Sawicka, M., Werner, A., Dierich, A. (2014). Urban agriculture of the future: an overview of sustainability aspects of food production in and on buildings. Agriculture and Human Values, 31(1), 33–51. Available at: http://doi.org/10.1007/s10460-013-9448-4. [Accessed January 15, 2022]

Thomaier, S., Specht, K., Henckel, D., Dierich, A., Siebert, R., Freisinger, U. B., &Sawicka, M. (2015). Farming in and on urban buildings: Present practice and specific novelties of Zero-Acreage Farming (zfarming). Renewable Agriculture and Food Systems, 30(1), 43–54. Available at: http://doi.org/10.1017/S1742170514000143. [Accessed April 21, 2022]

Tiller, A. (2008). June 30. Rooftop Farms Could Feed City Slickers. [Accessed February 9, 2016]. Available at: blog.alextiller.com:⟨http://blog.alextiller.com/_blog/Alex_Tiller's_Blog_on_Agriculture_and_Farming/post/Rooftop_Farms_Could_Feed_City_Slickers/⟩.

Wang, B. (2012). 4 Story tall vertical farm that is up to ten times more productive than regular farms. [Online] nextbigfuture.com. Available at: http://nextbigfuture.com/2012/11/4-story-tallvertical-farm-that-is-up.html. [Accessed 27 Sep. 2022].

Yüksel N (2013).Examination of Vertical Gardening Practices in Abroad and Istanbul (Thesis) Bahcesehir University Graduate School of Natural and Applied Sciences, Urban Systems and Transportation Management Master Program, Istanbul.