Project ID ---- 413

Competitive Research Grant

Sub-Project Completion Report
on

Assessment of ecosystem services and benefits of rooftop gardening for climate-friendly city development using geospatial technology

Project Duration

May 2016 to September 2018

Department of Agroforestry and Environmental Science
Sher-e-Bangla Agricultural University, Dhaka

Submitted to
Project Implementation Unit-BARC, NATP-2
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

September 2018

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Project Implementation Unit
National Agricultural Technology Program-Phase II Project (NATP-2)
Bangladesh Agricultural Research Council (BARC)
New Airport Road, Farmgate, Dhaka – 1215
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The execution of CRG sub-project has successfully been completed by Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University using the research grant of USAID Trust Fund and GoB through Ministry of Agriculture. We would like to thanks to the World Bank for arranging the grand fund and supervising the CRGs by BARC. It is worthwhile to mention the cooperation and quick responses of PIU-BARC, NATP 2, in respect of field implementation of the sub-project in multiple sites. Preparing the project completion report required to contact a number of persons for collection of information and processing of research data. Without the help of those persons, the preparation of this document could not be made possible. All of them, who made it possible, deserve thanks. Our thanks are due to the Director PIU-BARC, NATP 2 and his team who given their whole hearted support to prepare this document. We hope this publication would be helpful to the agricultural scientists of the country for designing their future research projects in order to technology generation as well as increasing production and productivity for sustainable food and nutrition security in Bangladesh. It would also assist the policy makers of the agricultural sub-sectors for setting their future research directions.

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Acronyms

BARC- Bangladesh Agriculture Research Council

NATP- National Agricultural Technological Project

SAU-Sher-e-Bangla Agricultural University

CRG-Competitive Research Grant

PCR-Project Completion Report

LoA- Letter of Agreement

DAE- Department of Agricultural Extension

RTG- Rooftop Gardening

RH- Relative Humidity

GPS- Geographical Positioning System

BADC- Bangladesh Agricultural Development Corporation

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Executive Summary

A questionnaire survey was conducted in forty households in four metropolitan areas of Mohammadpur, Adabar and Sher-e-Bangla Nagar of Dhaka North City Corporation and Dhanmondi, areas of Dhaka South City Corporation to assess existing plant species diversity and ecosystem services during November 22, 2017 to March 23, 2018. Results revealed that the plant diversity index and major ecosystem services were found satisfactorily in the four study areas. The Shannon-Weaver diversity index was found very high in the study area which was 4.51. Each rooftop garden acts as an urban ecosystem unit where plants don't grow naturally rather the plant species are grown according to the gardener's own will. That is the reason behind the higher diversity index resulted in the study. Fruits and vegetable production was the main provisioning service provided by RTGs. 40% of the garden owner get daily food supply from their roof gardens, 45% get weekly food supply and only 15% get the food supply monthly. Yearly food production was found mostly medium (21-40 kg/year) in 65% roof gardens while high food production (above 40 kg) was found in 22.5%. Inter-species diversity was found higher for flowering plant species (0.988) in the roof garden of the study area followed by vegetable species (0.977), ornamental species (0.966), fruit species (0.944) and medicinal species (0.895). Among 38 species of fruits, Mango (127.1%) was found the highest prevalent and Dragon fruit (10.2%) was found the lowest prevalent. Among 40 species of flowers, Beli (115.7%) was found the highest prevalent and Bottle Brush (24.1%) was found the lowest prevalent. Out of 25 vegetable species, egg plant (132.6%) was found the highest prevalent and Sharisha shak (31.1%) was found the lowest prevalent. Out of 32 ornamental species, croton (110.1%) was found the most prevalent and king sago palm (41.3%) was found the lowest prevalent. Out of 15 medicinal species, henna (113.4) was found the most prevalent and clove (23.4) was found the lowest prevalent. **An experiment** was conducted at the roof of four aforesaid residential area of Dhaka city which are, Mohammadpur, Sher-e-Bangla Nagar, Adabor and Dhanmondi during the period from October, 2017 to August, 2018. The experiment was laid out in Completely Randomized Design (CRD) having single factors with four replications. In the study area, eight blocks per roof was constructed very carefully. Each block was consists of 4 plots. The area of each block was 3.5m×1m. There were 16 unit plots in the experiment location. The high yielding variety of BARI invented vegetables and flowers crops seed of bitter gourd, bottle gourd, okra, pumpkin, spinach, amaranth and the seedlings of cabbage, cauliflower, tomato, chili, brinjal, flower seedlings of marigold, salvia, and dahlia were collected from Bangladesh Agricultural Research Institute (BARI), Bangladeh Agricultural Development Corporation and transplant on those rooftop buildings. All management practices were same in four areas. Data revealed that Plant height, stem diameter, number of leaves per plant, fruit length, fruit breadth, fruit weight, total fruit weight, total number of flowers, life span of flowers were found satisfactorily in the four selected rooftop gardens.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. Title of the CRG sub-project: Assessment of ecosystem services and benefits of rooftop gardening for climate-friendly city development using geospatial technology

2. Implementing organization: Sher-e-Bangla Agricultural University

3. **Name and full address with phone, cell and E-mail of PI/Co-PI (s):**

Principal Investigator	CO- Principal Investigator
Prof. Dr. Md. Forhad Hossain Department of Agroforestry and Environmental Science Sher-e-Bangla Agricultural University Dhaka-1207 Cell: 01716 23 63 85, 01677 29 92 42 E-mail: forhadsau@gmail.com FAX: +88 02 58155800	Prof. Dr. Md. Sekender Ali Department of Agricultural Extension and Information System Sher-e-Bangla Agricultural University Dhaka-1207 Cell: 01711230183, 0111230183 E-mail: msa_sau@yah6oo.com FAX: +88 02 58155800

4. Sub-project budget (Tk):

4.1 Total: 17,99,380/-

4.2 Revised (if any): 17,99,380/-

5. Duration of the sub-project: 18 months

5.1 Start date (based on LoA signed): May/2017 to September/2018

5.2 End date: 30 September 2018

6. Justification of undertaking the sub-project:

Cities are continuously in transition of urbanization process due to accommodate increasing number of population, industrialization, economic and social changes. Dhaka, the capital of Bangladesh and one of the fastest growing cities in the world is not an exception of this trend. Bangladesh's urban population has been growing at a yearly average rate of 6 percent since independence. As a result, urban population has grown six-fold, compared with a 70 percent increase in rural population (World Bank, 2007). As per recent UN data, approximately 25 percent of Bangladesh's current population currently lives in urban areas (Hoogerbrugge, I.D and Fresco, L. O.1993.). Of this urban population, more than half lives in the four largest cities: Dhaka, Chittagong, Khulna and Rajshahi, 58% of which live in Dhaka. With a population of almost 12 million, it is the 11th largest city in the world. At the same time, it is consistently ranked as one of the world's least livable city. In the process of urbanization, Dhaka, with an area of 140 sq mi has caused significant decline of green spaces, agricultural lands, wet lands and water bodies due to indiscriminate land use transformation. Over last few decades, this trend is leading to loss of natural resources and habitat fragmentation (Hafiz, R. 2004). Due to this rapid development, green areas and soft surfaces of cities, suburbs and communities are rapidly being grabbed by structures, roads, driveways, parking lots and other hard and impervious surfaces resulting from pressure of rapid and unplanned urbanization (Myers, N., *et. al*., 2001). However, due to destruction of green spaces, balance of thermal comfort and environmentalism is being disturbed through high temperature, high humidity, air pollution, heat waves, rising sea level, water log off, floods, noise pollution, heat island effect etc. (Hafiz, R. 2004). So, the necessity of recovering vanishing green spaces is becoming increasingly critical to maintain environmental quality. In this situation "Rooftop Gardens" and "Green Roofs" (roofs with a vegetated surface and substrate) can be a potential alternative remedy to reverse the problem through applying this green technology on contemporary houses in Dhaka city (World Population Prospects, 2016). Rooftop gardens (RTG) are man-made green spaces on the topmost levels of residential,

industrial and commercial structures. They may be designed to grow produce, provide play space, give shade and shelter, or simply be there as a living, green area. Plants are grown for a variety of utilitarian and non-utilitarian purposes (Sajjaduzzaman *et al.,* 2005). In environmental sector, green roofs and rooftop gardens proved its innovativeness to solve multiple environmental hazards by increasing aesthetic value, ensuring nutrition & recreation, reducing Urban Heat Island Effect, CO_2 and Green House Effect, air and noise pollution, run-off impacts, increasing thermal comfort among building occupants by increasing summer cooling and lengthening roof life two to three times, increasing urban biodiversity and many more ecosystem services.

Rooftop gardens can be effective stimulators of urban ecosystem. Rooftop gardens and Green roofs provide a number of ecosystem services in urban areas, including improved storm-water management, better regulation of building temperatures, reduced urban heat-island effects, and increased urban wildlife habitat. This project reviews the evidence for these benefits and examines the biotic and abiotic components that contribute to overall ecosystem services. The aim of this project is to identify and analyze the major ecosystem services generated by ecosystems within the roof garden area. The project will also explore the potential scopes to socialize green practices of rooftop gardens with the use of Geographical Information System (GIS) to visualize the spatial relationships with a view to improving climate resilience and quality of life in cities.

7. Sub-project goal: Improvement of urban ecosystem services through climate-friendly rooftop gardening and capacity building of urban household community to promote and strengthening urban agricultural economy activities.

8. Sub-project objective (s):

1. To identify existing plant species diversity of selected household rooftops of the study area;
2. To assess the benefits of rooftop gardens in providing thermal comfort and ecosystem services; and
3. To investigate and identify suitable vegetable and flower species for rooftop gardening through demonstration.

9. Implementing location (s): Selective wards of Mohammadpur, Adabar, Shere Bangla Nagar and Dhanmondi areas of Dhaka North and South City Corporation.

10. Methodology in brief:

<u>Part 1: Survey methodology</u> (Satisfying objectives 1&2)

This experimental survey was conducted to find out the potential of rooftop gardens in providing major ecosystem services. In this chapter the materials used, the methodologies followed and the related works done during experimental period are presented. The methods and procedures followed in conducting this study have been described in the following sections.

10.1 Description of the Study Area

10.1.1 Dhaka city

Dhaka is the capital and largest city of Bangladesh. With its colorful history and rich cultural traditions, Dhaka is known the world over as the city of mosques and muslin. Its fame attracted travelers from far and near throughout the ages. Dhaka has been expanding spatially as its population has increased.

Over the past decade, the core municipality, Dhaka, increased its population 45 percent. Dhaka may be the worst situated urban area in the world. Dhaka is located in wetlands and virtually surrounded by rivers.

10.1.2 Climate of Dhaka city

23°42'0"N90°22'30"E Dhaka experiences a hot, wet and humid tropical climate. Dhaka has a tropical wet and dry climate. The city has a distinct monsoonal season, with an annual average temperature of 25 °C (77 °F) and monthly means varying between 18 °C (64 °F) in January and 29 °C (84 °F) in August. Nearly 80 percent of the annual average rainfall of 1,854 millimeters (73.0 in) occurs during the monsoon season which lasts from May until the end of September. Increasing air and water pollution emanating from traffic congestion and industrial waste are serious problems affecting public health and the quality of life in the city. Water bodies and wetlands around Dhaka are facing destruction as these are being filled up to construct multi-storied buildings and other real estate developments. Coupled with pollution, such erosion of natural habitats threatens to destroy much of the regional biodiversity.

10.1.3 Demography of roof top gardening in Dhaka city

Rooftop gardening becomes growingly popular in the Dhaka city as the land for gardening shrinks every day with construction of more and more new buildings. City's gardeners and agriculturists, however, cite yet another reason why more house owners getting keen on having a patch of greenery on their roofs, which is, they want vegetables and fruits fresh and free from poisonous chemicals. The government Department of Agricultural Extension said around 6,000 rooftop gardens are in the Dhaka city. The DAE has divided the Dhaka city in three areas supervised by its three offices called Metropolitan Tejgaon, Metropolitan Gulshan and Metropolitan Mohammadpur. It has found 3082 rooftop gardens in the neighbourhoods overseen by its Gulshan office, 2000 have been spotted in areas under its Tejgaon office and 600 in the Mohammadpur neighbourhoods. These gardens have been providing a number of ecosystem services to the city dwellers and thus helping in uniting the urban ecosystem with the social and economic system.

10.1.4 Population and Sampling Procedure

The survey was conducted within the area of Dhaka city. Three metropolitan areas namely Dhanmondi, Mohammadpur and Sher-e-Bangla Nagar were selected as study area through consultation with relevant organizations e.g., DAE, Botanical Garden, Horticulture, Rajuk. These three areas were preferred due to having successful, effective and higher number of roof gardens. Mohammadpur metropolitan includes Adabor thana and Mohammadpur thana, Dhanmondi metropolitan includes Dhanmondi thana and Sher-e-Bangla Nagar thana and Shere Bangla Nagar area include Agargaon, Taltola, BNP Areas etc. Survey was conducted in several subareas of each ward of the corresponding thana where Individual households represented the sampling units. The populations are randomly selected as the sample of the study by using random number table (Table 10.1). Thus, sample size of the study was 40 rooftop buildings.

Table 10.1: Distribution of population and sample size in three selected metropolitan areas (Adabar, Mohammadpur and Sher-e- Bangla Nagar)

1.1: Dhaka North City Corporation

	Thana	Ward	Sub areas under Thana	No. of roof gardeners finally selected for data collection
Mohammadpur metropolitan area	**Mohammadpur**	Ward 42	Chinumia Road Area	1
			Tajmahal Road Area	1
			Madrasa Road	1
		Ward 44	Zakir HossainRoad Area	1
			Salimullah Road Area	1
		Ward 45	Lalmatia Housing Society	1
			Iqbal Road Area	1
		Ward 46 (Part)	Mohammadia Housing Society	2
			Mohammadia Housing Ltd.	1
			Nobodoy Housing	2
			Chanmia Housing	1
		Ward 47 (Part)	Jafrabad	1
			West Dhanmondi	1
			Shangkar	1
	Adabor	Ward 43	Uttor Adabor	1
			Baitul Aman Society	1
			Monsurabad Housing	2
		Ward 46 (part)	Pisciculture Housing	1
			Shekhertek	2
Shere Bangla Nagar Metropolitan Area	Sher-e- Bnangla Nagar	Ward 32	Agargaon	2
Total				**25**

1.2: Dhaka South City Corporation

	Thana	Ward	Sub areas under Thana	No. of roof gardeners finally selected for data collection
Dhanmondi				

metropolitan area	**Dhanmondi**	Ward 49	Dhanmondi Lake area	3
			Dhanmondi	3
		Ward 50	Dhanmondi 27	3
		Ward 51	Dhanmondi sat mosgit	3
		Ward 52	Jiga tola	3
				15
Grand Total (25+15)= 40				

10.1.5 Collection of necessary GIS information:

For collecting Spatial information about the study area, base maps of each wards under Dhanmondi metropolitan were collected from Dhaka South City Corporation office and base maps of each wards under Mohammadpur and Sher-e- Bangla Nagar metropolitan were collected from Dhaka North City Corporation Office. Geo-referencing was done of those maps using ArcGIS software to generate the final map of the study area. The results obtained from analysis have been shown spatially through different maps. The collected base maps of the corresponding wards have been given in Appendix IV. The GPS reading of each roof garden building location was taken during the survey. The collected coordinates of each location has been given in Appendix III.

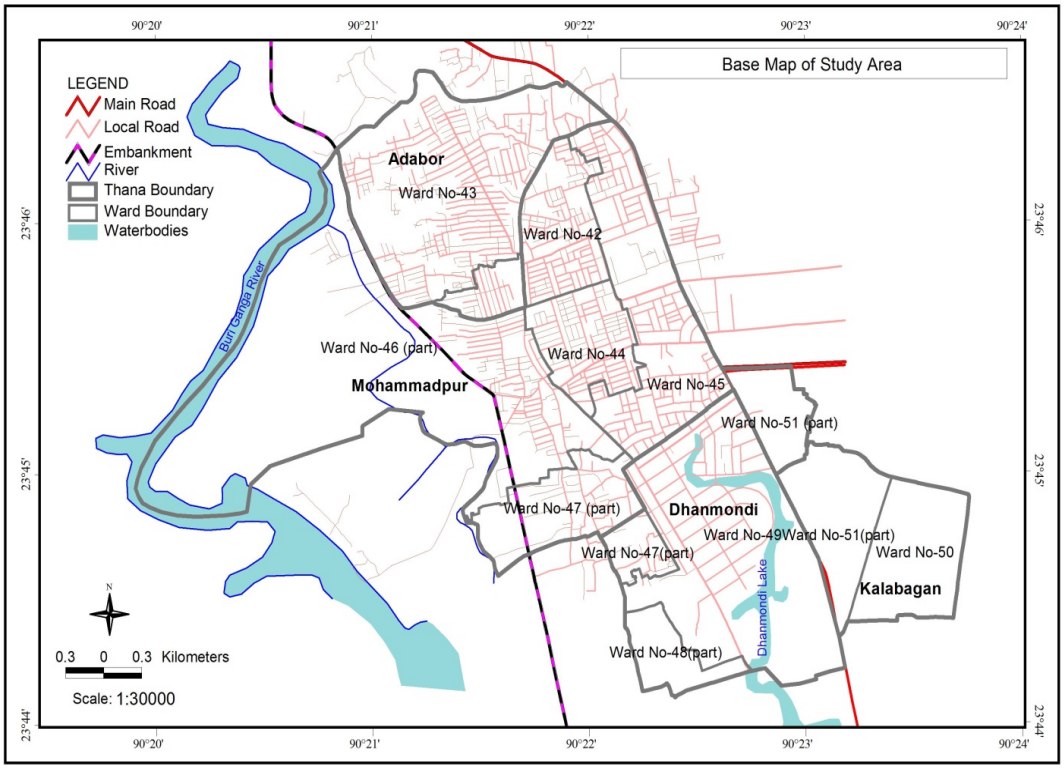

Figure 1: Base map of the study area

10.1.6 Developing questionnaire :

The questionnaire was developed according to the possible major ecosystem services provided by rooftop gardens in the city included provisioning, supporting, regulating, and aesthetic/cultural services. These ecosystem services were selected based on the field observations of all authors in 2015 and our previous knowledge. Besides ecosystem services that were obviously important in local communities, e.g., food and fiber, we also considered ecosystem services that in our perception were used less intensively by local communities,. Responses to open questions were collected on a variety of demographic and socioeconomic indicators: roof garden species, choice of species, consumption access of roof garden products, expenditure, production and so forth. On each topic, the garden owners were free to express their views. Survey instruments were collected on two parts, species information on one parts and the demographic information on the other parts. Enumerators were oriented in participatory way. Finalization of the questionnaire was made after pre-testing in adjacent roof gardeners of the project site. Direct observation of roof garden was also carried out simultaneously. For quality control, the surveyed questionnaires were passed through edition, revision in different tiers first by enumerator herself, then peer review and editing among enumerators and final editing by the researcher on the same date.

10.2 Data Collection

10.2.1 Primary data collection

Reconnaissance survey was carried out before conducting the detailed data collection. After getting the general information about the study area, primary data were collected by using following methods:

10.2.2 Direct observation of roof top garden with garden owners

Forty roof top gardens were visited with the help of Sub Assistant Agricultural Officer of metropolitan area and garden owners for obtaining the accurate information about the garden plants and their services. The geographical location of each Building was recorded accordingly using GPS. Total tree species and their numbers were counted species-wise with the help of garden owners in their garden using check list. The main emphasis was given on the counting and identification of plant species (biodiversity), provisioning services (food and fiber production) and cultural services (aesthetics and recreation).

10.2.3 Questionnaire Survey with schedule

The feasibility of RTG (Rooftop Garden) was explored through a questionnaire survey of selected public and commercial buildings. The detail of the questionnaire is given in Appendix-1. After modifying questionnaire, randomly chosen 40 garden owners were selected as a sample, which represent male female respondents. Head of family and elderly individuals were interviewed. Data were collected by face to face interviewing of the respondents' during period from November 22, 2017 to March 23, 2018.

10.2.4 Thermal Data Collection:

- For collecting thermal data for the evaluation of thermal performance of roof garden two most important thermal parameter namely, Air Temperature and Relative Humidity reading were taken. The physical measurement was carried out by using the instrument "Thermo-Hygrograph".A Thermo-hygrograph records air temperature and relative humidity on a continuous basis for every hour for seven days.
- The data were taken at the warmest week of the year from 25th April to 30th April 2018.
- The bare roof data were recorded from 6am to 6pm in the roof garden over the four storied academic Building of Sher-e- Bangla Agricultural University.
- Outdoor temperature and RH were recorded both under plant shade area of the roof garden and under the sun in the bare roof alternatively for 6 consecutive days.
- Indoor temperature and RH were taken in the top floor rooms both under the roof garden and under the bare roof alternatively for 6 consecutive days.
- The collected temperature and RH reading were averaged to generate the final data. A scanned copy of the Thermo-hygrograph reading has been given in appendix V.

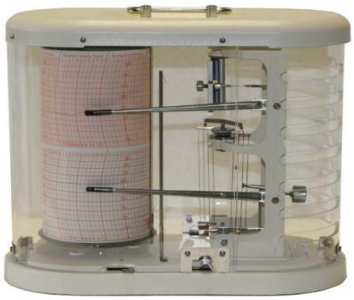

Plate 1: A Thermo-Hygrograph

Plate 2: Taking thermal data using Thermo-hygrograph on rooftop garden and bare roof

10.2.5 Secondary Data Collection

Secondary data were collected from the various sources and records like- reports published by related project, Department of Agricultural Extension, Metropolitan office. Maps, journals, publications, reports of other line agencies, published or unpublished and relevant literature were also consulted in the library and the relevant websites to make better understanding.

10.3 Measurement of Diversity

10.3.1 Shannon's Diversity Index

Shannon's diversity index is simply the ecologist's name for the communication entropy introduced by Claude Shannon:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where pi is the fraction of individuals belonging to the i-th species. This is by far the most widely used diversity index. The intuitive significance of this index can be described as follows. Suppose we devise binary code words for each species in our ecosystem, with short codeword used for the most abundant species, and longer codeword for rare species. As we walk around and observe individual organisms, we call out the corresponding codeword. This gives a binary sequence. If we have used an efficient code, we will be able to save some breath by calling out a shorter sequence than would otherwise be the case. If so, the average codeword length we call out as we wander around will be close to the Shannon diversity index. It is possible to write down estimators which attempt to correct for bias in finite sample sizes, but this would be misleading since communication entropy does not really fit expectations based upon parametric statistics. Differences arising from using two different estimators are likely to be overwhelmed by errors arising from other sources. Current best practice tends to use bootstrapping procedures to estimate communication entropy.

Shannon himself showed that his communication entropy enjoys some powerful formal properties, and furthermore, it is the unique quantity which does so. These observations are the foundation of its interpretation as a measure of statistical diversity.

10.3.2 Species richness

Species richness is the number of different species in a given area. Species richness is the fundamental unit in which to assess the homogeneity of an environment.

Typically, species richness is used in conservation studies to determine the sensitivity of ecosystems and their resident species. The actual number of species calculated alone is largely an arbitrary number. These

studies, therefore, often develop a rubric, measure for valuing the species richness number, or adopt one from previous studies on similar ecosystems.

The species richness is simply the number of species present in an ecosystem. This index makes no use of relative abundances. In practice, measuring the total species richness in an ecosystem is impossible, except in very depauperate systems. The observed number of species in the system is a biased estimator of the true species richness in the system, and the observed species number increases non-linearly with sampling effort. Species richness measures the number of species within an area. Roof top garden plants of the five locations were grouped into five categories namely fruits, flowers, and vegetables, ornamental and medicinal.

10.3.3 Inter species diversity

The most commonly used formula of calculating inter species diversity "Simpson index (D)" suggested by Simpson (1949) was used in this study which was as follows -

$D = 1 - Pi^2$

Where, Pi is the proportional abundance of the ith species such that

Pi = Ni/N

Ni = Plant population of ith species and

N = N1+N2+N3+…+Nn where n is the number of species

10.3.4 Relative prevalence (RP) of species

Relative abundances must add to unity (save perhaps for some rounding error). Note that relative abundance has no units (it is dimensionless). Alternatively, relative abundances can be expressed as a percentage.

Relative prevalence (RP) of species was calculated by using the following formula:

RP = Population of the species per roof garden × % roof gardens with the species.

These relative prevalence values were used to rank the species in different regions according to Millat-e-Mustafa (1997).

10.4 Measurement of Independent Variables

In this study selected personal, economic, social and psychological characteristics of the garden owners were considered as independent variables. These characteristics are as follows:

1. **Age:** Age of a respondent was measured in terms of years from birth to the time of interview which was found on the basis of response. It was located in the Q no. 2 of interview schedule.
2. **Marital Status**: Marital status was measured in terms of weather the respondent is married or single/unmarried or divorced. It was located in the Q no. 3 of interview schedule.

3. **Education:** Education was measured in terms of one's year of schooling. One score was given for passing each level in an educational institution. For example, if a respondent passed the SSC examination, educational score would be given as 10. If a respondent did not know how to read and write, his educational score would be given as '0'. It was located in the Q no.4 of interview schedule.
4. **Family size:** The family size was measured by the total number of members in the family of a respondent. The family members included family head and other dependent members like husband/wife, children, etc. who live and eat together. It was located in the Q no.6 of interview schedule.
5. **Occupation:** Occupation was measured according to the respondent's profession or walks of life. The general occupations included are service holder, Business and retired/housewife. It was located in the Q no. 5 of interview schedule.
6. **Family Annual Income:** Family annual income of the respondents was measured in terms of lack taka. Income from all sources by all the earning family members were added together to obtain family annual income. It was located in the Q no. 6 of interview schedule.
7. **House Ownership:** House ownership was measured by asking whether the respondent was building owner or tenant or lives in government quarter. It was located in the Q no. 7 of interview schedule.
8. **Surface area of roof garden:** The surface area of roof (sq. ft.) garden refer to the total area of roof on which his family carried out roof garden operation, the area being in terms of full benefit to the family. It was located in the Q no. 8 of interview schedule.
9. **Vegetation coverage**: Measuring the vegetation coverage of the RTG was done through visual observation of the roof garden and the roof gardens were grouped under the following categories for qualitative analysis. It was located in the Q no. 9 of interview schedule.

Extent of vegetation coverage	Weighting system
High (60-80% of the roof area)	3
Medium (40-50% of the roof area)	2
Low (20-30% of the roof area)	1

10. **Yearly food/fiber Production**: Yearly food/fiber production was measured by asking the respondent and grouped in the following categories for qualitative analysis. . It was located in the Q no. 10 of interview schedule.

Extent of yearly production	Weighting system
High (>30 kg)	3
Medium (15-30 kg)	2
Low (upto 15 kg)	1

11. **Meeting food demand**: The potential of RTG in meeting food demand was measured on daily, weekly and monthly basis. . It was located in the Q no. 11 of interview schedule.
12. **Spending time for gardening (hour):**Spending time for gardening (Hour) of a respondent was measured in terms of 1 hour, 2 hour and above 2 hours options on daily, weekly and monthly basis which was found on the basis of response. It was located in the Q no. 14 of interview schedule
13. **Mental Satisfaction:** Yearly food/fiber production was measured by asking the respondent and grouped in the following categories for qualitative analysis. . It was located in the Q no. 15 of interview schedule.

Extent of mental satisfaction	Weighting system
High	3
Medium	2
Low	1

14. **Thermal comfort**: Thermal comfort of the RTG was measured through observation of the garden and by asking the respondent's personal feelings about thermal comfort and grouped in the following categories for qualitative analysis. It was located in the Q no. 14 of interview schedule

Extent of thermal comfort	Weighting system
High	3
Medium	2
Low	1

15. **Yearly Expenditure**: For measuring yearly spent money for the RTG each garden owner was asked about their yearly expenditure and grouped in the following categories for qualitative analysis. It was located in the Q no. 15 of interview schedule.

Extent of yearly expenditure	Weighting system
High (>15000tk)	3
Medium (5001-15000tk)	2
Low (upto 5000tk)	1

16. **Nursing:** To measure the nursing characteristic of RTG, each respondent was asked whether the garden is nursed/maintained by the family members or family paid member or a well-paid gardener. It was located in the Q no. 16 of interview schedule.

17. **Technical Support:** Technical support of the garden owners were measured by asking the respondents with given choices. It was located in the Q no. 17 of interview schedule.
18. **Training:** Technical support of the garden owners was measured by asking the respondents with given choices according to DAE training. It was located in the Q no. 18 of interview schedule.

Extent of thermal comfort	Weighting system
High (4-5 days)	3
Medium (2-3 days)	2
Low (1 day)	1
No training	0

10.5 Measurement of Dependent Variables

Floral Diversity

Shannon's Diversity Index was used for measuring the plant species diversity of individual garden owner. For measuring the diversity, it was categorized into three groups such as low diversity, medium diversity and high diversity. Scores were assigned for all extension media in the following manner:

Extent of Diversity	Diversity Range
Low	0-2.4
Medium	2.5-3.5
High	>3.5

Diversity of the plants could range from 0 to above 3.5, where 0 indicating no diversity of RTG and above 3.1indicating high diversity of RTG.

Thermal performance

The temperature and RH reading of diurnal period (6am to 6pm) from the experiment was averaged to get the final data. Graphical analysis was done in MSExcel to visualize the actual change of temperature and RH both indoor and outdoor.

Purpose of gardening

Purpose of rooftop gardening was assessed using a semi-structured open questionnaire which was calculated as percentage in MS Excel in garden owners opinion. It was located in the Q no. 11 of interview schedule.

10.6 Compilation of Data

After completion of field survey all the data of the interview schedule were compiled. Local units were converted into standard unit. Appropriate coding and scoring technique was followed to convert the qualitative data into quantitative forms. The responses of the individual respondent contained in the

interview schedules were transferred to a master sheet for entering the data in the computer. As soon as the data entered into the computer, it was then analyzed in accordance with the objectives of the study.

Part 2: Experiment methodology (Satisfying objective 3)

10.7 Location of the experiment field

The experiment was conducted at the roof of four residential area of Dhaka city which are, Mohammadpur, Sher-e-Bangla Nagar, Adabor and Dhanmondi during the period from October 2016 to October 2017.

10.8 Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during the rest of the year (Rabi season). The total rainfall of the experimental site was 83.6 mm during the study period. The average monthly maximum and minimum temperature were 28 ºC and 17 ºC, respectively during the experimental period. Rabi season is characterized by plenty of sunshine.

10.9 Soil

The soil of the experimental site was collected from outside of Dhaka city which was sandy clay. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka.

10.10 Plant materials collection

For Robi and Kharif-I season, the high yielding variety of BARI invented vegetables and seeds of bitter gourd, bottle gourd, okra, pumpkin, spinach, amaranth and the seedlings of cabbage, cauliflower, tomato, chili, brinjal, marigold, salvia, and dahlia were collected from Bangladesh Agricultural Research Institute (BARI).

10.11 Treatment of the experiment

Every location of the experiment was counted as a treatment. Because the environmental conditions and topography of the rooftop gardens were not the same. The locations were:

T_1= Mohammadpur
T_2= Adabor
T_3= Kolabagan
T_4= Dhanmondi

10.12 Design of the experiment

The experiment was laid out in Completely Randomized Design (CRD) having single factors with four replications. In the study area, eight blocks per roof was constructed very carefully. Each block was consists of 4 plots. The area of each block was 3.5m×1m. There were 16 unit plots in the experiment location. The size of each plot was 1 m x 1 m, which accommodated 4 plants at a spacing of 0.3 m x 0.3 m.

10.13 Land preparation

Before starting the experiment a concrete structure called block using brick, cement and sand were prepared in every study area. Then polythene and newspaper were spread on the floor of each block. After that each block was filled with supplied soil. The supplied soil in each area was prepared and good tilth to ensure for vegetable and flower production on September, 2017. The land was spaded and larger clods were broken into smaller pieces. After spading all the stubbles and uprooted weeds were removed and then the land was made ready to plant.

10.14 Manure and fertilizers and its method of application

The recommended doses of Urea, Triple Super phosphate (TSP), Muriate of Potash (MP) and borax were used as source of nitrogen, phosphorus, potassium and boron, respectively for all crops. Well decomposed cow dung was also applied to the field before final ploughing.

10.15 Transplanting of seedlings

For tomato

Collected healthy and uniform 45 days old tomato seedlings were transplanted in the experimental plots in 23rd October, 2017 maintaining a spacing of 30 cm x 30 cm between the plants and rows, respectively. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

For chili and eggplant

Healthy and uniform 30 days old chili seedlings were transplanted in the experimental plots in 23rd October, 2017 maintaining a spacing of 30 cm x 30 cm between the plants and rows, respectively. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

For cabbage and cauliflower

About 23-25 days healthy and uniform seedlings were transplanted in the experimental plot in 23rd October, 2017 maintaining a spacing of 30 cm x 30 cm between the plants and rows, respectively. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

For marigold, salvia and dahlia

About 20-25 days old marigold, salvia and dahlia seedlings were transplanted in the experimental plots in 23rd October, 2017 maintaining a spacing of 30 cm x 30 cm between the plants and rows, respectively. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

Seeds of okra, bitter gourd, bottle gourd, pumpkin, amaranth and spinach

All this selected kharif-1 seeds were soaked in water for 24 hours and then wrapped with a piece of thin cloth. The soaked seeds were then spread over polythene sheet for 2 hours to dry out the surface water. This treatment was given to help quick germination of seeds. The seeds were sown in the rows of the raised bed on 20th April 2018. Row to row and plant to plant distance were maintained 30 cm and 30 cm, respectively. Two to three seeds were sown in each pit. Then the seeds were covered with fine soil by hand.

10.16 Intercultural operations

After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants, which are as follows:

a) Gap filling: When the seedlings were well established, the soil around the base of each seedling was pulverized. A few gaps filling was done by healthy seedlings of the same stock where initial planted seedling failed to survive.

b) Weeding: Weeding were accomplished as and whenever necessary to keep the crop free from weeds for better soil aeration and to break the crust.

c) Staking and Pruning: When the plants were well established, staking was given to each plant by bamboo sticks to keep them erect. Within a few days of staking, as the plants grew up, the plants were given a uniform moderate pruning.

d) Irrigation: Light irrigation was provided immediately after transplanting the seedlings and it was continued till the seedlings established in the field. Thereafter irrigation was provided as per when needed.

10.17 Harvesting: Harvesting was started from 15th January, 2018 and was continued up to 10 April 2018 for robi season crops based on different crops. Fruits were harvested through hand picking at tender and marketable stage. Kharif-1 crops harvesting was started from June, 2018- July, 2018 based on various crops.

10.18 Data collection

Three plants were selected randomly from each plot for data collection in such a way that the border effect could be avoided for the highest precision. Data on the different parameters were recorded from the sample plants during the course of experiment.

10.19 Data Analysis

The data were coded, categorized and fed in computer and analyzed using computer software packages MS Excel and SPSS (Statistical Package for Social Science) 22 versions. Quantitative data were analyzed by simple statistical tools such as frequency, mean, percentage and standard deviation and qualitative data were analyzed by ordering, ranking with descriptive manner. The impacts of various socio-economic factors such as education status, Occupation, surface area of roof garden, annual income of garden owners and the diversification of plant species with comparison of percent of plants present in roof garden and diversification present in roof top garden were analyzed by using SPSS. The results are presented through text, Tables, Graphical Figures and spatial distribution with interpretation accordingly

11. Results and discussion:

The survey results obtained from the present study on assessment of ecosystem services and benefits of rooftop gardening in Dhaka city were discussed in the results and discussion chapter. The first section deals with the four basic ecosystem services (provisioning, supporting, regulating and cultural) obtained from the qualitative and quantitative analysis while the second section deals with the selected individual

characteristics of the garden owners. The third section deals with the relationships between the garden owners selected characteristics with ecosystem services provided by the roof top gardens.

Part 1: Survey results and discussion (For satisfying objectives 1&2)

11.1. Provisioning services

Provisional services provided by rooftop gardens in the study area are food and fiber production particularly production of fruits and vegetables.

11.1.1 Provision of Food (Fruits and Vegetable)

The study result showed that seasonal fruits and vegetables were the major food produced from roof gardening. According to the survey, total 8 garden owners (20%) grow high food production which is more than 40kg/year and 21 of them (52.5%) grow 21-40 kg/year (medium) and 11 garden owners (27.5%) grow low production which is less than 20kg/year.

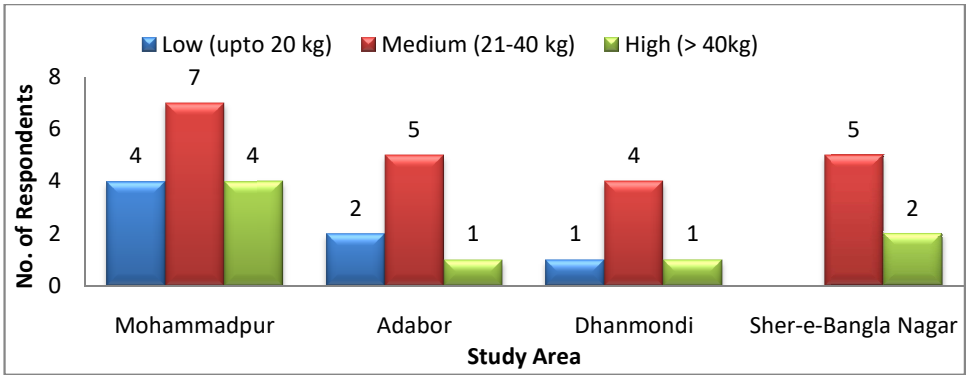

Figure 11.1: Yearly food production in the study area

High yearly food production (above 40kg) was mostly observed in Mohammadpur area which was found in 4 roof gardens followed by 2 roof gardens in Sher-e-Bangla Nagar and 1 in each of Adabor and Dhanmondi. Medium food production (21-40kg) was found in 7 roof gardens of Mohammadpur, 5 roof gardens of both Adabor and Sher-e-Bangla Nagar and 4 roof gardens of Dhanmondi. Yearly food production was found low (upto 20 kg) in 4 gardens of both Mohammadpur and Sher-e-Bangla Nagar followed by 2 gardens in Adabor and 1 in Dhanmondi. This distribution has been spatially shown in Figure 11.1.

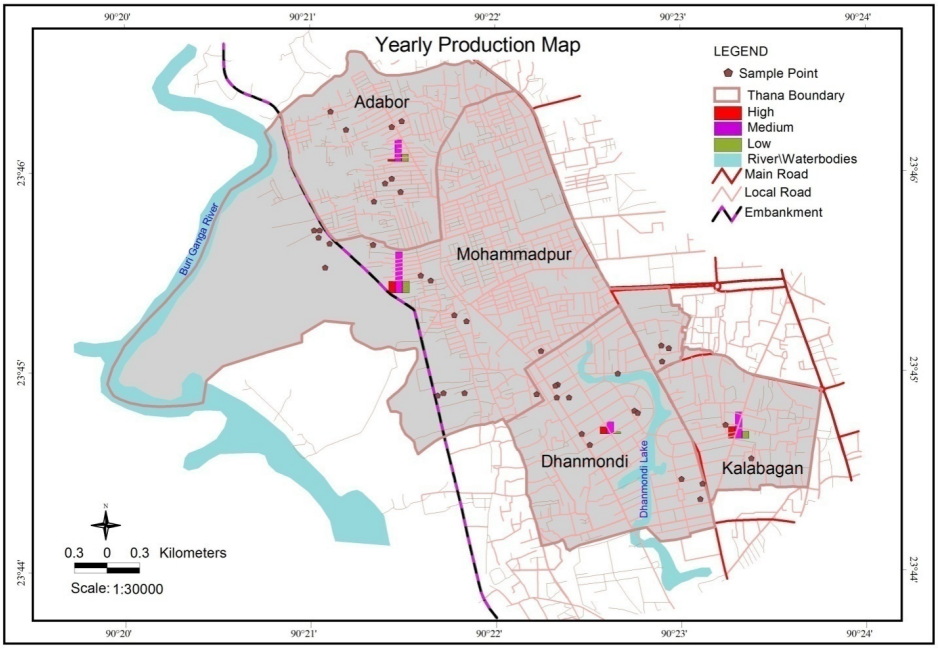

Figure 11.2: Spatial distribution of yearly food production across the study area

Spatial distribution shows that medium food production (21-40kg/year) was mostly found in all the four areas.

11.1.2. Regularity of food supply

The result revealed that most of the roof gardens in the study areas can meet up the food demand of the families in daily to weekly basis. 40% of the garden owners get daily food supply from their roof gardens, 45% get weekly food supply and only 15% get the food supply monthly.

Table 11.1: Distribution of garden owners according to regularity of food supply

Areas	Food Supply							
	High (Daily)		Medium (Weekly)		Low (Monthly)		Total	
	N	P(%)	N	P(%)	N	P(%)	N	P(%)
Mohammadpur	7	17.5	6	15	2	5	**15**	**37.5**
Adabor	2	5	5	12.5	1	2.5	**8**	**20**
Dhanmondi	1	2.5	4	10	1	2.5	**6**	**15**
Sher-e-Bangla Nagar	6	15	3	7.5	2	5	**11**	**27.5**
Total	**16**	**40**	**18**	**45**	**7**	**15**	**40**	**100**

11.2 Supporting service

11.2.1 Biodiversity and habitat conservation

11.2.1.1. Shannon diversity index

Shannon's index accounts for both abundance and evenness of the species present.

Table 11.2: Shannon diversity index in the study area:

Categories of Species	Grand total of each category	Relative abundance (Pi)	LN (Pi)	Pi*LN(Pi)
Fruit	1238	0.23	-1.46	-0.33
Vegetable	1695	0.32	-1.13	-0.36
Flower	791	0.15	-1.89	-0.28
Ornamental	963	0.18	-1.71	-0.308
Medicinal	564	0.108	-2.21	-0.23
Grand total	5251	1	**ΣPiLn(Pi)**	-1.51
				H'= -ΣPiln(Pi) 1.51
				e H' 4.51

The result revealed that Shannon-Weaver diversity index was found very high in the study area which was 4.51. Shannon's Diversity Index ranges from 0 to 5.

Typically the value of the index ranges from1.5 (low diversity) to 3.5 (high species diversity) in natural ecosystems, though values beyond the limits may has been countered (www.wikipedia.org). Each rooftop garden acts as an urban ecosystem unit where plants don't grow naturally rather the plant species are grown according to the gardener's own will. That is the reason behind the higher diversity index resulted in the study.

11.2.1.2. Species Richness

Table 11.3: Species Richness found in the study area

Categories of Species	Types of plants
Fruits	38
Vegetable	25
Flowers	40
Ornamental	32
Medicinal	15
Total	**150**

Almost all the roof top gardens had mixed vegetation with various annual and perennial trees and seasonal vegetables where 150 useful species were identified (Table 11.5, 11.6, 11.7, 11.8 and 11.9). Among them 38 species were fruits, 40 species were flowers, 25 species were vegetables, 32 species were ornamental and 15 species were medicinal which is shown in Table 11.3.

11.2.1.3. Inter-species Diversity

Species diversity index is a measure, which renders considerable ecological insight (Amin, 1997). Simpson index of species diversity (D) varied among the different groups of plant species. Inter-species diversity was found higher for Flowering plant species (0.988) in the roof garden of the study area followed by vegetable species (0.977), ornamental species (0.966), fruit species (0.944) and medicinal species (0.895).

Table 11.4: Interspecies diversity in the study area

Study areas	Fruits	Vegetables	Flowers	Ornamental	Medicinal	Average
Mohammadpur	0.885	0.887	0.883	0.904	0.812	0.874
Adabor	0.953	0.966	0.948	0.958	0.956	0.956
Dhanmondi	0.977	0.982	0.988	0.978	0.989	0.984
Sher-e-Bangla Nagar	0.912	0.879	0.896	0.883	0.933	0.901
Average	0.932	0.928	0.928	0.931	0.923	0.928
All	**0.944**	**0.977**	**0.988**	**0.966**	**.895**	

The result showed that diversity index varied with different plant species in different Thana area. The highest average inter-species diversity (0.984) was found in Dhanmondi area followed by Adabor (0.956) and Sher-e-Bangla Nagar (0.901) area. The lowest inter-species diversity was found in Mohammadpur area (0.874) where study area showed the moderate to higher inter-species diversity. This distribution has been spatially shown in Figure 11.4.

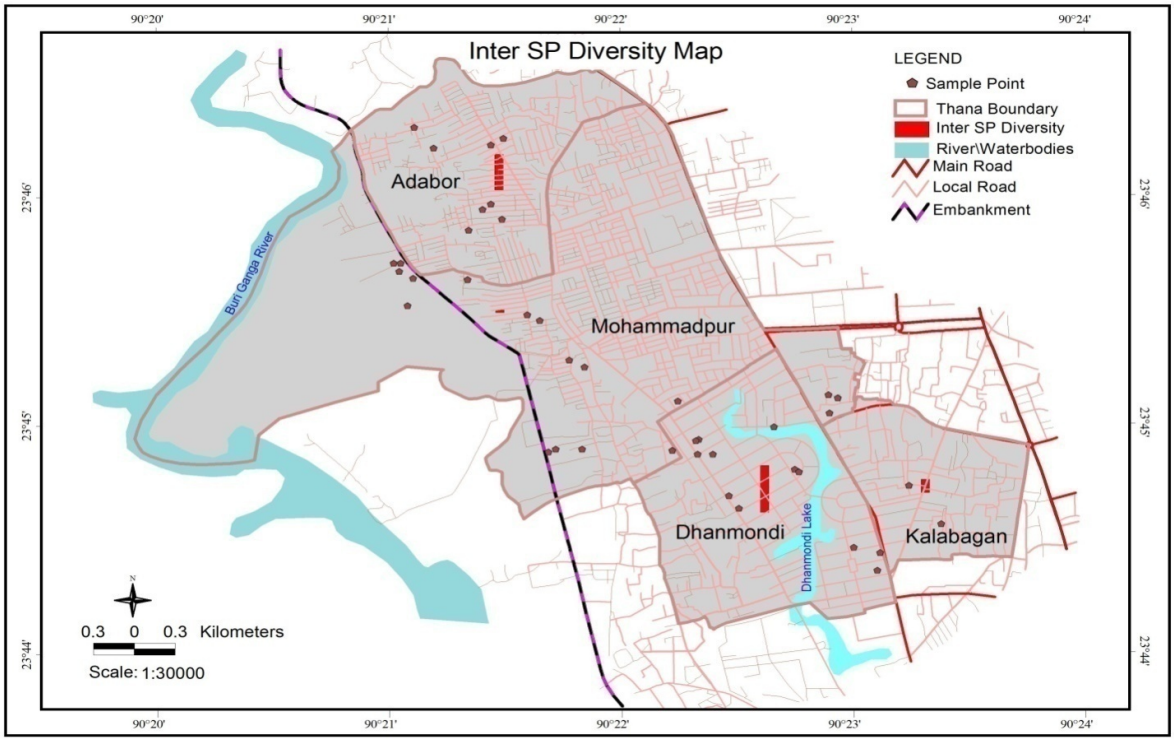

Figure 11.4: Spatial Distribution of inter species diversity across the study area

The spatial distribution shows that inter species diversity is found the highest in Dhanmondi, followed by Adabor, Sher-e-Bangla Nagar and Mohammadpur.

11.2.1.4. Relative prevalence and Density

Relative prevalence

The local name, scientific name, family name, habit and relative prevalence of 38 fruit species, 40 flower species, 25 vegetable species, 32 ornamental species and 15 medicinal species found in forty rooftop gardens of the study.

a) Fruit Species

Garden owners had different types of fruit species. Among them 35 fruit species were available in their garden where mango (127.1%) was found most prevalent and Passion fruit (9.02%) was found the lowest prevalent. On the basis of relative prevalence, mango, guava, Papaya, lebu and Jamrul were ranked in top position(Table 11.5).The result revealed that 38 fruit species were recorded under 33 genera and 23 families while 32 species were trees, 2 shrubs and 4 herbs in nature.

Table 11.5: Relative prevalence of fruit species with their local name, family name, genus, species and habit

Sl. No.	Local name	Family	Genus	Species	Habit	Relative prevalence
1	Mango	Anacardiaceae	*Mangifera*	*indica*	Tree	127.1
2	Guava	Moraceae	*Psidium*	*guajava*	Tree	114.6
3	Papaya	Caricaceae	*Carica*	*papaya*	Herb	113.5
4	lebu	Rutaceae	*Citrus*	*grandis*	Shrub	103.5
5	Jamrul	Myrtaceae	*Eugenia*	*javanica*	Tree	99.67
6	Kamrangha	Averrhoaceae	*Averrhoa*	*carambola*	Tree	76.44
9	Amloki	Euphorbiaceae	*Phyllanthus*	*embelica*	Tree	44.6
10	Billimbi	Averrhoaceae	*Averrhoa*	*bilimbi*	Tree	44.5
12	Lotkon	Phyllanthaceae	*Baccaurea*	*sapida*	Tree	40.11
13	Bael	Rutaceae	*Aegle*	*marmelos*	Tree	38.44
14	Malta	Rutaceae	*Citrus*	*sinensis*	Tree	34.1
15	Jalpai	Elaeocarpaceae	*Elaeocarpus*	*floribundus*	Tree	33.4
16	Lichu	Sapindaceae	*Litchi*	*chinensis*	Tree	30.1
17	Sofeda	Sapotaceae	*Achros*	*sapota*	Tree	28.88
18	Sarifa	Sapotaceae	*Chrysophyllum*	*cainito*	Tree	23.8
19	Kamala	Rutaceae	*Citrus*	*reticulata*	Tree	23.5
20	Ata	Annonaceae	*Annona*	*reticulata*	Tree	22.8
21	Khejur	Palmae	*Phoenix*	*sylvestris*	Tree	22.3
22	Rambutan	Sapindaceae	*Nephelium*	*lappaceum*	Tree	21.1
23	Banana	Musaceae	*Musa*	*sapientum*	Tree	21.0
24	koromcha	Apocynaceae	*Carissa*	*carandas*	Tree	19.6
25	Amra	Anacardiaceae	*Spondias*	*pinnata*	Tree	17.9
26	Kul	Rhamnaceae	*Zizyphus*	*mauritiana*	Tree	17.8
27	Naspati	Rosaceae	*Pyrus*	*communis*	Tree	17.7
28	Jambura	Rutaceae	*Citrus*	*grandis*	Tree	16.77
29	Dalim	Punicaceae	*Punica*	*granatum*	Shrub	15.99
30	Cherry	Rosaceae	*Prunus*	*avium*	Tree	13.8
31	Tentul	Caesalpiniaceae	*Tamarindus*	*indica*	Tree	13.3
32	Arboroi	Euphorbiaceae	*phyllanthus*	*acidus*	Tree	13.1
33	Kothbel	Rutaceae	*Feronia*	*limonia*	Tree	12.44
34	Straw berry	Rosaceae	*Fragaria*	*ananassa*	Herb	12.05
35	Panifol	Lythraceae	*Trapa*	*bicornis*	Herb	11.23
36	Kanthal	Moraceae	*Artocarpus*	*heterophyllus*	Tree	10.2
37	Passion fruit	Passifloraceae	*Passiflora*	*edulis*	Tree	9.02
38	Dragan Fruit	Cacteceae	*Hylocereus*	*undatus*	Herb	9.73
Total=38		Family=23	Genus=33			

b) Flower Species

Various flower species were found in the study area. Among 40 flower species, Beli (115.7%) was found most prevalent and Bottle Brush (24.1%) was found the lowest prevalent. On the basis of relative prevalence, beli, Baganbilash, Rangan, Musanda and Nayantara were ranked in top position (Table 11.6). The result indicated that 40 flower plants species were recorded fewer than 37 genera and 22 families while 8, 15, 15 and 2 species were found as trees, shrubs, herbs and climbers, respectively.

Table 11.6: Flower plant species with their Local name, family name, genus, species, habit and relative prevalence

Sl. No.	Local name	Family	Genus	Species	Habit	Relative prevalence
1	Beli	Oleaceae	*Jasminum*	*sambac*	Shrub	115.7
2	Baganbilash	Nyctaginacea	*Bougainvillea*	*grabra*	Climber	114.8
3	Rangan	Rubiaceae	*Ixora*	*singaporensis*	Shrub	113.6
4	Musanda	Apocynaceae	*Musanda*	*sp.*	Tree	112.4
5	Nayantara	Apocynaceae	*Vinca*	*rosea*	Herb	111.1
6	Allamonda	Apocynaceae	*Allamanda*	*cathartica*	Shrub	109.3
7	Joba	Malvaceae	*Hibiscus*	*rosa sinensis*	Shrub	109.1
8	Rose	Rosaceae	*Rosa*	*sp.*	Shrub	101.2
9	Orchid	Orchidaceae	*Orchis*	*Sp.*	Herb	100.6
10	Malotilota	Combretaceae	*Combretum*	*indicum*	Vine	100.2
11	Chondro mollika	Oleaceae	*Jasminum*	*angustifolium*	Tree	98.2
12	Togor	Apocynaceae	*Tubernaemontana*	*divaricata*	Shrub	98.1
13	Hasnahenna	Solanaceae	*Cestrum*	*nocturnum*	Shrub	95.6
14	Petunia	Solanaceae	*Petunia*	*hybrida*	Herb	92.4
15	Gerbera	Asteraceae	*Gerbera*	*Sp.*	Herb	90.7
16	Kolaboti	Cannaceae	*Canna*	*indica*	Herb	88.1
17	Lily	Liliaceae	*Lilium*	*lanciflorum*	Herb	81.8
18	Ganda	Asteraceae	*Asteroideae*	*Sp.*	Herb	79.7
19	Dahlia	Asteraceae	*Dahlia*	*pinnata*	Shrub	77.5
20	Oporajita	Fabaceae	*Clitoria*	*ternatea*	Vine	68.1
21	Dolonchapa	Zingiberaceae	*Hedychium*	*coronarium*	Shrub	67.3
22	Euphorbia	Euphorbiaceae	*Euphorbia*	*Sp.*	Herb	66.6
23	Shondhamaloti	Nyctaginaceae	*Mirabilis*	*jalapa*	Climber	63.7
24	Radhachura	Fabaceae	*Caesalpinia*	*pulcherrima*	Tree	62.7
25	Krishnacura	Fabaceae	*Delonyx*	*rejia*	Tree	56.1

26	Kamini	Rutaceae	*Murraya*	*exotica*	Shrub	55.7
27	Sheuli	Oleaceae	*Nyctanthes*	*Arbor-tristis*	Tree	50.9
28	Bakul	Sapotaceae	*Mimosops*	*elengi*	Tree	48.7
29	Chrysanthemum	Asteraceae	*Crysanthemum*	*indicum*	Herb	45.6
30	Lojjaboti	Fabaceae	*Mimosa*	*pudica*	Bush	44.7
31	Gondhoraj	Rubiaceae	*Neolamarckia*	*cadamba*	Shrub	41.2
32	Kanur	Nymphaeaceae	*Nerium*	*indicum*	Herb	40.8
33	Gladiolous	Iridaceae	*Gladiolous*	*communis*	Herb	38.7
34	Sonalu	Fabaceae	*Cassia*	*fistula*	Tree	37.4
35	Kolke	Apocynaceae	*Cascabela*	*peruviana*	Shrub	36.5
36	Shapla	Nymphaeaceae	*Nymphaea*	*Nouchali*	Herb	35.2
37	Nilpoddo	Nymphaeaceae	*Nymphaea*	*Sp.*	Herb	35.1
38	Hydranjea	Hydrangiaceae	*Hydrangea*	*arborescens*	Shrub	33.4
39	Nightqueen	Solaneceae	*Cestrum*	*nocturnum*	Shrub	25.3
40	Bottle Brush	Myrtaceae	*Callistemon*	*Sp.*	Tree	24.1
Total=40		Family=22	Genus=37			

c) Vegetable Species

All the garden owners grow seasonal vegetables for their daily consumption. Out of 25 vegetable species, Egg plant (132.6%) was found in most prevalent and Sharisha shak (31.1%) was found in lowest prevalent. On the basis of relative prevalence, Egg plant, Lau, Tomato, Korolla and Dherosh were ranked in top position (Table 11.7). The result revealed that 25 vegetable plant species were recorded under 21 genera and 11 families with 1, 1, 14 and 9 species were found as trees, shrubs, herbs and climbers, respectively.

Table 11.7: Vegetable species with their local name, family name, genus, species, habit and relative prevalence

Sl. No.	Local name	Family	Genus	Species	Habit	Relative prevalence
1	Egg plant	Solanaceae	*Solanum*	*melongena*	Shrub	132.6
2	Lau/kadhu	Cucurbitaceae	*Lagenaria*	*siceraria*	Climber	130.8
3	Tomato	Solanaceae	*Lucopersicon*	*esculentum*	Herb	125.7
4	Korolla	Cucurbitaceae	*Momordica*	*acutangula*	Climber	116.5
5	Dherosh	Malvaceae	*Abelmoschus*	*esculentus*	Shrub	115.8
6	morich	Solanaceae	*Capsicum*	*annum*	Herb	115.2
7	Puishak	Basellaceae	*Basella*	*alba*	Herb	114.9
8	Lettuce	Compositae	*Lactuca*	*sativa*	Herb	102.3
9	Sheem	Fabaceae	*Lablab*	*purpureus*	Climber	101.7

10	Mistikumra	Cucurbitaceae	*Luffa*	*charantia*	Climber	88.5
11	Kakrol	Cucurbitaceae	*Momordica*	*dioica*	Climber	79.4
12	Shajna	Moringaceae	*Moringa*	*oleifera*	Tree	78.3
13	Dhundul	Cucurbitaceae	*Luffa*	*cylindrica*	Climber	77.9
14	Naga morich	Solanaceae	*Capsicum*	*chinense*	Herb	75.8
15	Borboti	Fabaceae	*Vigna*	*unguiculata*	Climber	74.4
16	Chalkumra	Cucurbitaceae	*Benincasa*	*hispida*	Climber	72.1
17	MukhiKachu	Araceae	*Colocasia*	*esculenta*	Herb	70.3
	Dudh Kachu	Araceae	*Xanthosoma*	*violaceum*	Herb	68.3
18	Potol	Cucurbitaceae	*Trichossanthes*	*dioica*	Climber	67.9
19	Lalshak	Amaranthaceae	*Amaranthus*	*tricolor*	Herb	66.3
20	Danta shak	Amaranthaceae	*Amaranthus*	*lividus*	Herb	63.7
21	Capsicum	Solanaceae	*Capsicum*	*sp.*	Herb	60.1
22	Shosha	Cucurbitaceae	*Cucumis*	*sativus*	Herb	44.8
23	Fulkopi	Brassicaceae	*Brassica*	*Campestris*	Herb	33.4
24	Badhakopi	Brassicaceae	*Brassica*	*oleracea*	Herb	33.3
25	Sarisha shak	Brassicaceae	*Brassica*	*Sp.*	Herb	31.1
Total=25		Family=11	Genus=21			

d) Ornamental Species

Out of 32 ornamental species, Croton (110.1%) was found in most prevalent and King Sago Palm (41.3%) was found in lowest prevalent. On the basis of relative prevalence, Croton, Pathos(Money plant), Cactus and Spider plant were ranked in top position (Table 11.8). The result indicated that 32 ornamental plant species were recorded under 31 genera and 22 families with 7were trees, 15 shrubs, 9 herbs and 1 climber in nature.

Table 11.8: Ornamental species with their local name, family name, genus, species, habit and relative prevalence

Sl. No.	Local name	Family	Genus	Species	Habit	Relative prevalence
1	Croton	Euphorbiaceae	*Croton*	*Sp.*	Shrub	110.1
2	Pathos	Araceae	*Epipremnum*	*aureum*	Climber	109.7
3	Cactus	Cactae	*Cactus*	*sp*	Herb	105.6
4	Spider	Liliacea	*Cholophytum*	*comosum*	Herb	100.7
5	Areca Palm	Arecaceae	*Dypsis*	*lutescens.*	Shrub	99.8
6	Arrowhead	Alismataceae	*Sagittaria*	*Latifolia*	Herb	99.7
7	Snake plant	Asparagaceae	*Sansevieria*	*trifasciata*	Shrub	99.0
8	Dracaena	Liliacea	*Dracaena*	*merginata*	Shrub	97.5
9	Fern	Polypodiaceae	*Pteris*	*sp.*	Herb	97.3
10	Phylodendron	Araceae	*Phylodendron*	*Sp.*	Shrub	98.3
11	Duranta	Verbenaceae	*Duranta*	*repens*	Shrub	98.1
12	Christmas tree	Araucariaceae	*Araucaria*	*excelsa*	Tree	97.6

13	Thuja	Pinaceae	*Thuja*	*orientalis*	Shrub	96.7
14	Blood leaf	Amaranthaceae	*lindenii*	*Iresine*	Shrub	95.4
15	Ribbon plant	Liliaceae	*Dracaena*	*sanderiana*	Shrub	94.6
16	Cycus	Cycadaceae	*Cycus*	*circunalis*	Shrub	92.8
17	Lantana	Verbenaceae	*Lantana*	*camara*	Shrub	91.7
18	Purple heart	Commelinaceae	*Tradescantia*	*pallida*	Herb	91.2
19	Chinese Evergreen	Araceae	*Aglaonema*	*Sp.*	Shrub	90.7
20	Aralia	Araliaceae	*Aralia*	*Sp.*	Shrub	88.3
21	Cyperus	Cyperaceae	*Cyperus*	*rotundus*	Herb	81.4
22	Cast iron	Asparagaceae	*Aspidistra*	*elatir*	Herb	80.3
23	Garnet robe	Lamiaceae	*Solenostemon*	*scutellarioides*	Herb	78.5
24	Ficus	Moraceae	*Ficus*	*benjamina*	Tree	77.4
25	Peace Lily	Araceae	*Spathiphyllum*	*wallisii*	Herb	75.1
26	Monstera	Araceae	*Monstera*	*deliciosa*	Tree	67.3
27	Soft Succulents	Crassulaceae	*Echeveria*	*Sp.*	Herb	61.9
28	Jade plant	Crassulaceae	*Crassula*	*Sp.*	Herb	54.3
29	Rhapis palm	Arecaceae	*Rhapis*	*excelsa*	Shrub	
30	Chinese Bamboo	Poaceae	*Bambusa*	*Sp.*	Herb	50.3
31	Cardboard palm	Zamiaceae	*Zamia*	*furfuracea*	Tree	46.7
32	King Sago Palm	Cycadaceae	*Cycas*	*Revolute*	Tree	41.3
Total=32		Family=22	Genus=31			

e) Medicinal Species

Out of 15 medicinal species, Henna (113.4) was found most prevalent and Clove (23.4) was found the lowest prevalent. On the basis of relative prevalence, Henna, Pudina, Dhonia, Tulsi and Aloevera were ranked in top position (Table 11.9). The result showed that 10 medicinal plant species were recorded under 13 genera and 13 families with 1 were climber, 5 were herbs, 4 was shrub and 5 were trees in nature.

Table 11.9: Medicinal species with their local name, family name, genus, species, habit and relative prevalence

Sl. No.	Local name	Family	Genus	Species	Habit	Relative prevalence
1	Henna	Lythraceae	*Lawsonia*	*inermis*	Tree	113.4
2	Pudina	Labiatae	*Mentha*	*spicata*	Herb	112.9
3	Dhonia	Apiaceae	*Coriandum*	*sativum*	Herb	110.2
4	Tulsi	Labiatae	*Ocimum*	*sactum*	Shrub	107.3
5	Alovera	Liliacieae	*Aloe*	*barbadensis*	Herb	106.6
6	Neem	Meliaceae	*Azadirachta*	*indica*	Tree	99.5
7	Gainura	Asteraceae	*Gainura*	*procimbens*	Climber	95.8
8	Thankuni	Umbelliferae	*Centella*	*asiatica*	Herb	88.2
9	Patharcuchi	Crassulaceae	*Kalanchae*	*pinnata*	Herb	85.6
10	Basok	Acanthaceae	*Adhtoda*	*vasica*	Shrub	63.7
11	Tejpata	Lauraceae	*Cinnamomum*	*tamala*	Tree	59.8
12	Long pepper	Piperaceae	*Piper*	*longum*	Tree	42.7
13	Cinnamon	Lauraceae	*Cinnamomum*	*verum*	Tree	32.6
14	Tokma seed	Lamiaceae	*Ocimum*	*basilicum*	Shrub	28.8
15	Clove	Myrtaceae	*Syzygium*	*aromaticum*	Shrub	23.4
Total=15		Family=13	Genus=13			

Species Density:

Plant density is important factor to supply ecosystem services. Higher density of fruits and vegetable plants will give higher provision of food. Higher density of flowering and ornamental plants will provide higher aesthetic value. Similarly, higher medicinal plants density indicates higher disease regulation.

Table 11.10: Density of plants with frequency and percentage found in the survey

No. of Plants	Fruits		Vegetables		Flowers		Ornamental Plants		Medicinal Plants	
	N	P(%)	N	P(%)	N	P(%)	N	P(%)	N	P(%)

Low(1-20)	8	20	9	22.5	15	37.5	22	55	30	75
Medium (21-50)	26	65	17	42.5	18	45	11	27.5	9	22.5
High (51-100)	5	12.5	9	22.5	5	12.5	5	12.5	1	2.5
Very high (>100)	1	2.5	5	12.5	2	5	2	5	0	0
Total	**40**	**100**	**40**	**100**	**40**	**100**	**40**	**100**	**40**	**100**

According to the survey, very high density of (above 100) fruits, vegetables, flowers and ornamental plants were found in 2.5%, 12.5%, 5% and 5% roof gardens respectively while medicinal plants over 100 was not found. 51 to 100 plants of fruits, vegetables, flowers, ornamentals and medicinal were found in 12.5%, 22.5%, 12.5%, 12.5% and 2.5% roof gardens, respectively. 21 to 50 plants of fruits, vegetables, flowers, ornamentals and medicinal plants were found in 65%, 42.5%, 45%, 27.5% and 22.5% roof gardens respectively. Low density (1-20) plants of fruits, vegetables, flowers, ornamentals and medicinal were found in 20%, 22.5%, 37.5%, 55% and 75% roof gardens, respectively.

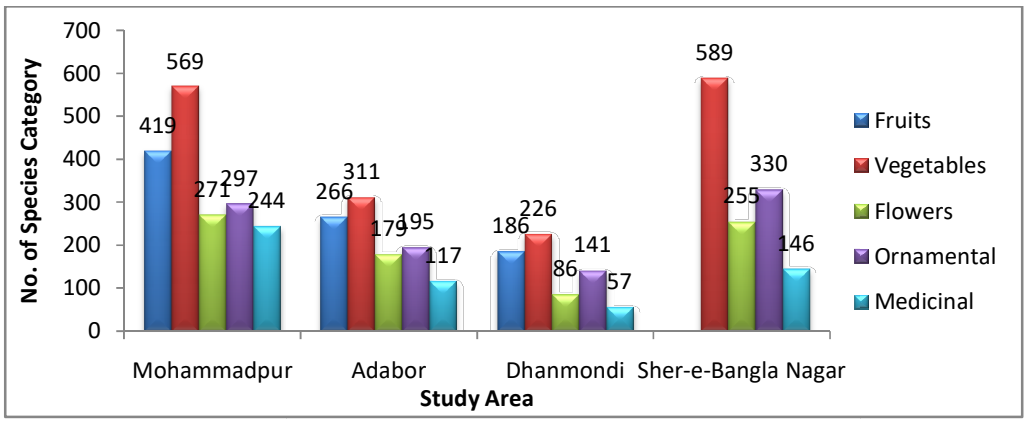

Figure 11.4: Total number of plants of each category found in the study area

The highest number of fruits were found in Mohammadpur (419) followed by Sher-e-Bangla Nagar (367), Adabor (266) and Dhanmondi (186). The highest number of vegetables were found in Sher-e-Bangla Nagar (589), followed by Mohammadpurr (569), Adabor (311) and Dhanmondi (226). The highest number of flowering plants (271) were found in Mohammadpur, followed by Sher-e-Bangla Nagar (255), Adabor (179) and Dhanmondi (86). The highest number of ornamental plants (330) were found in Sher-e-Bangla Nagar followed by Mohammadpur (297), Adabor (195) and Dhanmondi (141). The highest number of medicinal plants were found in Mohammadpur (244), followed by Sher-e-Bangla Nagar (146), Adabor (117) and Dhanmondi (57). This distribution has been spatially shown in Figure 11.4.

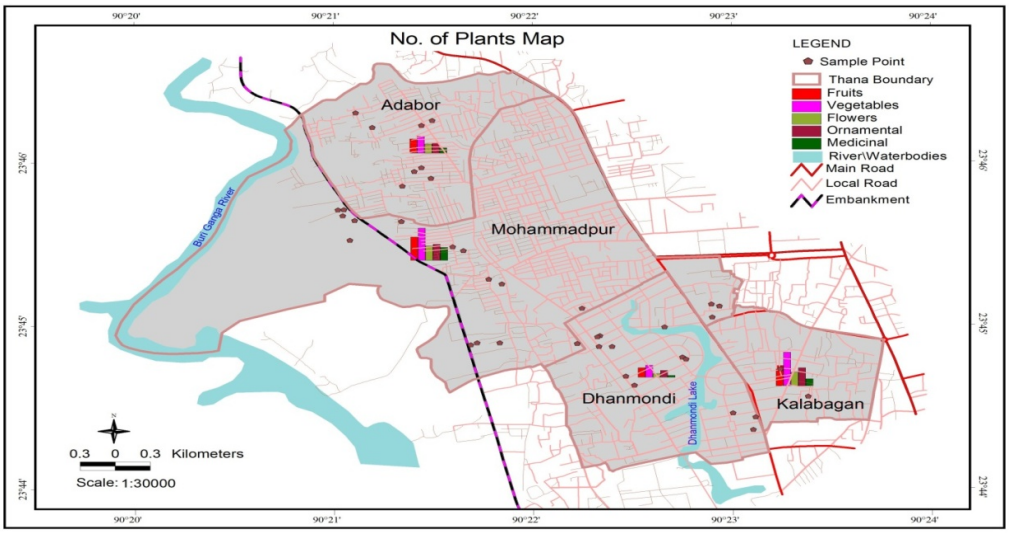

Figure 11.5: Spatial distribution of total no. of plant species of each category across the study area

According to spatial distribution it can be seen that vegetables are mostly grown(1695) in all the four thanas, followed by fruits (1238), Ornamental (963), flowering (791) and medicinal plants (564).

11.2.1.5. Plant species diversity across the study area

Plant species diversity of the garden owners in the study area were ranged from 0 to above 5 which was shown in Table 11.2.

Shannon's index accounts for both abundance and evenness of the species present. The proportion of species *i* relative to the total number of species (*pi*) is calculated, and then multiplied by the natural logarithm of this proportion (ln *pi*). The resulting product is summed across species, and multiplied by -1.

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

H' = the Shannon-Weaver Diversity Index

But the S-W index is usually expressed as ***eH'***

Table 11.11: Distribution of the garden owners according to their plant species diversity

Areas	Floral species diversity							
	Low (0-2)		Medium (2.1-3.5)		High (>3.5)		Total	
	N	P(%)	N	P(%)	N	P(%)	N	P(%)
Mohammadpur	0	0	3	7.5	12	30	**15**	**37.5**
Adabor	0	0	2	5	6	15	**8**	**20**

Dhanmondi	0	0	2	5	4	10	**6**	**15**
Sher-e-Bangla Nagar	1	2.5	2	5	8	20	**11**	**27.5**
Total	**1**	**2.5**	**9**	**22.5**	**30**	**75**	**40**	**100**

The result showed that 75% percent garden owners had high plant species diversity while 22.5% percent garden owners had medium plant species diversity and only 2.5% roof garden was found to have low diversity.

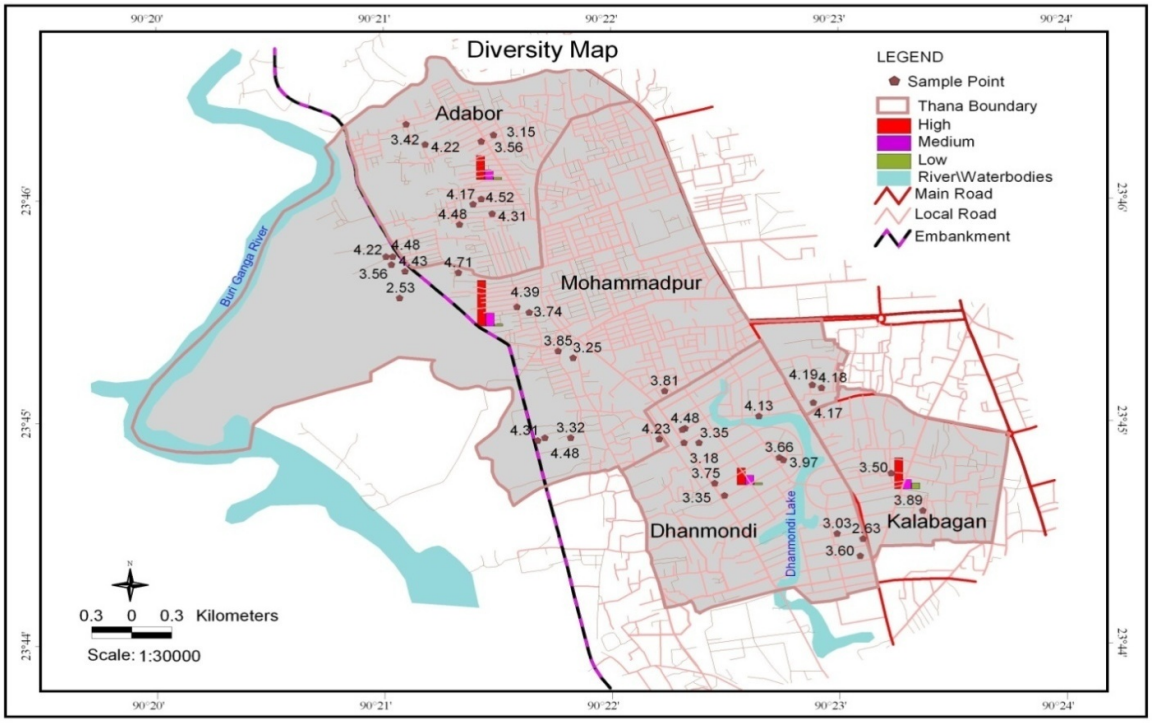

Figure 11.6: Spatial distribution of floral diversity of the roof gardens across the study area

According to spatial distribution the highest diversity was found in Mohammadpur, followed by Sher-e-Bangla Nagar, Adabor and Dhanmondi. The survey revealed that high plant species diversity (above 3.5) was found in 30% roof garden in Mohammadpur area followed by Sher-e-Bangla Nagar (20%), Adabor (15%) and Dhanmondi (10%). Medium species diversity (2.1-3.5) was found in 7.5% roof garden in Mohammadpur area 5% of roof garden in the rest of the study areas. Only 1 roof gaden (2.5%) was found to have low diversity (0-2) in Sher-e-Bangla Nagar area.

11.3. Economic Support

11.3.1. Marketing of the produce

Table 11.12: Distribution of garden owners according to their involvement in marketing

Areas	Involvement in marketing	Total

	Involved		Not involved			
	N	P(%)	N	P(%)	N	P(%)
Mohammadpur	**1**	2.5	14	35	15	37.5
Adabor	**1**	2.5	7	17.5	8	20
Dhanmondi	0	0	6	15	6	15
Sher-e-Bangla Nagar	**1**	2.5	10	25	11	27.5
Total	**3**	**7.5**	37	92.5	40	100

Survey revealed that generally very few people consider rooftop gardening commercially to get profit. Among 40 respondents, only 3 of them from Mohammadpur, Adabor and Sher-e-Bangla Nagar were found to be involved in marketing of their produce. Gardeners sell their surplus products sporadically in different local markets, directly or through intermediaries, with no uniform pricing system.

11.3.2. Relation between yearly expenditure and yearly food production

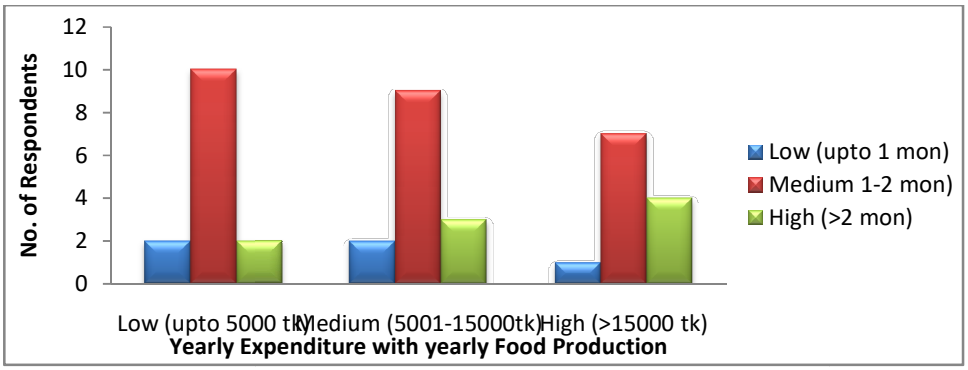

Figure 11.7: Yearly Expenditure with Yearly Food Production

Comparing yearly expenditure with yearly production it was found that with low investment 2 garden owners could yield low production/year, 10 of them could yield medium production while 2 of them could yield high production/year. With medium expenditure 2 garden owners grew low production, 9 grew medium production and 3 of them had high production/year. With high expenditure, 8 garden owners grew medium production and 4 of them grew high production/year. This comparison indicates that the garden owners can yield medium to high production even with low to medium expenditure.

11.3.3. Employment opportunities

Survey revealed that Rooftop gardening practice can generate employment in society to a satisfactory level. The result showed that 50% garden owner recruited well paid gardener for nursing their garden and 25%

garden owner had family paid personnel or extra paid made servant while 20% roof gardens were nursed by the family members of the garden owners

Table 11.13: Distribution of garden owners according to nursing

Areas	Nursing							
	Family members		Family paid personnel		Gardener		Total	
	N	P(%)	N	P(%)	N	P(%)	N	P(%)
Mohammadpur	5	12.5	3	7.5	7	17.5	**15**	**37.5**
Adabor	2	5	2	5	4	12.5	**8**	**20**
Dhanmondi	0	0	2	5	4	7.5	**6**	**15**
Sher-e-Bangla Nagar	3	7.5	3	7.5	5	10	**11**	**27.5**
Total	**10**	**20**	**10**	**25**	**20**	**50**	**40**	**100**

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Among the four study areas, nursing by well paid gardener was found in 7 roof gardens in Mohammadpur, 5 roof garden in Sher-e-Bangla Nagar and 4 roof garden in each Adabor and Dhanmondi. Nursing by family paid personnel was found in 3 roof gardens of Mohammadpur and Sher-e-Bangla Nagar and 2 roof gardens in Adabor and Dhanmondi. This distribution has been spatially shown in Figure 11.13.

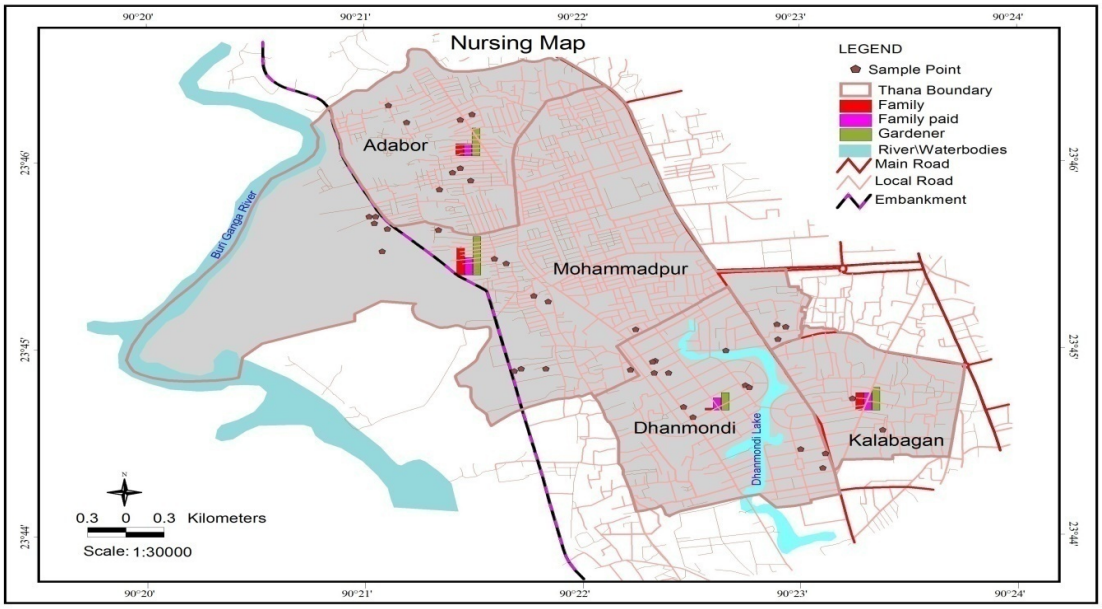


Figure 11.8: Spatial distribution of nursing categories across the study area

The spatial distribution shows that nursing by gardeners and family paid personnel is a common phenomenon in all the four areas. Nursing by family members were found the lowest in Dhanmondi than the other areas.

11.4. Regulating Service

11.4.1. Thermal regulation

11.4.1.1 Quantitative analysis of thermal regulation

There are four parameters of thermal performance:

1. Temperature
2. Humidity
3. Wind velocity and
4. Solar radiation.

The most commonly used indicator of thermal comfort is air temperature and relative humidity. It is easy to use and most people can relate to it. The thermal performance of roof top greenery and bare roof was compared to identify the ability of the green roof in reducing the indoor and outdoor air temperature of the high-rise building and the surrounding environmental effects on micro climate of the ambient environment. The result is analyzed by comparing the ambient air temperature and relative humidity. A scanned copy of the Thermo-hygrograph reading containing indoor and outdoor temperature and RH has been given in Plate 1&2.

a) Outdoor Thermal performance

i) Temperature:

The thermal performance result of the environment on this research concludes that greenery contributes thermal benefit to both micro climates of the roof environment and surrounding outdoor ambient environment of the building. It is found that the average roof air temperature is reduced by 5.2°C with green roof during sunshine hours.

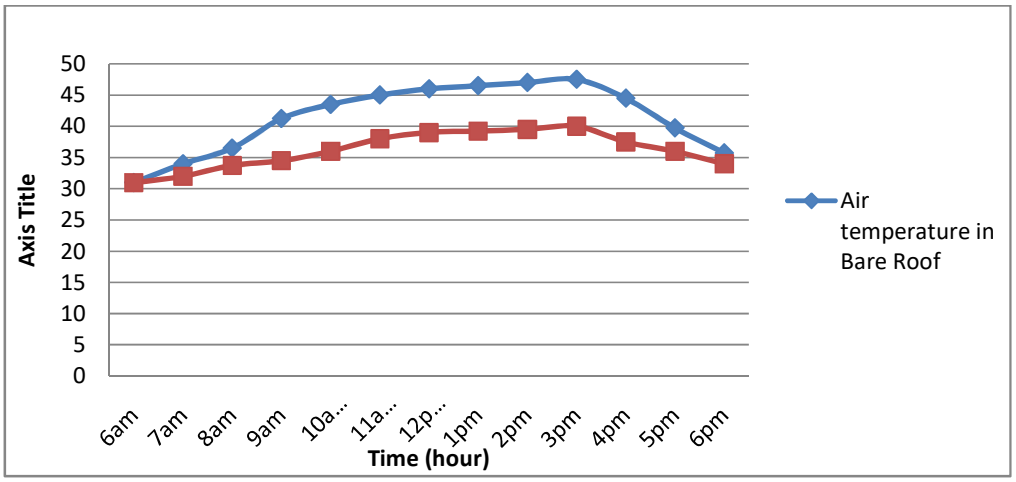


Figure 11.9: Air Temperature with Roof Garden and Without Roof Garden

However the reduction of air temperature follows a pattern. A maximum reduction of temperature is observed during peak heating period of 2pm to 3:30pm and minimum reduction occurs during in off sunshine period.

ii) Relative Humidity

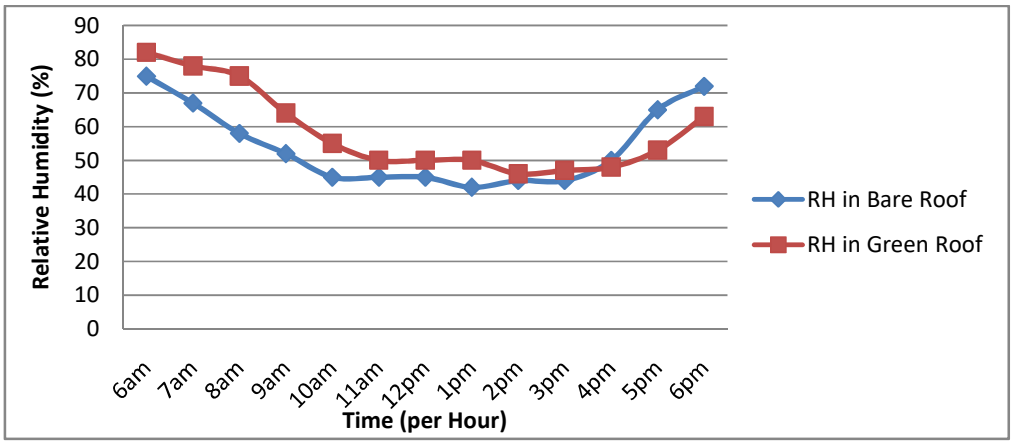


Figure 11.10: Relative Humidity with Roof garden and Without Roof Garden

It was found that the RH reading in bare roof was lower than the RH reading in roof garden for most of the time in a day. The RH reading was more or less similar from 2pm to 4pm in both roof garden and bare roof.

b) Indoor thermal performance

i) Temperature:

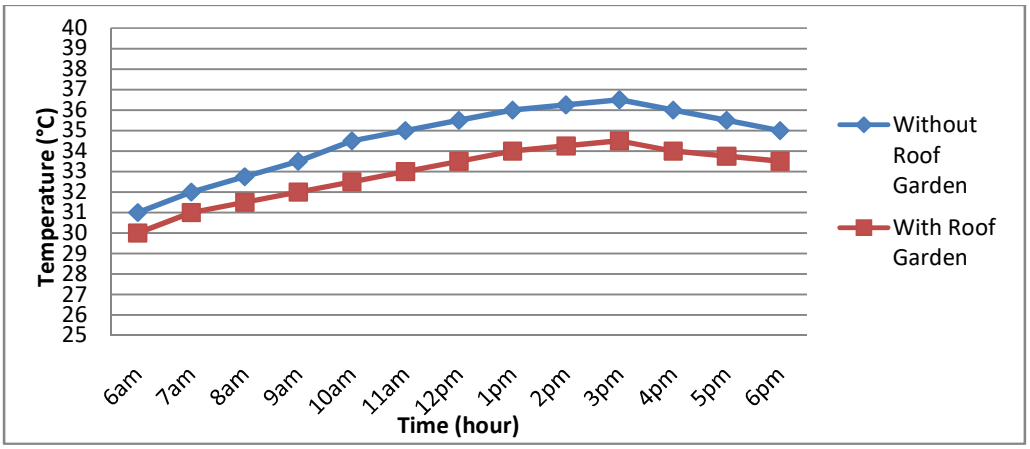


Figure 11.11: Indoor Temperature with Roof Garden and Without Roof Garden

It was found that the average indoor air temperature was reduced by 1.7°C with an extensive roof garden from 6am to 6pm. Daily average indoor air temperature is 34.6°C with bare roof. This is reduced by 1.7°C with roof garden, thereby reducing the average indoor air temperature to 32.8°C

ii) Relative Humidity:

It was found that the average indoor RH was more or less similar in both rooms under roof garden and bare roof until 11 am. The RH of the room under bare roof started to fall from 12 pm to 3pm from 60% to 45% while the RH of the room under roof garden was 55% at 1 pm. Moreover, the RH fluctuation was higher in the room under bare roof.

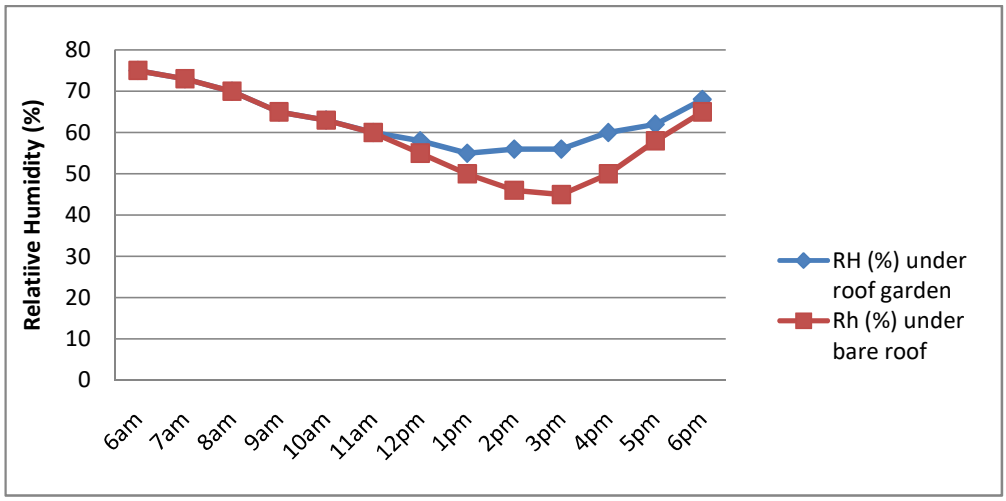


Figure 11.12: Indoor RH (%) with Roof Garden and Without Roof Garden

comfort zone analysis for Bangladesh according to Sharma, Ali and Mallick (1995) during the summer season, the comfort temperature range is between 24 ºC to 32 ºC while relative humidity range is fixed in 50% (lower limit) to 90% (upper limit). According to the graph profile the indoor temperature of the residence shows that maximum hour of the day is stay within comfort temperature range. It is a desirable condition for the resident.

11.4.1.2. Qualitative analysis of thermal regulation

Table 11.14: Distribution of garden owners according to thermal comfort

Areas	Thermal comfort								Total	
	High		Medium		Low		Not at all			
	N	P(%)	N	P(%)	N	P(%)	N	P(%)	N	P(%)
Mohammadpur	4	10	6	15	5	12.5	0	0	**15**	**37.5**
Adabor	1	2.5	4	10	2	5	1	2.5	**8**	**20**
Dhanmondi	1	2.5	4	10	1	2.5	0	0	**6**	**15**
Sher-e-Bangla Nagar	6	15	3	7.5	1	2.5	1	2.5	**11**	**27.5**

Total	**12**	**30**	**17**	**42.5**	**9**	**22.5**	**2**	**5**	**40**	**100**

Qualitative analysis of thermal comfort was assessed using a semi-structured open questionnaire. Each respondent were asked about their personal thermal comfort with given choices. The result revealed that 30% roof garden provide high thermal comfort while 42.5% roof garden provide medium thermal comfort followed by 22.5% low thermal comfort and 5% provide no thermal comfort at all.

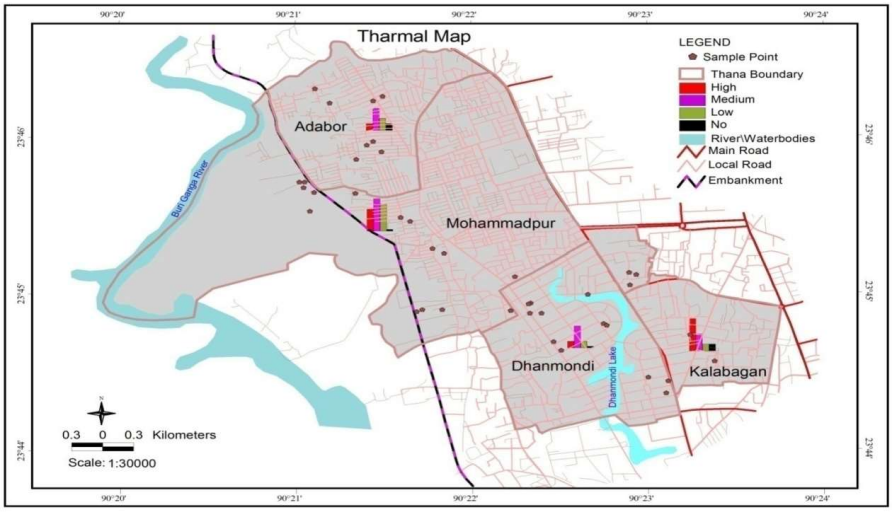


Figure 11.13: Spatial Distribution of Thermal Comfort of Across the Study Area

Among the four study areas, high thermal comfort was found in 15 roof garden in Sher-e-Bangla Nagar, followed by 10 roof garden in Mohammadpur and 1 roof garden in Adabor and Dhanmondi. Medium thermal comfort was found in 6 roof garden in Mohammadpur, followed by 4 roof garden in Adabor and Dhanmondi and 3 roof garden in Sher-e-Bangla Nagar. Low thermal comfort was found in 5 roof garden in Mohammadpur, followed by 2 roof garden in Adabor and 1 roof garden in Dhanmondi and Sher-e-Bangla Nagar. No thermal comfort was found in 1 roof garden of Adabor and 1 of Sher-e-Bangla Nagar. This distribution has been spatially shown in Figure 11.14.

11.4.1.3. Thermal comfort with vegetation coverage

Figure 11.14: Relationship between thermal comfort and vegetation coverage

Figure shows the relationship between vegetation coverage and thermal comfort, where the findings showed that Thermal comfort is proportional to vegetation coverage. Higher thermal comfort was mostly found in the roof gardens with high vegetation coverage.

11.4.1.4. Thermal comfort with Species diversity

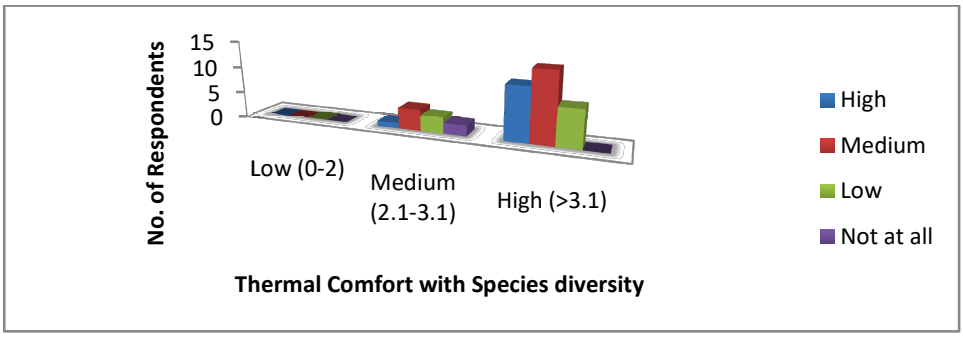


Figure 11.15: Relationship between thermal comfort and species diversity

Figure shows the relationship between plant species diversity and thermal comfort, where the findings showed that Thermal comfort is proportional to plant species diversity. The higher the plant species diversity the higher the thermal comfort is.

11.5. Disease Regulation

According to the survey the gardeners grew 564 number of 15 different species of medicinal plants (Table 11.9) which provide the gardeners' families with necessary health support and help in common disease regulation periodically.

11.6. Cultural Service

11.6.1. Aesthetics

According to the survey the 40 different flower species (Table 11.6) and 32 different ornamental plant species (Table 11.8) were found which contribute to the aesthetics of the roof area of the growers and create a platform for recreation and leisure time activity, improve psychological health and spiritual strength.

11.6.2. Frequency of Visit

The frequency of visiting the roof garden by the gardener and his family members is an indicator of recreation or leisure time activity which is an important factor of psychological health and thus considered as cultural service of RTG.

Table 11.15: Distribution of garden owners according to their frequency of visiting the roof garden

Category	Areas								Total	
	Mohammadpur		Adabor		Dhanmondi		Sher-e-Bangla Nagar			
	N	P(%)	N	P(%)	N	P(%)	N	P(%)	N	P(%)
Daily	12	30	7	17.5	6	15	7	17.5	**32**	**80**
Weekly	2	5	1	2.5	0	0	4	10	**7**	**17.5**
Monthly	1	2.5	0	0	0	0	0	0	**2**	**2.5**
Total	**15**	**37.5**	**8**	**20**	**6**	**15**	**11**	**27.5**	**40**	**100**

The survey revealed that 32 (80%) roof gardens are visited daily while 7 (17.5%) roof gardens are visited weekly and only 1 (2.5%) roof garden is visited monthly.

11.6.3. **Time spent**

The time spent by the gardener and his family members is an indicator of recreation or leisure time activity which is an important factor of psychological health and thus considered as cultural service of RTG. The result showed that 22.5% garden owners spend upto 1 hour for gardening activities while 50% garden owners spend 1 to 2 hours and 27.5% garden owners spend more than 2 hours for gardening activities.

Table 11.16: Distribution of garden owners according to time spent on roof garden

Time (hour)	Areas								Total	
	Mohammadpur		Adabor		Dhanmondi		Sher-e-Bangla Nagar			
	N	P(%)	N	P(%)	N	P(%)	N	P(%)	N	P(%)
0-1	4	10	1	2.5	3	7.5	1	2.5	**9**	**22.5**
1-2	8	20	4	10	2	5	6	15	**20**	**50**
>2	3	7.5	3	7.5	1	2.5	4	10	**11**	**27.5**
Total	**15**	**37.5**	**8**	**20**	**6**	**15**	**11**	**27.5**	**40**	**100**

11.6.4. Mental satisfaction

Mental satisfaction or spiritual improvement was assessed using a semi-structured open questionnaire. Gardeners' choice was given as high, medium and low. The result showed that High mental satisfaction was mostly found in Mohammadpur and Sher-e-Bangla Nagar than the other two areas. Mental satisfaction was found high in 7 garden owners in Mohammadpur and Sher-e-Bangla Nagar, followed by 3 in Adabor and 2 in Dhanmondi.

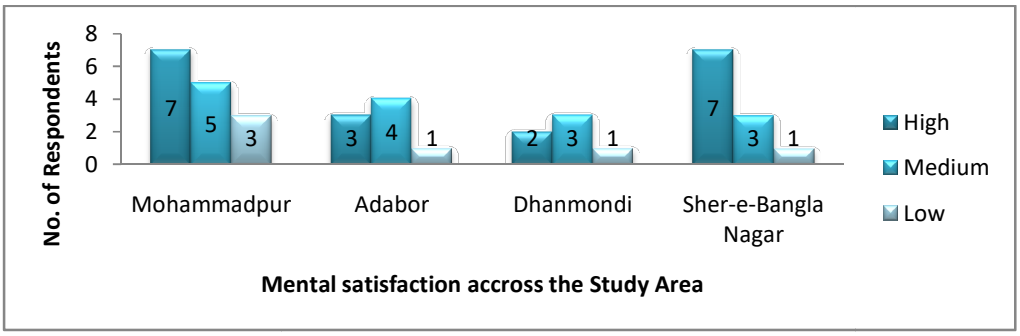


Figure 11.16: Distribution of garden owners according to mental satisfaction

Mental satisfaction was found medium in 5 garden owners in Mohammadpur, followed by 4 in Adabor and 3 in both Dhanmondi and Sher-e-Bangla Nagar. Mental satisfaction was found low in 3 garden owners in Mohammadpur and only one garden owner of Adabor, Dhanmondi and Sher-e-Bangla Nagar. This distribution has been shown spatially in Figure 11.16.

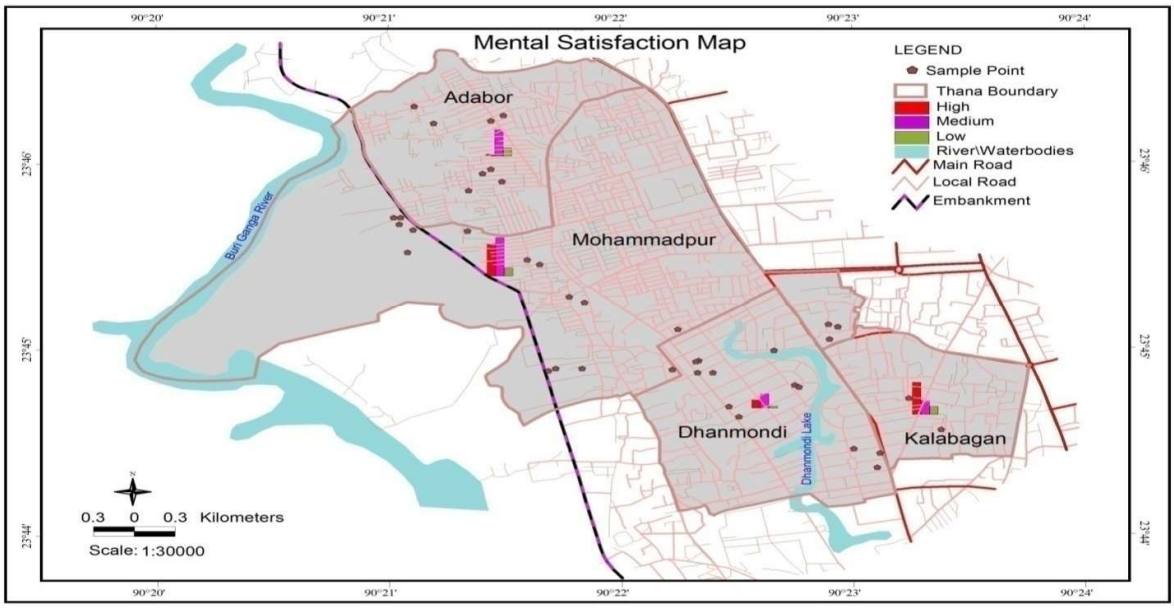


Figure 11.17: Spatial Distribution of Mental Satisfaction Across the Study Area

11.6.5. Mental satisfaction with species diversity

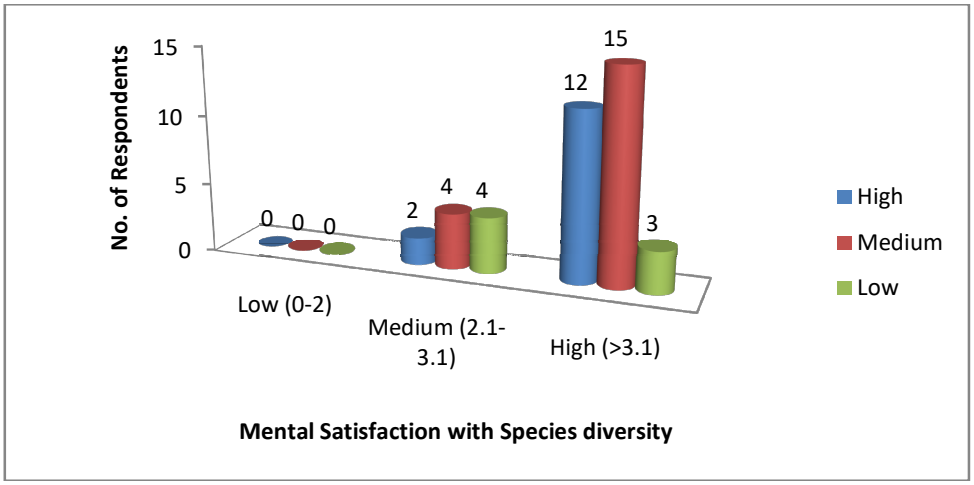


Figure 11.18: Relationship between mental satisfaction and species diversity

A qualitative analysis was done by analyzing the relationship between mental satisfaction and plant species diversity, where the findings showed that mental satisfaction is proportional to plant species diversity. Mental satisfaction increases with species diversity.

11.6.6. Mental satisfaction with yearly food production

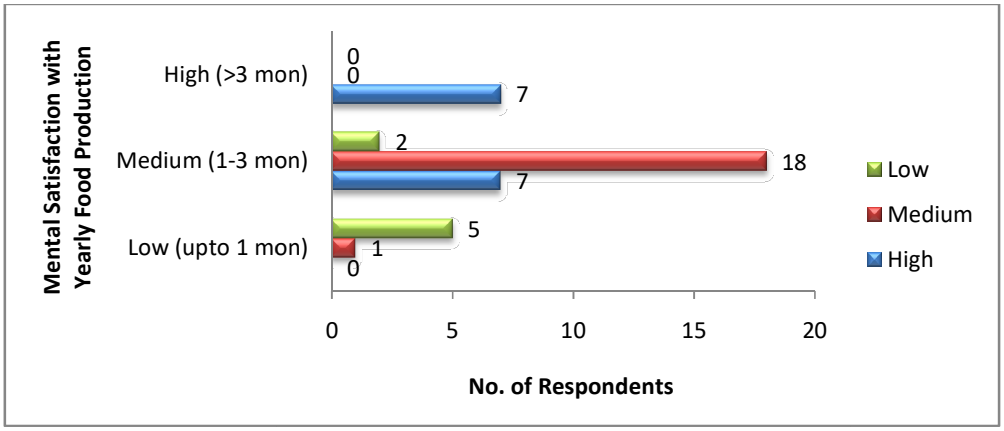


Figure 11.19: Relationship between mental satisfaction and Yearly food production

A qualitative analysis was done by analyzing the relationship between mental satisfaction and yearly food production, where the findings showed that mental satisfaction is proportional to yearly food production. Mental satisfaction increases with food production.

11.6.7. Education and learning

Through experimentation with gardening practices, the garden owners get the opportunity to improve their education and learning on various aspects regarding gardening. Moreover, they face various problems going through this practice for which they periodically contact with relevant personnel or organizations for necessary technical support or go for training and gathering knowledge. All these activities enhance their learning and experience.

11.6.8. Technical Support of the garden owners

According to the survey, 17 garden owners get technical support from Agricultural offices, while 10 garden owners from nearby nurseries, 5 from media and 8 of them get no technical support.

Table 11.17: Distribution of garden owners according to technical support:

Area	Technical Knowledge								Total	
	Agricultural office		Nearby Nursery		Media		No technical support			
	N	P(%)	N	P(%)	N	P(%)	N	P(%)	N	P(%)
Mohammadpur	7	17.5	4	10	1	2.5	3	7.5	**15**	**37.5**
Adabor	3	7.5	2	5	2	5	1	2.5	**8**	**20**
Dhanmondi	1	2.5	3	7.5	1	2.5	1	2.5	**6**	**15**
Sher-e-Bangla Nagar	5	12.5	1	2.5	1	2.5	4	10	**11**	**17.5**
Total	**17**	**40**	**10**	**25**	**5**	**12.5**	**8**	**22.5**	**40**	**100**

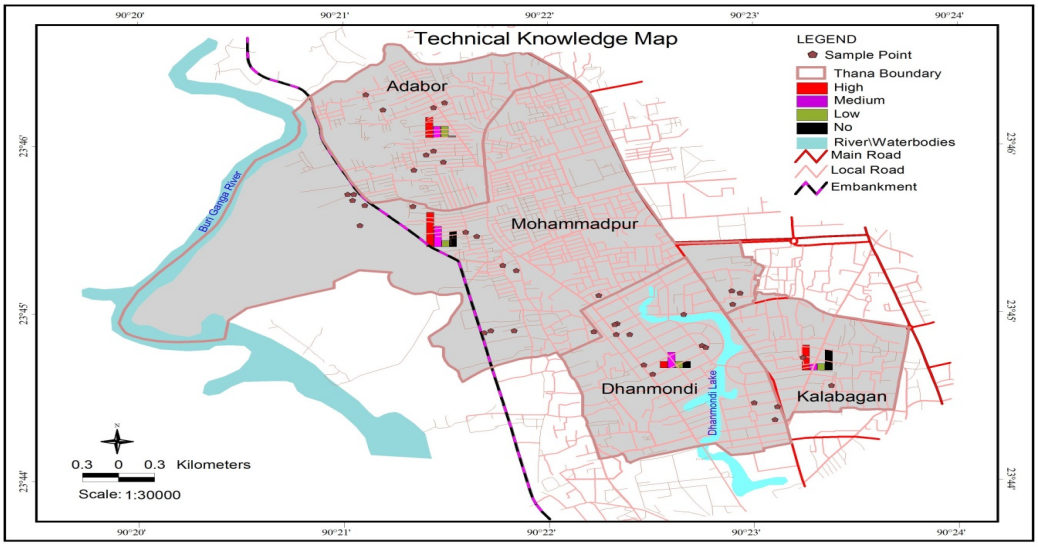


Figure 11.20: Spatial distribution of technical knowledge of the garden owners

Spatial distribution shows that garden owners receive their technical support from agricultural offices were found in higher number in Mohammadpur (17.5%) and Sher-e-Bangla Nagar (12.5%). Garden owners with no technical support were mostly found in Sher-e-Bangla Nagar (10%) and Mohammadpur (7.5%).

11.7. Training of the garden owners

Table 11.18: Distribution of garden owners according to their training

Area	Categories (days)								Total	
	No training		Low (1 day)		Medium (2-3 days)		High (4-5 days)			
	N	P(%)	N	P(%)	N	P(%)	N	P(%)	N	P(%)
Mohammadpur	6	15	3	7.5	3	7.5	3	7.5	15	37.5
Adabor	0	0	3	7.5	3	7.5	2	5	8	20
Dhanmondi	2	5	2	5	2	5	0	0	6	15
Sher-e-Bangla Nagar	0	0	2	5	5	12.5	4	10	11	17.5
Total	**8**	**20**	**10**	**25**	**13**	**32.5**	**9**	**22.5**	**40**	**100**

Garden owners received training (days) from DAE project training program for gardening which was categorized into five (0 to 5 days) groups where 0 day indicated no training received for gardening and 5 days indicated better training received for gardening.

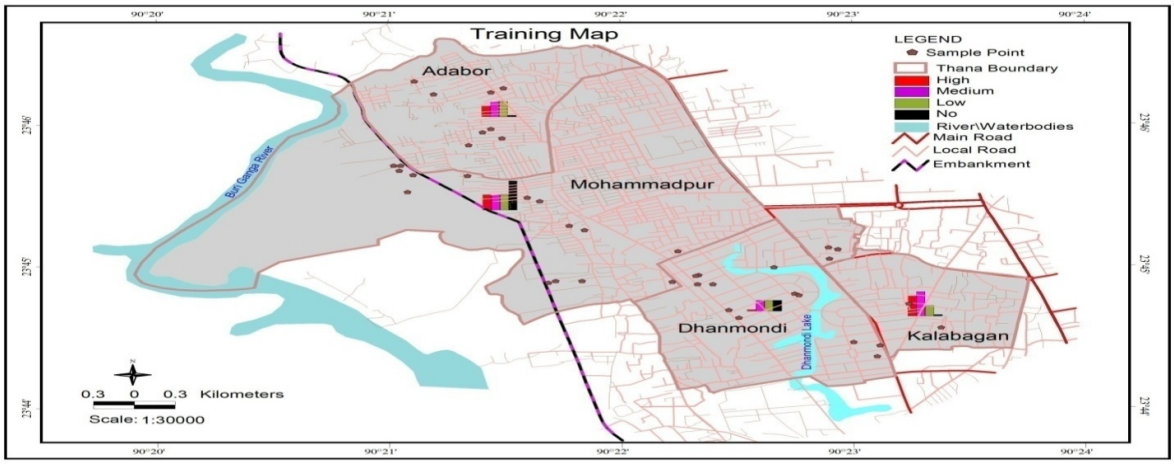


Figure 11.21: Spatial distribution of training facilities of the garden owners across the study area

According to the survey, 3 garden owners received 5 days training, while 6 of them received 4 days training, 6 of them received 3 days training, 7 of them received 2 days training, 10 garden owners received 1 day

training and 8 garden owners received no training at all. This distribution has been spatially shown in Figure 11.18.

11.8. Individual characteristics of the garden owners

In this section the findings of the garden owner's individual characteristics have been discussed. Descriptive statistics of twenty Two characteristics of the garden owners have been presented in Appendix-II.

11.8.1. Gender, age and marital status of the garden owners

Survey result showed 55% garden owners were male and 45% of them were female, where most of them are middle aged.

Table 11.19: Distribution of garden owners according to their gender, age and marital status

	Gender				**Marital Status**					
Age Categories	**Male**		**Female**		**Married**		**Unmarried**		**Divorced**	
	N	**P(%)**	**N**	**P(%)**	**N**	**P(%)**	**N**	**P(%)**	**N**	**P(%)**
Young (upto 30)	3	7.5	2	5	3	7.5	2	5	0	0
Middle age (31-50)	9	22.5	9	22.5	16	40	0	0	2	5
Old (above 50)	10	25	7	17.5	17	42.5	0	0	0	0
Total	**22**	**55**	**18**	**45**	**36**	**90**	**2**	**5**	**2**	**5**

According to the survey, 12.5% garden owners are upto 30 years old while 45% garden owners age ranges between 31 to 50 and 42.5% garden owners are above 50 years old. The marital status showed that 90% respondents are married while only 5% are unmarried and 5% are divorced.

11.8.2. Education of the garden owners

According to the survey, 25% respondents were found being post graduate, 45% respondents were found being graduate, 25% were found educated to secondary/higher secondary level while only 5% were found educated to primary level.

Table 11.20: Distribution of garden owners according to their Education

Area	Education									
	Primary		Secondary/ Higher Secondary		Graduate		Post Graduate		Total	
	N	P(%)	N	P(%)	N	P(%)	N	P(%)	N	P(%)
Mohammadpur	0	0	4	10	5	12.5	6	15	**15**	**37.5**
Adabor	0	0	1	2.5	5	12.5	2	5	**8**	**20**
Dhanmondi	0	0	1	2.5	4	10	1	2.5	**6**	**15**
Sher-e-Bangla Nagar	2	5	4	10	4	10	1	2.5	**11**	**17.5**
Total	**3**	**5**	**10**	**25**	**19**	**45**	**8**	**25**	**40**	**100**

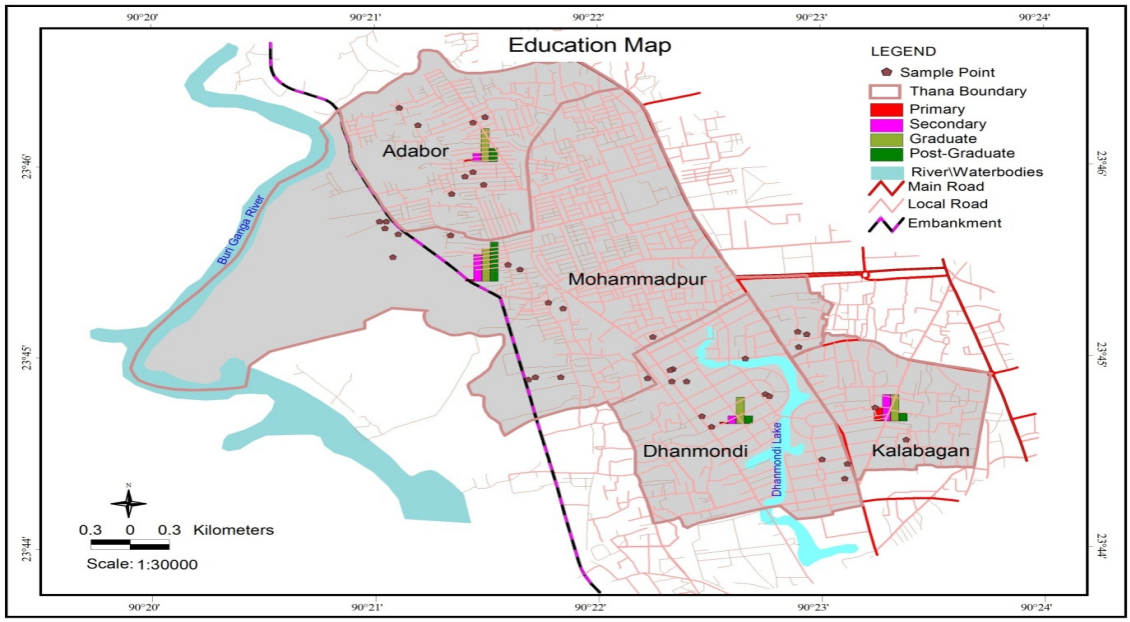


Figure 11.22: Spatial distribution of education of the garden owners across the study area

In Mohammapur area, 4 garden owners of secondary/higher secondary level, 5 graduate and 6 post graduate were found. In Adabor area, 1 garden owner of secondary/higher secondary level, 5 graduate and 4 post graduate were found. In Dhanmondi area, 1 garden owner of secondary/higher secondary level, 4 graduates and 1 post graduate were found. In Sher-e-Bangla Nagar area 4 garden owners of secondary/higher secondary level, 4 graduate and 1 post graduate were found. This distribution has been spatially shown in Figure 11.22.

11.8.3. **Occupation of the garden owners**

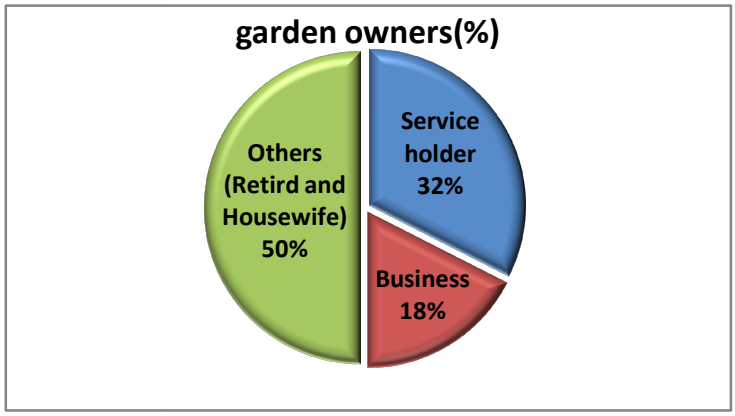


Figure 11.23: Distribution of garden owners according to their occupation

According to the survey, 32% garden owners were service holder, while 18% were businessmen and 50% (20 respondents) were retired and housewife.

11.8.4. **House ownership of the garden owners**

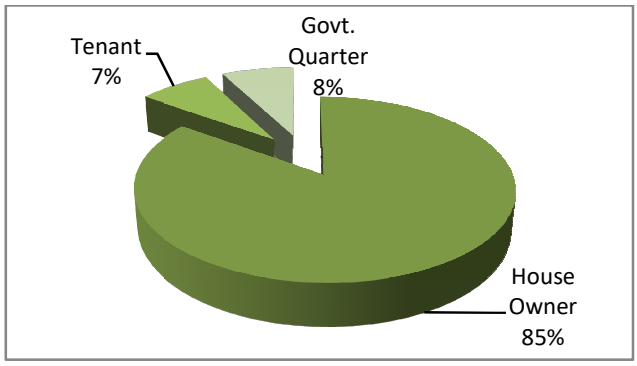


Figure 11.24: Distribution of garden owners according to house ownership

According to the survey, 85% garden owners were owner of their house buildings, while only 7% garden owners were tenant and only 8% roof gardens were found in Government quarters.

11.8.5. Family size of the garden owners

According to the survey, most of the families of the garden owners belong to small to medium families. 17 garden owners (42.5%) had small family size and 16 garden owners (40%) had medium family size while only 7 of them (17.5%) had large family size.

Table 11.21: Distribution of garden owners according to their family size

Family size	Frequency	Percentage (%)
Small (2-4)	17	42.5
Medium(5-7)	16	40
Large (>7)	7	17.5
Total	**40**	**100**

11.8.6. Annual income of the garden owners

According to the survey, rooftop gardening practice was mostly observed in the higher class people of the society. Among 40 respondents, 18 respondents had higher annual income, 15 respondents had middle annual income while only 1 respondent were found to have lower annual income.

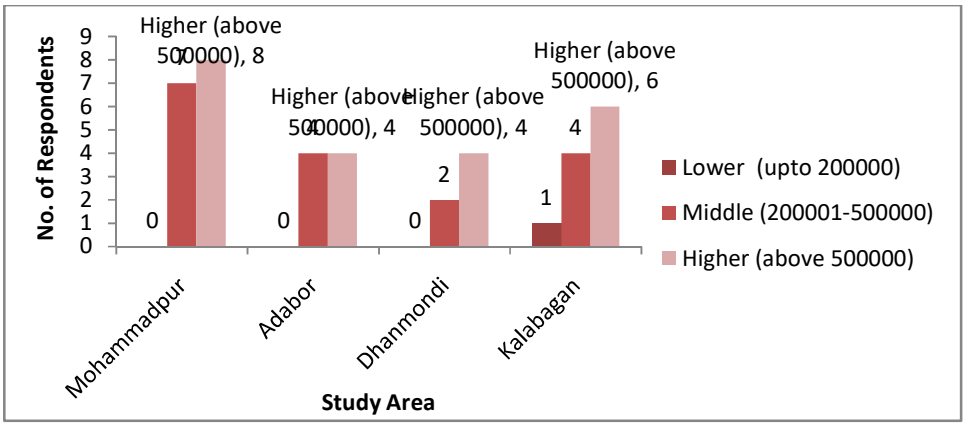


Figure 11.25: Distribution of garden owners according to their annual income

In Mohammadur Thana area, 8 garden owners had higher annual income while 7 had middle annual income. In Adabor thana area, both higher and middle annual income was found among 4 garden owners. In Dhanmondi Thana area, 4 higher and 2 middle annual incomes were found among the respondents. In Sher-e-Bangla Nagar Thana area, 6 higher, 4 middle and only 1 lower annual income were found among the respondents.

11.8.7. Surface area of the roof gardens

According to the survey the surface area was found large (above 2100 sq.ft.) in 32.5% roof gardens while 55% roof gardens had medium surface area (1601-2100 sq.ft.) and small surface area (1000-1600 sq.ft.) were found in 12.5% roof gardens.

Table 11.22: Distribution of garden owners according to roof surface area

Surface area	Areas								Total	
	Mohammadpur		Adabor		Dhanmondi		Sher-e-Bangla Nagar			
	N	P(%)	N	P(%)	N	P(%)	N	P(%)	N	P(%)
Small (1000-1600 sq.ft.)	2	5	1	2.5	0	0	2	5	**5**	**12.5**
Medium (1601-2100 sq.ft.)	9	22.5	5	12.5	3	7.5	5	12.5	**22**	**55**
Large (>2100 sq.ft.)	4	10	2	5	3	7.5	4	10	**13**	**32.5**
Total	**15**	**37.5**	**8**	**20**	**6**	**15**	**11**	**17.5**	**40**	**100**

In Mohammadpur, 10% roof gardens were found with large surface area, 22.5% were medium and 5% were found small. In Adabor thana, 5% roof surface were found large while 12.5% were medium and 2.5% small. In Dhanmondi, 7.5% roof surface area were found large, 7.5% medium and no small roof surface area were found there. In Sher-e-Bangla Nagar, 10% roof gardens were found with large surface area, 12.5% medium and 5% were found with small surface area.

11.8.8. Purpose of gardening

Purpose of rooftop gardening was assessed using a semi-structured open questionnaire.

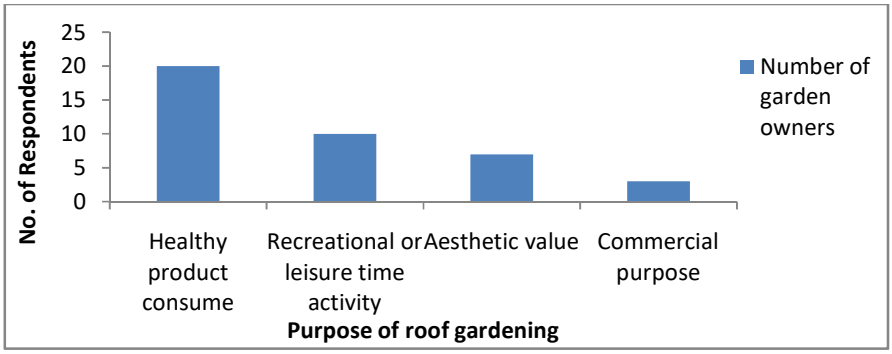


Figure 11 .26: Distribution of garden owners according to purpose of gardening

The result showed that 20 garden owners were interested for rooftop gardening because they thought that gardening products were healthy for consumption (50%), 10 garden owners were interested for rooftop gardening as leisure time activity or recreational activity (25%), 7 garden owners practiced gardening for aesthetic value (17.5%) while only 3 garden owners had roof gardens for commercial purpose (7.5%).

11.9. Overall Ecosystem Services through qualitative analysis in the Survey:

The overall ecosystem services from the 40 rooftop gardens of the study area have been presented in this section. The results are derived from the previous qualitative analytical tables and categorized as high, medium, low and not at all. The percentage of garden owners receiving major ecosystem services is listed in table 11.23.

The provisioning service includes fruits and vegetable production which is evaluated as regularity of food supply from Table 11.1. Supporting services are evaluated according to plant species diversity across the study area. Regulating services include thermal regulation and disease regulation. Thermal regulation was evaluated according to qualitative analytical and disease regulation was evaluated according to medicinal plants density. Among the cultural services mental satisfaction was evaluated according to Graphical representation and education and learning were also evaluated.

Table 11.23: Overall Ecosystem Services Provided by RTGs in the Study

Ecosystem Services		**Categories**			
		High	**Medium**	**Low**	**Not at all**
Provisioning	1. Food supply	40%	45%	15%	--
Supporting	2. Biodiversity	75%	22.5%	2.5%	--
	3. Economic	7.5%	57.5%	32.5%	2.5%
Regulating	4. Thermal Regulation	27.5%	42.5%	22.5%	5%
	5. Disease Regulation	2.5%	22.5%	75%	--
Cultural	6. Mental Satisfaction	47.5%	37.5%	15%	--
	7. Education & Learning	22.5%	32.5%	25%	20%

The overall findings of the survey showed that provisioning services provided by RTGs are mostly medium; Supporting services include high biodiversity conservation and medium economic support. Regulating services are mostly medium as RTGs provide medium thermal and disease regulation. Cultural services of RTGs are mostly high. So, it is clear from the above Table 11.23 that the potential of RTGs in providing ecosystem services is high and it can improve the overall wellbeing of city dwellers if practiced in large context.

Part 2: Experiment results and discussion (For satisfying objective 3)

11.10 Effect of treatment on robi season vegetables crop in roof top garden

11.10.1 Growth and yield performance of cabbage

11.10.1.1: Effect of treatment on morphological characteristics of cabbage

Plant height

Plant height is one of the important parameter, which is positively correlated with the yield of cabbage. Non-significant variation was observed in experiment location. The highest plant height of cabbage (42.12 cm) was observed in Dhanmondi area which was statistically different from Mohammadpur and Sher-e-Bangla Nagar area. The lowest plant height (36.62 cm) was observed in Sher-e-Bangla Nagar (Table 11.24).

Number of leaves per plant

In case of the number of leaves per plant, non-significant effect was observed in different locations due to different climatic conditions of the locations. The highest number of leaves per plant of cabbage (13.75) was found in Adabor which was statistically similar to Sher-e-Bangla Nagar and Dhanmondi. But in Mohammadpur the lowest number of leaves (12.50) was observed for cabbage.

Leaf length

The highest leaf length was observed in Dhanmondi which was 26.35 cm while the lowest leaf length (23.16 cm) was observed from Sher-e-Bangla Nagar which was statistically similar with Adabor and MOhammadpur. So in that case, non-significant variation was found in leaf length of cabbage in different experiment location s(Table 11.24).

Leaf breath

A significant variation was observed in leaf breath of cabbage. The highest leaf breath (14.20 cm) was observed in Sher-e-Bangla Nagar which was statistically similar with Dhanmondi and Mohammadpur. The lowest leaf breath (13.83 cm) was observed in Adabor (Table 11.24).

Stem Diameter

Stem diameter was found highly significant in terms of various locations. The highest stem (2.10 cm) diameter was observed from Adabor which was not similar with Sher-e-Bangla Nagar and Mohammadpur. The lowest stem diameter (1.98 cm) was observed in Dhanmondi (Table 11.24).

Table 11.24: Effect of treatment on morphological characteristics of cabbage

Treatment	Plant height (cm)	Number of leaf	Leaf length (cm)	Leaf breath (cm)	Stem diameter (cm)
Mohammadpur	40.87 b	12.50 b	23.85 b	14.11 a	2.05 b
Adabor	38.37 c	13.75 a	23.71 b	13.83 b	2.10 a
Sher-e-Bangla Nagar	36.62 d	13.63 a	23.16 b	14.20 a	2.05 b

Dhanmondi	42.12 a	13.50 a	26.35 a	14.19 a	1.98 c
Level of Significance	NS	NS	NS	*	**
CV (%)	16.94%	11.52%	14.15%	7.45%	12.42%

11.10.1.2: Effect of treatment on yield contributing characteristics of cabbage

Head diameter

Different treatment had showed significant variations on curd diameter of cabbage. The highest curd diameter (14.58 cm) was observed from Mohammadpur which was statistically different from Adabor and Sher-e-Bangla Nagar. The lowest head diameter (13.85 cm) was observed from Dhanmondi (Table 11.25).

Fruit weight

The highest fruit weight (0.86 kg) was found from Mohammadpur whereas the lowest fruit weight (0.84 kg) was observed from Dhanmondi. So, it can be said that the treatment have non-significant effect on fruit weight of cabbage (Table11.25).

Fruit weight/ plot

The highest fruit weight per plot (15.53 kg) was observed from Mohammadpur which was statistically dissimilar from Adabor and Sher-e-Bangla Nagar. The lowest fruit weight per plot (14.18 kg) was observed from Dhanmondi .

Fruit weight/ hectare

The highest fruit weight per hectare of cabbage was observed from Mohammadpur which was 34.50 ton/ha. The lowest fruit weight per hectare (33.21 ton/ha) was observed from Adabor. But in reference field condition, the highest yield was 40-45 ton per hectare. But in roof top garden the highest yield was found 34.50 ton/ha. So, the production of cabbage on roof top garden was profitable for city dweller for their daily nutrient requirement.

Table 11.25: Effect of treatment on yield contributing characteristics of cabbage

Treatment	Curd diameter (cm)	Individual fruit wt. (kg)	Fruit wt./plot (kg)	Fruit wt. ton/ha	Reference yield (ton/ha)
Mohammadpur	14.58 a	0.86 a	15.53 a	34.50 a	40-45
Adabor	14.18 b	0.83 b	14.96 b	33.21 c	
Sher-e-Bangla Nagar	14.06 b	0.84 b	15.19 b	33.75 b	
Dhanmondi	13.85 c	0.79 c	14.18 c	31.50 b	
Level of Significance	*	NS	NS	NS	
CV (%)	10.69%	24.96%	24.96%	24.96%	

11.10.2 Growth and yield performance of cauliflower

11.10.2.1 Effect of treatment on morphological characteristics of cauliflower

Plant height

A significant variation of plant height of cauliflower was observed in various locations. The highest plant height of cauliflower (52.63 cm) was observed in Dhanmondi which was statistically similar to Adabar. However, the lowest plant height (47.50 cm) was observed in Mohammadpur (Table 11.26).

Number of leaves per plant

Different treatment had non-significant effect on number of leaves of cauliflower. The highest number of leaves (22.00) obtained from Adabor. The lowest number of leaves (20.38) was observed from Dhanmondi which was statistically similar with Mohammadpur and Sher-e-Bangla Nagar (Table 11.26).

Leaf length

Different treatment had significant effect of the leaf length of cauliflower. The highest leaf length was observed from Sher-e-Bangla Nagar which was statistically similar with Dhanmondi. The lowest leaf length was observed from Mohammadpur which was statistically different from Adabor (Table 11.26).

Leaf breath

The study revealed that there was highly significant effect of different treatment on leaf breath of cauliflower. Average maximum leaf breath (13.14 cm) was observed from Mohammadpur which was statistically similar with Sher-e-Bangla Nagar and Dhanmondi. The average lowest leaf length (12.84 cm) was observed from Adabor (Table 11.26).

Stem Diameter

Different treatments had significant influences on stem diameter of cauliflower. The highest stem diameter (3.13 cm) was observed from Adabor. Whereas, the lowest number of stem diameter (2.73 cm) was observed from Mohammadpur which was statistically similar with Sher-e-Bangla Nagar and Dhanmondi (Table 11.26).

Table 11.26: Effect of treatment on morphological characteristics of Cauliflower

Treatment	Plant height (cm)	Number of leaf (Nos.)	Leaf length (cm)	Leaf breath (cm)	Stem diameter (cm)
Mohammadpur	47.50 c	20.75 b	35.50 c	13.14 a	2.73 b
Adabor	52.13 a	22.00 a	36.25 b	12.84 b	3.13 a
Sher-e-Bangla Nagar	49.88 b	20.63 b	38.50 a	13.08 a	2.85 b
Dhanmondi	52.63 a	20.38 b	38.13 a	13.13 a	2.96 b
Level of Significance	**	NS	*	**	**
CV (%)	6.64%	15.04%	10.89%	4.66%	8.12%

11.10.2.2: Effect of treatment on yield contributing characteristics of cauliflower

Fruit Diameter

Different treatments had significant influences of fruit diameter of cauliflower. The highest fruit diameter (14.88 cm)was observed from Dhanmondi which was statistically similar with Mohammadpur and Sher-e-Bangla Nagar. The lowest fruit diameter (13.41 cm) was observed from Adabor (Table 11.27).

Curd Weight

Curd weight was not varied significantly due to the effect of different treatment. The highest curd weight (0.84 kg) was observed from Sher-e-Bangla Nagar and the lowest curd weight (0.72 kg) was observed from Dhanmondi which was statistically similar with Adabor and Mohammadpur (Table 11.27).

Curd weight per plot

The highest curd weight per plot (39.24 kg) of cauliflower was observed from Sher-e-Bangla Nagar. The lowest curd weight (35.22 kg) was observed from Mohammadpur which was statistically similar with Adabor. In that case, data revealed that the treatment had no significant variation on the curd weight per plot of cauliflower.

Curd weight per hectare

There was no significant variation on curd yield of cauliflower in different treatments. The highest amount of yield (40.25 ton/ha) was observed from Sher-e-Bangla Nagar which was identical for reference yield of cauliflower in field condition (37-45 ton/ha). The lowest number of yield (36.13 ton/ha) was obtained from Mohammadpur which was statistically similar with Adabor (Table 11.27).

Table 11.27: Effect of treatment on yield contributing characteristics of Cauliflower

Treatments	Curd Diameter (cm)	Curd Weight (kg)	Curd wt./Plot (kg)	Curd Wt./Ha (ton)	Reference Yield (ton/ha)
Mohammadpur	14.49 a	0.75 b	35.22 c	36.13 c	37-45
Adabor	13.41 b	0.74 b	35.83 c	36.75 c	
Sher-e-Bangla Nagar	14.05 a	0.84 a	39.24 a	40.25 a	
Dhanmondi	14.88 a	0.72 b	37.17 b	38.13 b	
Level of Significance	**	NS	NS	NS	
CV (%)	7.78%	28.88%	28.88%	28.88%	

11.10.3: Growth and yield performance of tomato

11.10.3.1: Effect of treatment on morphological characteristics of tomato

Plant height

No significant variation was observed due to the effect of different treatments. However, the tallest plant (175.25 cm) was observed in Mohammadpur which was statistically different from Sher-e-Bangla Nagar and Dhanmondi. The shortest plant (168.38 cm) of tomato was observed in Adabor. Buitellar (1989) reported that the increased height of plants was possibly due to better availability of soil moisture and optimum soil temperature provided by the mulches (Table 11.28).

Number of leaves per plant

In case of number of leaves per plant, no significant differences was observed. The average of maximum number of leaves (469.13) was observed in Sher-e-Bangla Nagar which was different from Dhanmondi. The lowest number of leaves (437.5) was observed from Adabor which was statistically similar with Mohammadpur.Ashrafuzzaman *et al.,* (2011) reported that the microclimatic condition improved by the mulches might have provided a suitable condition for producing higher number of leaves in the plants (Table 11.28).

Leaf Length

There is no significant variation was observed due to the effect of different treatments. The highest leaf length was observed from Adabor which was 13.16 cm. This result was statistically similar with Dhanmondi (13.10 cm) and Sher-e-Bangla Nagar (12.96 cm). The shortest leaf length was observed from Mohammadpur (12.75 cm) (Table 11.28).

Leaf breath

Leaf breath was significantly influenced by different treatment. The highest leaf breath (4.66 cm) was observed from mohammadpur which was similar from Adabor. The lowest leaf breath was observed from Dhanmondi which was 4.03 cm (Table 11.28).

Number of branch per plant

Different treatment had significantly influenced on the number of branches of tomato plants. The highest number of branch (43.00) was observed from Mohammadpur. The lowest number of branches per plant (33.13) was found from Sher-e-Bangla Nagar (33.63) which was statistically similar from dhanmondi (Table 11.28).

Table 11.28: Effect of treatment on morphological characteristics of tomato

Treatment	Plant height (cm)	Number of leaf	Leaf Length (cm)	Leaf Breath (cm)	Number of branch
Mohammadpur	175.25 a	441.13 c	12.75 b	4.66 a	43.00 a
Adabor	168.38 c	437.50 c	13.16 a	4.46 a	42.62 a
Sher-e-Bangla Nagar	172.63 b	469.13 a	12.96 a	4.13 b	33.13 b

Dhanmondi	171.25 b	461.00 b	13.10 a	4.03 c	33.63 b
Level of Significance	NS	NS	NS	*	*
CV (%)	7.95%	12.09%	7.44%	22.73%	55.61%

11.10.3.2: Effect of treatment on yield contributing characteristics of tomato

Number of fruits per plant

Treatment causes a significant variation in number of fruit per plants in tomato. The highest number of fruits (69.63) was observed from Mahammudpur whereas the second highest was observed from Adabor. The lowest number of fruit (61.88) was obtained from Dhanmondi which was statistically similar from Sher-e-Bangla Nagar (Table 11.29).

Fruit diameter

In case of fruit diameter, different treatment had no significant variations on tomato. The highest fruit diameter (8.69 cm) was observed from Mohammadpur which was statistically similar from Adabor and Sher-e-Bangla Nagar. The lowest fruit diameter (8.35 cm) was observed from Dhanmondi (Table11.29).

Fruit weight per plant

The highest fruit weight (4.90 kg) per plant was observed from Mohammadpur which was statistically similar to Sher-e-Bangla Nagar while the lowest fruit weight was observed from Adabor (3.93 kg). There was no significant variation was found here.

Fruit weight per plot

The highest fruit weight per plot (95.55 kg) was obtained from Mohammadpur which is statistically different from Sher-e-Bangla Nagar. The lowest number of fruit per plot (76.54 kg) was observed from Adabor which was statistically similar with Dhanmondi (Table 11.29).

Fruit weight (ton/ha)

In case of fruit weight per hectare, the reference yield was 95-100 ton per hectare. The highest number of fruit weight per hectare (98 ton) was gained from Mohammadpur. The lowest number of fruit weight per hectare was observed from Adabor which was 78.50 ton (Table 11.29).

Table 11.29: Effect of treatment on yield contributing characteristics of tomato

Treatment	Number of fruit	Fruit diameter (cm)	Fruit weight/ plant (kg)	Fruit wt./plot (kg)	Fruit wt. (ton/ha)	Reference yield (ton/ha)
Mohammadpur	69.63 a	8.69 a	4.90 a	95.55 a	98.00 a	95-100
Adabor	66.13 b	8.54 a	3.93 b	76.54 c	78.50 c	
Sher-e-Bangla Nagar	62.75 c	8.38 a	4.76 a	92.87 b	95.25 b	
Dhanmondi	61.88 c	8.35 a	4.00 b	78.00 c	80.00 c	
Level of Significance	*	*	NS	NS	NS	
CV (%)	14.14%	5.21%	26.00%	26.00%	26.00%	

11.10.4: Growth and yield performance of chili

11.10.4.1: Effect of treatment on morphological characteristics of chili

Plant height

Different treatment showed significant variation in plant height of chili. The tallest plant (125.25 cm) was observed from Adabor which was statistically different from Sher-e-Bangla Nagar and Mohammadpur. The shortest plant height (113.38 cm) observed from Dhanmondi (Table 11.30).

Number of leaves

Different treatment had positive significance on generating and retaining higher number of leaves per plant. The maximum number of leaves (308.00) was obtained from Sher-e-Bangla Nagar whereas the lowest number of plant leaves (275.38) from Mohammadpur (Table 11.30).

Leaf length and leaf breadth

There was no significant variation found in leaf length and leaf breath of chili due to variation in treatments. The highest leaf length (13.50 cm) was obtained from Dhanmondi. The lowest leaf length (12.58 cm) was observed in Mohammadpur. For leaf breath, the highest leaf breath (3.54 cm) observed from Adabor which was statistically similar with Mohammadpur and Sher-e-Bangla Nagar. However, the lowest leaf breath (3.09 cm) was observed in Dhanmondi.

Number of Branch

Different treatment had significant variation for the branching number of chili. The highest number of branch (30.75) was observed from Mohammadpur which was statistically similar with Adabor. The lowest number of branch was found in Dhanmondi which was 26.75 (Table 11.30).

Stem Diameter

The present study showed that different treatment had significant effect on stem diameter of chili. Average highest stem diameter (1.20 cm) was observed from Sher-e-Bangla nagar whereas the lowest stem diameter (1.08 cm) was observed in Adabor (Table 11.30).

Table 11.30: Effect of treatment on morphological characteristics of chili

Treatment	Plant height (cm)	Number of leaf	Leaf length (cm)	Leaf breath (cm)	Number of branch (nos.)	Stem diameter (cm)
Mohammadpur	119.00 b	275.38 d	12.58 a	3.39 a	30.75 a	1.09 a
Adabor	125.25 a	308.00 a	13.05 a	3.54 a	29.75 a	1.08 a
Sher-e-Bangla Nagar	120.13 b	295.75 b	13.06 a	3.30 a	27.88 b	1.20 a
Dhanmondi	113.38 c	281.25 c	13.50 a	3.09 a	26.75 b	1.18 a
Level of	*	*	NS	NS	*	*

Significance						
CV (%)	4.45%	9.51%	9.41%	14.92%	34.23%	18.09%

11.10.4.2: Effect of treatment on yield contributing characteristics of chili

Fruit weight per plant

Fruit weight of chili per plant was varied significantly due to various treatment locations. There was a significant variation was found in fruit weight per plant of chili due to various treatments. The highest fruit weight (0.688 kg) was obtained from Adabor which was statistically similar to Mohammadpur, Sher-e-Bangla Nagar and Dhanmondi areas.. However, the lowest fruit weight per plant (0.44 kg) was observed from Dhanmondi (Table 11.31).

Fruit weight per plot

The highest amount of fruit per plot (6.70 kg) was obtained from Adabor which was statistically different from Sher-e-Bangla Nagar and Mohammadpur. While the lowest amount of fruit weight per plot (4.33 kg) gathered from Dhanmondi.

Fruit weight per hectare

The reference yield of chili was 8-12 ton per hectare whereas in the roof top garden the highest fruit weight per hectare (6.88 ton/ha) was observed from Adabor which was statistically different from Sher-e-Bangla Nagar and Mohammadpur. The lowest yield per hectare was observed from Dhanmondi (Table 11.31).

Table 11.31: Effect of treatment on yield contributing characteristics of chili

Treatment	Fruit weight/plant (kg)	Fruit weight/plot (kg)	Fruit weight (ton/ha)	Reference yield (ton/ha)
Mohammadpur	0.53 ab	5.12 b	5.25 b	8-12
Adabor	0.68 a	6.70 a	6.88 a	
Sher-e-Bangla Nagar	0..55 ba	5.36 b	5.50 b	
Dhanmondi	0.44 ab	4.33 c	4.44 c	
Level of Significance	*	*	*	
CV (%)	22.00%	22.00%	22.00%	

11.10.5: Growth and yield performance of egg plant

11.10.5.1: Effect of treatment on morphological characteristics of eggplant

Plant height

Different treatment had positive effect on plant height of eggplant. The highest plant height (92.25 cm) was observed from Sher-e-Bangla Nagar. The lowest plant height (81.50 cm) was observed from Mohammadpur which was statistically similar with Adabor (Table 11.32).

Number of leaves

A significant variation was observed in number of leaves in the study area. The highest number of leaves (185.63) was found in Sher-e-Bangla Nagar which was statistically different from Mohammadpur and Adabor. The lowest number of leaves (170.63) was observed in Dhanmondi (Table 11.32).

Number of branch per plant

The highest number of branch (7.38) was obtained from Adabor which was statistically similar with Dhanmondi. The lowest number of branch (7.00) was observed in Mohammadpur. So it is said that, different location of the experimental site created a significant variation in the number of branch of eggplant.

Table 11.32: Effect of treatment on morphological characteristics of eggplant

Treatment	Plant Height (cm)	Number of leaf (nos.)	Number of branch (nos.)
Mohammadpur	81.50 c	173.00 b	7.00 b
Adabor	83.13 c	173.13 b	7.38 a
Sher-e-Bangla Nagar	92.25 a	185.63 a	6.50 b
Dhanmondi	86.00 b	170.63 c	7.38 a
Level of Significance	*	*	*
CV (%)	8.11%	7.99%	13.06%

11.10.5.2: Effect of treatment on yield contributing characteristics of eggplant

Number of fruit per plant

In case of number of fruit per plant, location of experiments played a significant role in the production of the number of fruit. The highest number of fruit (32.50) was observed in Sher-e-Bangla Nagar which was statistically similar with Adabor and Dhanmondi. The lowest number of fruit (31.25) was observed in Mohammadpur (Table 11.33).

Fruit weight per plant

Fruit weight per plant was significantly influenced by different treatment of the experiment. The highest fruit weight per plant (3.55 kg) was observed from Dhanmondi which was similar with Mohammadpur and Sher-e-Bangla Nagar. The lowest number of fruit weight per plant (3.46 kg) was observed in Adabor (Table 11.33).

Fruit weight per plot

The fruit weight per plot (13.73 kg) was found in Mohammadpur. The lowest amount of fruit per plot was observed in Adabor which was statistically similar with Sher-e-Bangla Nagar and Dhanmondi .

Fruit weight per hectare

On an average the highest fruit weight per hectare (38.14 ton) was observed in Mohammadpur. The second highest yield (35.40 ton) was obtained from Dhanmondi. The lowest yield per hectare (34.53 ton) was observed from Adabor which was similar with Sher-e-Bangla Nagar. This yield performance of eggplant was identical to the production of eggplant in reference field (40-45 ton). So, roof top production of eggplant was effective for city dwellers for their daily need (Table 11.33).

Table 11.33: Effect of treatment on yield contributing characteristics of eggplant

Treatment	Number of fruit (nos)	Fruit weight /plant (kg)	Fruit wt. /plot (kg)	Fruit wt. (ton/ha)	Reference yield (ton/ha)
Mohammadpur	31.25 b	3.50 a	13.73 a	38.14 a	40-45
Adabor	32.13 a	3.46 a	12.43 b	34.53 c	
Sher-e-Bangla Nagar	32.50 a	3.49 a	12.52 b	34.78 c	
Dhanmondi	31.75 a	3.55 a	12.74 b	35.40 b	
Level of Significance	*	NS	*	*	
CV (%)	13.18%	16.82%	16.82%	16.82%	

11.10.6: Effect of treatment on winter flower in roof top garden (robi season)

11.10.6.1: Growth and yield performance of marigold

11.10.6.1.1: Effect of treatment on morphological characteristics of marigold

Plant height

Different treatment had significant effect on plant height of marigold. The highest plant height (42.37 cm) was observed from Sher-e-Bangla Nagar which was statistically similar from Adabor and Dhanmondi. The lowest plant height (40.88 cm) was observed from Mohammadpur (Table 11.34).

Number of leaf per plant

The highest number of leaves per plant (552.13) was obtained from Dhanmondi which was statistically different from Mohammadpur and Sher-e-Bangla Nagar. The lowest number of of leaves per plant (511.13) was observed from Adabor (Table 11.34).

Leaf length

Average highest leaf length (4.04 cm) was observed from Dhamondi which was statistically similar from Sher-e-Bangla Nagar and Mohammadpur. The lowest leaf length (3.88 cm) was observed from Adabor .

Leaf breath

Non-significant variation was observed in leaf breath of plant due to application of different treatment. The highest number of leaf breath (1.06 cm) was obtained from Dhanmondi. The lowest leaf breath (0.95 cm) was found in Adabor (Table 11.34).

Number of branch

The number of branch of marigold was found the highest in Mohammadpur which was 26.25. while it was 25.50 in Dhanmondi. However, the lowest number of branch (23.13) per plant of marigold was observed in Sher-e-Bangla Nagar which was statistically similar from Sher-e-Bangla Nagar (Table 11.34).

Table 11.34: Effect of treatment on morphological characteristics of Marigold

Treatment	Plant Height	Number of leaf (nos.)	Leaf Length (cm)	Leaf Breath (cm)	Number of branch
Mohammadpur	40.88 a	535.75 b	3.94 a	1.04 a	26.25 a
Adabor	41.87 a	511.13 d	3.88 a	0.95 a	23.88 c
Sher-e-Bangla Nagar	42.37 a	527.50 c	3.98a	0.97 a	23.13 c
Dhanmondi	41.37 a	552.13 a	4.04 a	1.06 a	25.50 b
Level of Significance	*	NS	*	NS	NS
CV (%)	10.62%	7.48%	19.94%	19.68%	19.65%

11.10.6.1.2: Effect of treatment on yield contributing characteristics of marigold

Number of flower per plant

There is no significant difference found on the number of flower per plant of marigold due to different treatments. However, the highest number of flower per plant (21.75) was observed from Mohammadpur which was statistically similar from Adabor and Dhanmondi. The lowest number of flower (19.75) was observed from Sher-e-Bangla Nagar (Table 11.35).

Number of flower per plot

Number of flower per hectare of marigold was found similar as compared to the reference yield of 400000-50000 flower per hectare. The highest number of flower per hectare (435000) was obtained from Mohammadpur which was statistically similar from Dhanmondi. The lowest number of flower (395000) was observed from Sher-e-Bangla Nagar which was statistically similar with Adabor (Table 11.35).

Table 11.35: Effect of treatment on yield contributing characteristics of marigold

Treatment	Number of flower/ plant	Number of flower/ha	Reference yield Number of flower/ha
Mohammadpur	21.75 a	435000 a	400000-500000
Adabor	20.38 a	407500 b	
Sher-e-Bangla Nagar	19.75 a	395000 b	
Dhanmondi	21.38 a	427500 a	
Level of Significance	NS	NS	
CV (%)	40.60%	40.60%	

11.10.7: Growth and yield performance of dahlia

11.10.7.1: Effect of treatment on morphological characteristics of dahlia

Plant Height

The highest plant height (152.25 cm) of dahlia was observed in Sher-e-Bangla Nagar which was statistically similar with Dhanmodi (152.00 cm) and Mohammadpur (149.50 cm). However the lowest plant height (142.62 cm) was observed in Adabor (Table 11.36).

Number of leaf per plant

Number of leaf per plant of dahlia was found statistically similar to all treatments. However, the highest number of leaf per plant was observed in Mohammadpur (82.00). The lowest number of leaf per plant was observed from Adabor which was 81.12 (Table 11.36).

Leaf length

Leaf length of dahlia was found statistically same as compared to different treatments. The highest leaf length of dahlia was observed in Mohammadpur and Dhanmondi which was (20.75 cm). The lowest number of leaf length (19.62 cm) was observed from Adabor which was also statistically similar from Sher-e-Bangla Nagar (Table 11.36).

Leaf breath

The highest leaf breath (5.50 cm) was observed from Dhanmondi which was similar from Adabor and Mohammadpur. The lowest leaf breath was observed in Sher-e-Bangla Nagar which was 5.27 cm.

Number of branch per plant

There was no significant variation found in the number of branch per plant due to the effect of different treatments. The highest number of branch (19.75) was observed from Sher-e-Bangla Nagar whereas the lowest number of branch was observed from Adabor which was 18.25 (Table 11.36).

Table 11.36: Effect of treatment on morphological characteristics of dahlia

Treatment	Plant height (cm)	Number of leaf /plant	Leaf Length (cm)	Leaf Breath (cm)	No. of branch / plant
Mohammadpur	149.50 ab	82.00 a	20.75 a	5.40 a	18.50 a
Adabor	142.62 b	81.12 a	19.62 a	5.35 a	18.25 a

Sher-e-Bangla Nagar	152.25 a	81.50 a	19.68 a	5.27 a	19.75 a
Dhanmondi	152.00 a	82.00 a	20.75 a	5.50 a	19.12 a
Level of Significance	*	NS	NS	NS	NS
CV (%)	9.66%	3.30%	10.87%	10.17%	14.17%

11.10.7.2: Effect of treatment on yield contributing characteristics of dahlia

Number of flower per plant

The highest number of flower per plant (23.25) of dahlia was observed from Dhanmondi. The lowest number of flower per plant was obtained from Mohammadpur which was 18.13 (Table 11.37).

Number of flower/plot

A significant difference was observed of number of flower per plot of dahlia. The highest number flower per plot of dahlia (226.68) was observed from Dhanmondi. The lowest number of flower per plot was observed from Mohammadpur which was 176.72 (Table 11.37).

Number of flower per hectare

The highest number of flower per hectare (232500) was observed from Dhanmondi which was statistically different from Adabor and Sher-e-Bangla Nagar. The lowest number of flower (181250) was found from Mohammadpur. But the reference yield of salvia was around 250000-300000 per hectare (Table 11.37).

Table 11.37: Effect of treatment on yield contributing characteristics of dahlia

Treatment	Number of flower/plant	Number of flower/plot	Number of flower/ha	Reference yield/ ha
Mohammadpur	18.13 c	176.72 c	181250 d	250000-300000
Adabor	21.00 b	204.75 b	210000 b	
Sher-e-Bangla Nagar	20.62 bc	201.09 bc	206250 c	
Dhanmondi	23.25 a	226.68 a	232500 a	
Level of Significance	*	*	*	
CV (%)	32.30%	32.30%	32.30%	

11.10.8: Growth and yield performance of salvia

11.10.8.1: Effect of treatment on morphological characteristics of salvia

Plant Height

There were no significant differences found in plant height of salvia as compared to different treatments. The maximum plant height of salvia (44.87 cm) was obtained from Adabor which was statistically similar

from Dhanmondi and Sher-e-Bangla Nagar. The lowest plant height of salvia was obtained 43.25 cm from Mohammadpur. But there was no significant difference as well (Table 11.38).

Number of leaf per plant

Different locations with different characteristics of the area showed significant variations on number of leaf per plant of salvia. The highest number of leaves (182.87) was observed from Adabor. The lowest number of leaves (157.00) was observed from Mohammadpur.

Leaf length

Different treatment had no significant effect with the leaf length of salvia. However the highest leaf length (15.14 cm) was observed from Mohammadpur. The lowest leaf length of salvia (14.21 cm) observed from Adabor (Table 11.38).

Leaf breath

No significant variation was observed of leaf breadth of salvia as compared to various treatments. The highest leaf breath of salvia was 5.25 cm which was observed from Mohammadpur that was similar from Sher-e-Bangla Nagar (5.24 cm). The lowest leaf breath (5.03 cm) observed from Adabor (Table 11.38).

Number of branch per plant

Branching of flower plant is an important characteristic for the maximum production of salvia. The highest number of branch per plant of salvia (23.88) was observed from Sher-e-Bangla Nagar and the lowest number of branch per plant (23.00) was obtained from Adabor (Table 11.38).

Table 11.38: Effect of treatment on morphological characteristics of salvia

Treatment	Plant height (cm)	Number of leaf	Leaf length (cm)	Leaf breath (cm)	Number of branch/plant
Mohammadpur	43.25 a	157.00 c	15.14 a	5.25 a	23.13 a
Adabor	44.87 a	182.87 a	14.21 a	5.03 a	23.00 a
Sher-e-Bangla Nagar	43.62 a	163.13 b	14.66 a	5.24 a	23.88 a
Dhanmondi	44.12 a	161.75 b	14.55 a	5.08 a	23.13 a
Level of Significance	NS	**	NS	NS	NS
CV (%)	8.17%	17.16%	5.04%	7.15%	9.42%

11.10.8.2: Effect of treatment on yield contributing characteristics of salvia

Number of flower per plant

Data revealed that different treatments had highly significant effect on the number of flower per plant od salvia. The highest number of flower per plant obtained from Mohammadpur which was (20.00) statistically

similar from Sher-e-Bangla Nagar (18.38) and Dhanmondi (18.87). The lowest number of flower per plant (16.50) was obtained from Adabor (Table 11.39).

Number of flower per plot

The maximum number of flower per plot (195.00) was observed from Mohammadpur which was statistically different from Dhanmindi and Sher-e-Bangla Nagar. The lowest number of flower per plot (160.87) was found from Adabor.

Number of flower per hectare

The highest number of flower per hectare (200000) was observed from Mohammadpur and the second highest number of flower was obtained from Dhanmondi. The lowest number of flower per hectare (165000) was obtained from Adabor. The reference yield of salvia was 200000-250000 (Table 11.39).

Table 11.39: Effect of treatment on yield contributing characteristics of salvia

Treatment	Number of flower/plant	Number of flower/plot	Number of flower/ha	Reference yield/ ha
Mohammadpur	20.00 a	195.00 a	200000 a	200000-250000
Adabor	16.50 b	160.87 d	165000 c	
Sher-e-Bangla Nagar	18.38 a	179.15 c	183750 b	
Dhanmondi	18.87 a	184.03 b	188750 b	
Level of Significance	**	**	**	
CV (%)	14.92%	14.92%	14.92%	

11.10.9: Effect of treatment on kharif-1 season vegetable crops in roof top garden

11.10.9.1: Growth and yield performance of okra

11.10.9.1.1: Effect of treatment on morphological characteristics of okra

Plant Height

Different treatment had significant influence on plant height of okra produced in Kharif-1 season. The maximum plant height of okra (102.00 cm) was observed from Adabor which was statistically different from Dhanmondi and Mohammadpur. The average lowest number of plat height of okra was obtained from Sher-e-Bangla Nagar which was 88.38 cm (Table 11.40).

Number of leaves per plant

Number of leaves per plant of okra is an important character for production of okra. On average the highest number of leaves per plant of okra (77.38) was observed from Sher-e-Bangla Nagar. The average of lowest number of leaves (62.63) was found from Dhanmondi (Table 11.40).

Leaf length

The highest leaf length of okra (15.63 cm) was observed from Dhanmondi which was statistically similar from Sher-e-Bangla Nagar and Mohammadpur. The lowest leaf length (13.50 cm) was observed from Adabor.

Stem diameter

No significant variations were observed of stem diameter of okra due to different treatments. The highest stem diameter (1.16 cm) was observed from Adabor which was similar from Mohammadpur and Sher-e-Bangla Nagar. The lowest number of stem diameter was observed from Dhanmondi which was 1.03 cm (Table 11.40).

Table 11.40: Effect of treatment on morphological characteristics of okra

Treatment	Plant height (cm)	Number of leaf/plant	Leaf length (cm)	Stem diameter (cm)
Mohammadpur	95.37 b	68.88 b	15.50 a	1.15 a
Adabor	102.00 a	69.75 b	13.50 b	1.16 a
Sher-e-Bangla Nagar	88.38 c	77.38 a	15.13 a	1.10 a
Dhanmondi	98.13 b	62.63 c	15.63 a	1.03 a
Level of Significance	**	**	**	NS
CV (%)	11.62%	22.52%	17.37%	20.88%

11.10.9.1.2: Effect of treatment on yield contributing characteristics of okra

Fruit length

Data showed that a significant variation was observed from fruit length of okra due to different treatments. The highest fruit length () was observed from Adabor which was statistically similar from Mohammadpur and Dhanmondi. The lowest number of fruit length (15.25 cm) was observed from Sher-e-Bangla Nagar (Table 11.41).

Fruit weight per plant

There was no significant variation observed of fruit weight per plant of okra due to different treatments. The maximum fruit weight per plant of okra (1.42 kg) was observed from Mohammadpur. However, the lowest number of fruit weight (1.11 kg) was obtained from Adabar (Table 11.41).

Fruit weight per plot

The highest fruit weight per plot of okra (13.89 kg) was obtained from Mohammadpur which was similar from Sher-e-Bangla Nagar and Dhanmondi. The lowest fruit weight per plot (10.84 kg) was observed from Adabor (Table 11.41).

Fruit weight per hectare

The highest fruit weight per hectare of okra (14.25 ton) was observed from Mohammadpur which was statistically similar from Sher-e-Bangla Nagar (13.25 ton) and Dhanmondi (14.00 ton). The lowest fruit per

hectare was obtained from Adabor which was 11.12 ton/hectare. The reference yield of okra per hectare was 15-18 ton per hectare. So, in this case, okra production was identical for roof garden in the city like Dhaka (Table 11.41).

Table 11.41: Effect of treatment on yield contributing characteristics of okra

Treatment	Fruit length (cm)	Fruit weight (kg)/ plant	Fruit weight kg/plot	Fruit weight (ton/ha)	Reference yield (ton/ha)
Mohammadpur	15.87 a	1.42 a	13.89 a	14.25 a	15-18
Adabor	16.43 a	1.11 a	10.84 b	11.12 b	
Sher-e-Bangla Nagar	15.25 a	1.32 a	12.91 a	13.25 a	
Dhanmondi	15.50 a	1.38 a	13.52 a	14.00 a	
Level of Significance	NS	NS	*	*	
CV (%)	12.88%	26.33%	26.33%	26.33%	

11.10.10: Growth and yield performance of bitter gourd

Lobes per leaves

Bitter gourd leaves are divided into number of lobes. On an average the highest number lobes (6.63) are observed in Mohammadpur which was similar to Adabor and Dhanmondi. The lowest number of lobes (5.88) was observed in Sher-e-Bangla Nagar (Table 11.42).

Fruit length

No significant variations were observed in fruit length of bitter gourd. However, the highest fruit length of bitter gourd (16.60 cm) was obtained in Dhanmondi which was similar to Sher-e-Bangla Nagar and Adabor. Whereas, the lowest number of fruit weight was obtained from Mohammadpur which was 15.03 cm (Table 11.42).

Fruit breadth

The highest fruit breath of bitter gourd (3.36 cm) was observed from Adabor whereas, the lowest fruit breath (3.09) was observed from Dhanmondi. In case of fruit breath, there is no significant variations on fruit breath were not found due to application of different treatment.

Fruit weight per plant

The highest fruit weight per plant (4.03 kg) was observed from Sher-e-Bangla Nagar. The lowest fruit weight was observed from 3.61 kg from Mohammadpur.

Fruit weight per plot

The heighest fruit weight per plot (39.24 kg) was found in Sher-e-Bangla Nagar and the second highest fruit weight per plot was observed from Dhanmondi which was 37.17 kg. The lowest fruit weight (35.22 kg) was found from Mohammadpur (Table 11.42).

Fruit weight per hectare

In case of bitter gourd, the highest fruit weight per hectare (40.25 ton) was obtained from Sher-e-Bangla Nagar. The lowest fruit weight per hectare (36.13 ton) was obtained from Mohammadpur which was statistically similar from Adabor. The reference yield per hectare of bitter gourd was 35-45 ton/ha. The roof top production of bitter gourd was identical to reference field (Table 11.42).

Table 11.42: Effect of treatment on growth and yield of bitter gourd

Treatment	Lobes/ leaf	Fruit length (cm)	Fruit breath (cm)	Fruit weight (kg/ plant)	Fruit wt. (kg/plot)	Fruit weight (ton/ha)	Reference yield (ton/ha)
Mohammadpur	6.63 a	15.03 a	3.17 a	3.61 a	35.22 c	36.13 c	35-45
Adabor	6.00 a	15.47 a	3.36 a	3.68 a	35.83 c	36.75 c	
Sher-e-Bangla Nagar	5.88 a	15.88 a	3.28 a	4.03 a	39.24 a	40.25 a	
Dhanmondi	5.88 a	16.60 a	3.09 a	3.81 a	37.17 b	38.13 b	
Level of Significance	NS	NS	NS	NS	*	*	
CV (%)	21.83%	12.46%	9.94%	23.58%	23.58%	23.58%	

11.10.11: Yield performance of bottle gourd

Fruit weight per plant

Data revealed that fruit weight of bottle gourd had a significant variation for applying various level of treatments. The highest fruit weight per plant of bottle gourd (25.37 kg) was observed from Dhanmondi. The lowest fruit weight (22.37 kg) was observed from Sher-e-Bangla Nagar (Table 11.43)

Fruit weight per plot

The highest fruit weight per plot (61.85 kg) was obtained from Dhanmondi which was statistically similar from Adabor. The lowest fruit weight per plot (53.53 kg) was obtained from Sher-e-Bangla Nagar (Table 11.43).

Fruit weight per hectare

The reference yield of bottle gourd was 60-65 ton per hectare. In roof top experiments, the highest fruit weight per hectare (63.43 ton) was observed from Dhanmondi. The lowest fruit weight per hectare was observed from Sher-e-Bangla Nagar which was 55.94 ton (Table 11.43).

Table 11.43: Effect of treatment on yield of bottle gourd

Treatment	Fruit weight (kg/plant)	Fruit weight (kg/plot)	Fruit weight (ton/ha)	Reference yield (ton/ha)
Mohammadpur	24.00 b	58.50 b	60.00 b	60-65
Adabor	25.12 a	61.24 a	62.81 a	
Sher-e-Bangla Nagar	22.37 c	54.53 c	55.94 b	
Dhanmondi	25.37 a	61.85 a	63.43 a	
Level of Significance	*	*	*	
CV (%)	16.55%	16.55%	16.55%	

11.10.12: Yield performance of pumpkin

Fruit weight per plant

In case of pumpkin, there was no significant variation was found due to different treatment. The highest fruit weight per plant (7.88 kg) was observed in Mohammadpur and Dhanmondi. The lowest fruit weight per plant (7.50 kg) was obtained from Sher-e-Bangla Nagar (Table 11.44).

Fruit weight per plot

On an average the highest fruit weight of pumpkin (23.99 kg) was obtained from Dhanmondi and Mohammadpur. The lowest fruit weight per plot (23.23 kg) was obtained from adabor which was similar to Sher-e-Bangla Nagar (Table 11.44).

Fruit weight per hectare

The average fruit weight per hectare (24.61 ton) was found from Dhnmondi and Mohammadpur. The lowest fruit weight per hectare was observed from Sher-e-Bangla Nagar which was 23.43 ton per hectare. This result also similar from the reference yield which was 20-30 ton/ha (Table 11.44).

Table 11.44: Effect of treatment on yield of pumpkin

Treatment	Fruit weight (kg/plant)	Fruit weight (kg/plot)	Fruit weight (ton/ha)	Reference yield (ton/ha)
Mohammadpur	7.88 a	23.99 a	24.61 a	20-30
Adabor	7.63 a	23.23 a	23.82 a	
Sher-e-Bangla Nagar	7.50 a	22.85 a	23.43 a	
Dhanmondi	7.88 a	23.99 a	24.61 a	
Level of Significance	NS	NS	NS	
CV (%)	20.51%	20.51%	20.51%	

11.10.13: Yield performance of spinach

The highest yield of spinach was observed in Dhanmondi which was 15 kg per plot and 82 ton per hectare. The lowest production of spinach (9 kg) was observed in the rooftop of the Adabor area. The lowest yield per hectare was observed in Adabor which was 49 ton.

Table 11.45: Effect of treatment on yield of spinach

Treatment	Yield kg/plot	Yield ton/ha
Mohammadpur	12kg	26 ton
Adabor	9kg	19 ton
Sher-e-Bangla Nagar	11kg	20 ton
Dhanmondi	15kg	32 ton

11.10.14: Yield performance of amaranth

The highest amount of amaranth was observed in Adabor and Sher-e-Bangla Nagar which was 7 kg per plot and 39 ton per hectare. The lowest amount of yield was obtained from Mohammadpur which was 6 kg per plot and 33 ton per hectare.

Table 11.46: Effect of treatment on yield of amaranth

Treatment	Yield kg/plot	Yield ton/ha
Mohammadpur	6kg	33 ton
Adabor	7kg	39 ton
Sher-e-Bangla Nagar	7kg	39 ton
Dhanmondi	6.5kg	36 ton

12. Research highlight/findings (Bullet point – max 10 nos.):

Findings of two major part of this project:

1st part: Questionnaire survey:

- About 65% RTG (rooftop garden) owners of selected areas get 21-40 kg of various products/year.
- Dhaka city rooftop gardens posses high species diversity (Shannon Weaver Diversity Index-4.51) and high interspecies diversity.
- About 90% RTG owners consumed fresh products from their rooftop garden while only 9% RTG owners sell their products in the local markets.
- The survey result showed that the air temperature reduced by 5.2^0C as compared to bare roof.
- About 30% RTG owners felt thermal comfort in their room as compared to without garden.

2nd part: rooftop experiment:

- Selected Robi vegetables like cabbage, cauliflower, brinjal, and tomato grows satisfactorily.
- Selected Kharif-1 vegetables like okra, bitter gourd, bottle gourd, pumpkin, spinach and amaranth produce significant yield and
- Selected flowers like dahlia, marigold, and Sylvia grow satisfactorily with significant life span.

B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP Target		Achievement		Remarks
	Phy	Fin (Tk)	Phy (%)	Fin (Tk)	
a) Office equipment	Laptop, UPS, Laser Printer, Scanner, Digital Camera	130000	100	130000	
b) Lab &field equipment	Soil Moisture Meter, Electric Balance, Thermo Meter	60500	100	60500	
c) Other capital items	Executive Table Executive Chair Front Chair Computer Table Computer Chair File Cabinet	78500	100	78500	

2. Establishment/renovation facilities: Not applicable

Description of facilities	Newly established		Upgraded/refurbished Remarks		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. Training/study tour/ seminar/workshop/conference organized:

Description	Number of participant			Duration (Days)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop	19	11	30	1	

C. Financial and physical progress

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Refund to NATP	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	493980	493980	493980		100	
B. Field research/lab expenses and supplies	684400	630658	630658		92.15	
C. Operating expenses	119000	118050	118050		99.20	
D. Vehicle hire and fuel, oil & maintenance	35000	34750	34750		99.29	
E. Training/workshop/seminar etc.	90000	81000	81000		90.00	
F. Publications and printing	88000	85230	25650	62350	29.15	
G. Miscellaneous	20000	17000	17000		85.00	
H. Capital expenses	269000	252608	252608		93.91	

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
To identify existing plant species diversity of selected household rooftops of the study area.	Survey of 40 rooftop gardens and identify major species of fruit, flower, ornamental and medicinal plants.	• Names of the major species of plants found in the rooftop gardens shown in the results and discussion chapter. • During survey city dwellers inspired to develop rooftop gardens for fulfillment of their desired food products.	• The roof garden microclimate is improved by decreasing urban heat generation and atmospheric contaminants
To assess the benefits of rooftop gardens in providing thermal comfort and ecosystem services	• Set instruments to collect thermal data on gardens of roof and bare roof. • Food supply, biodiversity, economic, disease regulation, mental satisfaction and education & learning were identify based on survey data collection	• Rooftop garden owners have seen the difference of temperature on rooftop gardens and bare roof and believe the temperature on rooftop gardens is less then bare roof. • RTG owners get about • -40% food supply -75% biodiversity conservation -7.5% economic support	•Contribute to food security, safety and nutrition through growing crops in the roof garden successfully.

		-2.5% disease regulation -47.5% mental satisfaction 22.5% education & learning	
To investigate and identify suitable vegetable and flower species for rooftop gardening through demonstration	• Four rooftop demonstration plot consisting eight concrete bed were constructed on the top of four buildings in the areas of Adabar, Mohammadpur,Dhanmondi and Sher-e-Bangla Nagar	• Selected Robi vegetables like cabbage, cauliflower, brinjal, and tomato grows satisfactorily • Selected Kharif-1 vegetables like okra, bitter gourd, bottle gourd, pumpkin, spinach and amaranth produce significant yield and • Selected flowers like dahlia, marigold, and Sylvia grows satisfactorily with significant life span	Contribute to food security, safety and nutritional security through growing vegetables and flowers in the roof garden successfully.

E. Materials Development/Publication made under the Sub-project:

Publication	**Number of publication (e.g. paper title, name of journal, conference name, etc.)**		**Remarks**
	Under preparation	**Completed and published**	
Technology bulletin/ booklet/leaflet/flyer etc.	-	-	-
Journal publication	**Under preparation**	-	-
Information development	**Under preparation**		
Other publications, if any	-	-	-

F. Technology/Knowledge generation/Policy Support (as applied):

i. Generation of technology (Commodity & Non-commodity)

• Rooftop garden have a positive impact on the urban surroundings of Dhaka city with changing environment.

• Concrete bed with netting is suitable to cultivate robi, kharif-1 vegetables and winter season flower cultivation in the rooftop garden.

•The combined application of cowdung and soil gave higher yield of vegetables and flowers.

ii. **Generation of new knowledge that help in developing more technology in future**

Growing safe and fresh vegetable production on the roof garden as a part of sustainable urban agriculture in the Dhaka city.

iii. Technology transferred that help increased agricultural productivity and farmers' income

Further research is necessary to generate matured technologies on model improvement and crop production in the roof garden.

iv. Policy Support

Ministry of Agriculture is also laying emphasis on the sustainable development of rooftop garden in Dhaka city under several projects/programs viz. "Urban Agricultural Production Support Project for Roof Gardening".

G. Information regarding Desk and Field Monitoring

i) Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.):

- A roof garden model is to be developed with various fruits, vegetables and flowers.
- Roof top gardening is an important issue in urban area. So further study on roof top gardening is needed to generate appropriate production technology.
- Investigate insect pest and disease infestation in roof top gardening

ii) Field Monitoring (time& No. of visit, Team visit and output):

The sub-project is visited by a team of Bangladesh Agricultural Research Council on 26 February 2018. The team suggested to request the Director, PIU, BARC, NATP-2 for monitoring the sub-project with his team. They also recommended continuing this research activity.

H. Lesson Learned/Challenges (if any)

i) The rooftop gardening improves urban surroundings by decreasing temperature as well carbon dioxide (CO_2) and increasing oxygen (O_2) content in the atmosphere; it also makes bridge between city dwellers and the nature thus increase urban resilience with changing environment.

ii) Safe and fresh vegetable production in the urban rooftop gardens is the major concern and city dwellers increasingly practice this new technology as a part of daily practice.

I. Challenges (if any)

Erratic rainfall, delay fund release and deficiency of sufficient fund made some barrier to start and complete the sub-project activities smoothly.

Signature of the Principal Investigator Date ……. Seal	Counter signature of the Head of the organization/authorized representative Date …….. Seal

APPENDICES

Appendix 1

AN ENGLISH VERSION OF THE INTERVIEW SCHEDULE

Department of Agroforestry and Environmental Science

Sher-e-Bangla Agricultural University

Dhaka, Bangladesh

An interview schedule for a research study entitled

Assessment of Ecosystem services and Benefits of Rooftop Gardening for Eco-friendly City Development in Dhaka City using Geospatial Technology

Serial No.…….

Date: ……..

Name of the Survey Collector: Iffat Jahan Nur

Name of the garden owners:

Address of the Respondent	**House no.**	**Road no.**	**Area**	**GPS reading**

Q:1. Gender: Male…… female…….

Q:2. How old are you? ……Years

Q:3. Marital Status: Married/Unmarried/Divorced

Q:4. Education of the garden owners: ……..

Q:5.	**Give information about your annual income:**	
	Sources of income	**Amount of annual income (Taka)**
	1. Service holder	
	2. Business	
	3.Others	

Q:6. Family size:

Male …….. Female ……..…. Total ……..……..

Q:7. House Ownership:

1. Owner…… 2. Rent…… 3. Government Quarter……

Q:8.	**a) What is the approximate surface area of your roof garden?**	**square feet**
Q:9.	**b) What is the approximate surface area of your roof covered by vegetation?**	

Q:10. What is your purpose of practicing rooftop gardening?

1. Recreation ☐ 2. Economic ☐ 3.Nutritional ☐ 4. Aesthetic ☐

Q:11.	**What kind of species would you have in your roof garden which indicates diversification of plant species?**		
	i. Fruit species		
Sl. No.	**Plants name**	**Plants Number**	**Habit, family, genus and species**
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			
16.			
17.			
18.			
19.			
20.			
ii. Vegetable species			
Sl. No.	**Plants name**	**Plants Number**	**Habit, family, genus and species**
1.			
2.			

3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			
16.			
17.			
18.			
19.			
20.			

iii. Flower species			
Sl. No.	**Plants name**	**Plants Number**	**Habit, family, genus and species**
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			

iv. Ornamental species			
Sl No.	**Plants name**	**Plants Number**	**Habit, family, genus and species**
1.			
2.			
3.			

4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			
16.			
17.			
18.			
19.			
20.			

v. **Medicinal species**			
Sl. No.	**Plants name**	**Plants Number**	**Habit, family, genus and species**
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Q:12. What is the approximate yearly food production from your roof garden?……kg/year

Q: 13 .	**How does your garden help you to meet your domestic food demand?**	**Daily**	**weekly**	**yearly**

Q:14.	**How much daily time do you like to spend in your roof garden ?:**	**Extent of Informations**		
		Daily	**Weekly**	**Monthly**
	1. Below 1 hr			
	2. Below 2 hr			

	3. Above 2 hr			

Q:15.	What is the level of your mental satisfaction?	High	Medium	Low

Q:16. Do you feel cooler environment in your garden and in adjacent rooms near the garden?	Extent of Informations		
	Roof Temperature (C^o)	Room temperature (C^o)	Temperature outside (C^o)
1. High ☐ edium ☐			
3. Low ☐ 4. Not at all ☐			

Q:17. What is the approximate yearly expenditure for your garden?

.....taka

Q:18. Who nurses your garden ? :

1. Family member ☐
2. Family paid personel ☐
3. Gardener ☐

Q:19.	From where you get technical support ? :			
	Agricultural office	☐	Nearby Nurseries	☐
	Media/Book and printed matters	☐	No technical support	☐

Q:20. Did you receive any training on roof top gardening?

1. YES 0. NO

If YES, how many days (mention): ……

Appendix II

Descriptive Statistics

Sl. No.	Variable	N	Minimum	Maximum	Mean	Std. Deviation
1	Gender	40	1	2	1.4500	.50383
2	Age	40	26.00	67.00	46.0500	11.60007
3	Marital status	40	1	3	1.1500	.48305
4	Education	40	3.00	20.00	14.0500	3.88257
5	Occupation	40	1	3	2.1750	.90263
6	Family size	40	2.00	12.00	5.5000	2.60177
7	Annual income	40	200000.00	1200000.00	589250.0000	220470.21428
8	House ownership	40	1	3	1.2250	.57679
9	Surface area	40	950.00	3500.00	2070.0000	539.91927
10	Vegetation coverage	40	1.00	3.00	2.3500	.62224
12	Yearly food production	40	10.00	60.00	26.9500	12.01271
13	Regularity of Food supply	40	1.00	3.00	2.2250	.61966
14	Species diversity	40	2.53	4.71	3.8965	.57645
15	Thermal comfort	40	.00	3.00	1.9750	.83166
16	Yearly expenditure	40	1200.00	70000.00	12302.5000	15122.36394
17	Nursing	40	1.00	3.00	2.2250	.83166
18	Frequency of visit	40	1.00	3.00	1.2250	.47972
19	Spending time	40	1.00	3.00	2.0750	.72986
20	Mental atisfaction	40	1.00	3.00	2.3000	.68687
21	Technical support	40	1.00	4.00	2.1000	1.17233
22	Training	40	.00	3.00	1.7250	1.17642

Appendix III

Coordinates of the roof garden locations of the study area

Thana	Ward	Sub areas under thana	Coordinates of the roof garden location	
Mohammadpur	42	Chinumia Road Area (2)	**23.7682 90.3596**	**23.7686 90.3602**
		Tajmahal Road Area (1)	**23.7667 90.3586**	
	44	Zakir HossainRoad Area (1)	**23.7572 90.3658**	
		Salimullah Road Area (1)	**23.7601 90.3637**	
	45	Lalmatia Housing Society (1)	**23.7567 90.3669**	
		Iqbal Road Area (1)	**23.7605 90.3628**	
	46 (part)	Mohammadia Housing Society (2)	**23.7631 90.3585**	**23.7632 90.3546**
		Mohammadia Housing Ltd.(1)	**23.7612 90.3542**	
		Nobodoy Housing (2)	**23.7643 90.3537**	**23.7637 90.3536**
	47	Jafrabad (2)	**23.7507 90.3667**	**23.7505 90.3643**
		Shangkar (1)	**23.7507 90.3648**	
		Total=15		

Thana	Ward	Subareas under thana	Coordinates of the roof garden locations	
Adabor	Ward 43	Adabor (1)	**23.7729 90.3602**	
		Baitul Aman Society (1)	**23.7727 90.3561**	
		Monsurabad Housing (3)	**23.7734 90.3611**	**23.7734 90.3611**
	Ward 46 (part)	Pisciculture Housing (1)	**23.7675 90.3611**	
		Shekhertek (2)	**23.7668 90.3632**	**23.7678 90.3627**
		Total=8		

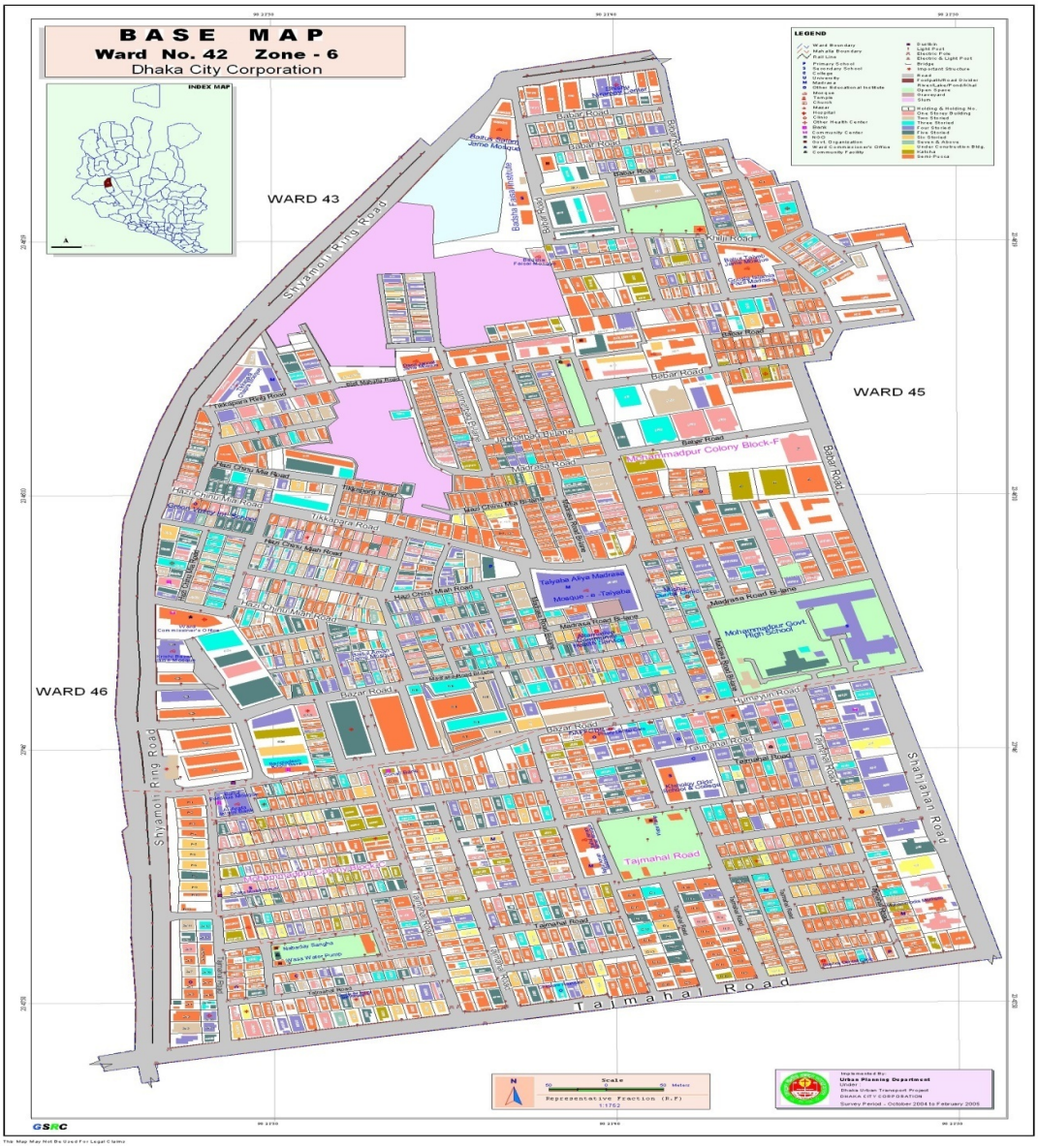
Thana	Ward	Subareas under thana		Coordinates of the roof garden locations	
Kalabagan	Ward 50	Kathalbagan Area (1)		**23.748 90.3902**	
		Panthapath Area (2)		**23.7533 90.3845**	**23.7533 90.3845**
		North Road Area(1)		**23.7435 90.3862**	
		Central Road Area (1)		**23.7418 90.3879**	
		Hatir pool (1)	Voter goli (1)	**23.7452 90.3925**	**23.7431 90.3881**
	Ward 51 (part)	Kalabagan Lake circus Area (2)		**23.7492 90.3820**	**23.7492 90.3820**
		Sobhanbagh (2)		**23.7468 90.3731**	**23.7478 90.3737**
		Total=11			

Thana	Ward	Subareas under thana	Coordinates of the roof garden locations		
Dhanmondi	Ward 49	Dhanmondi area	**23.7514 90.3751**	**23.7513 90.3749**	**23.7514 90.3751**
		Dhanmondi lake area	**23.7542 90.3736**	**23.7506 90.3732**	**23.7542 90.3736**
		Total=6			

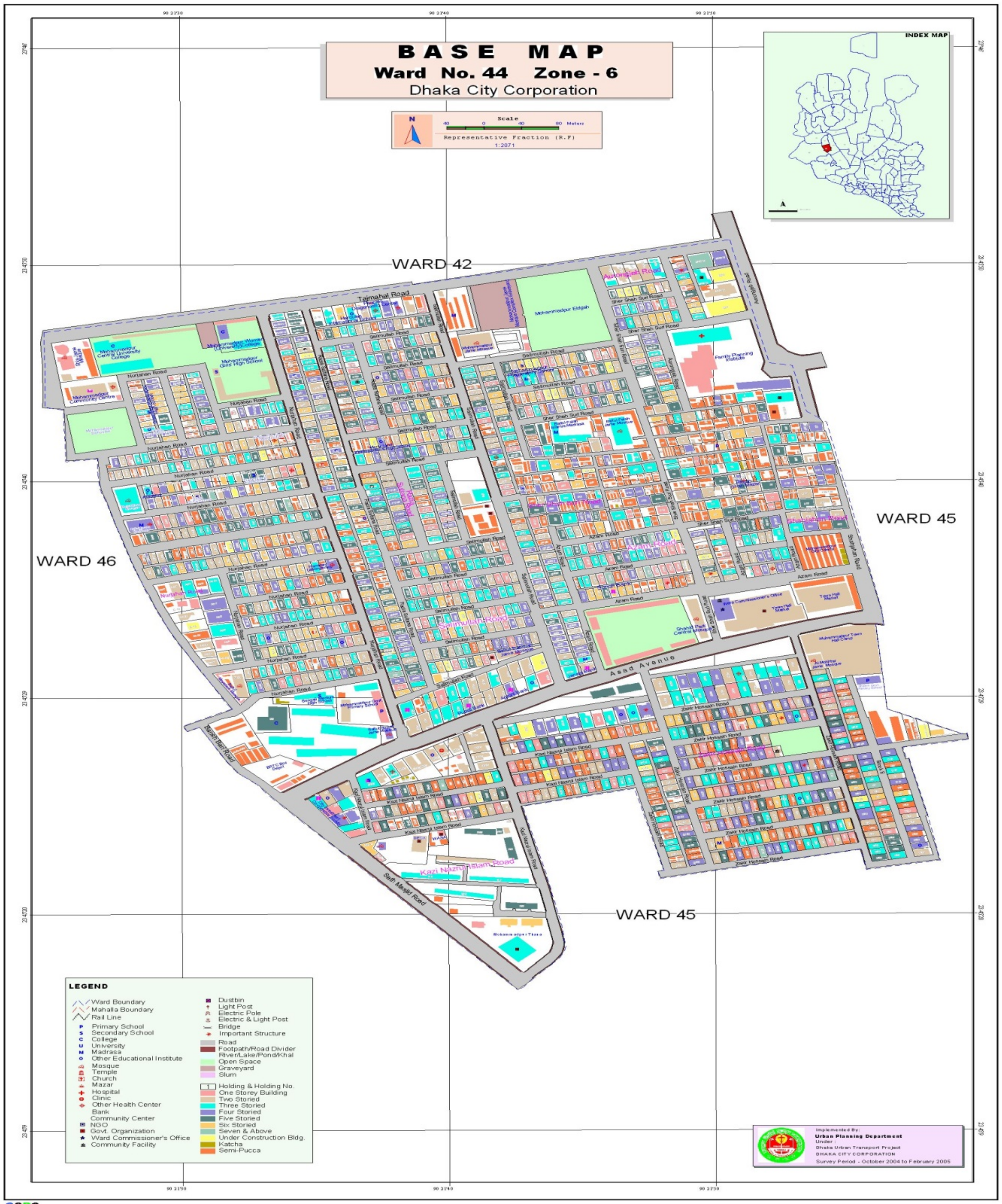
Appendix IV

Base maps of ward maps

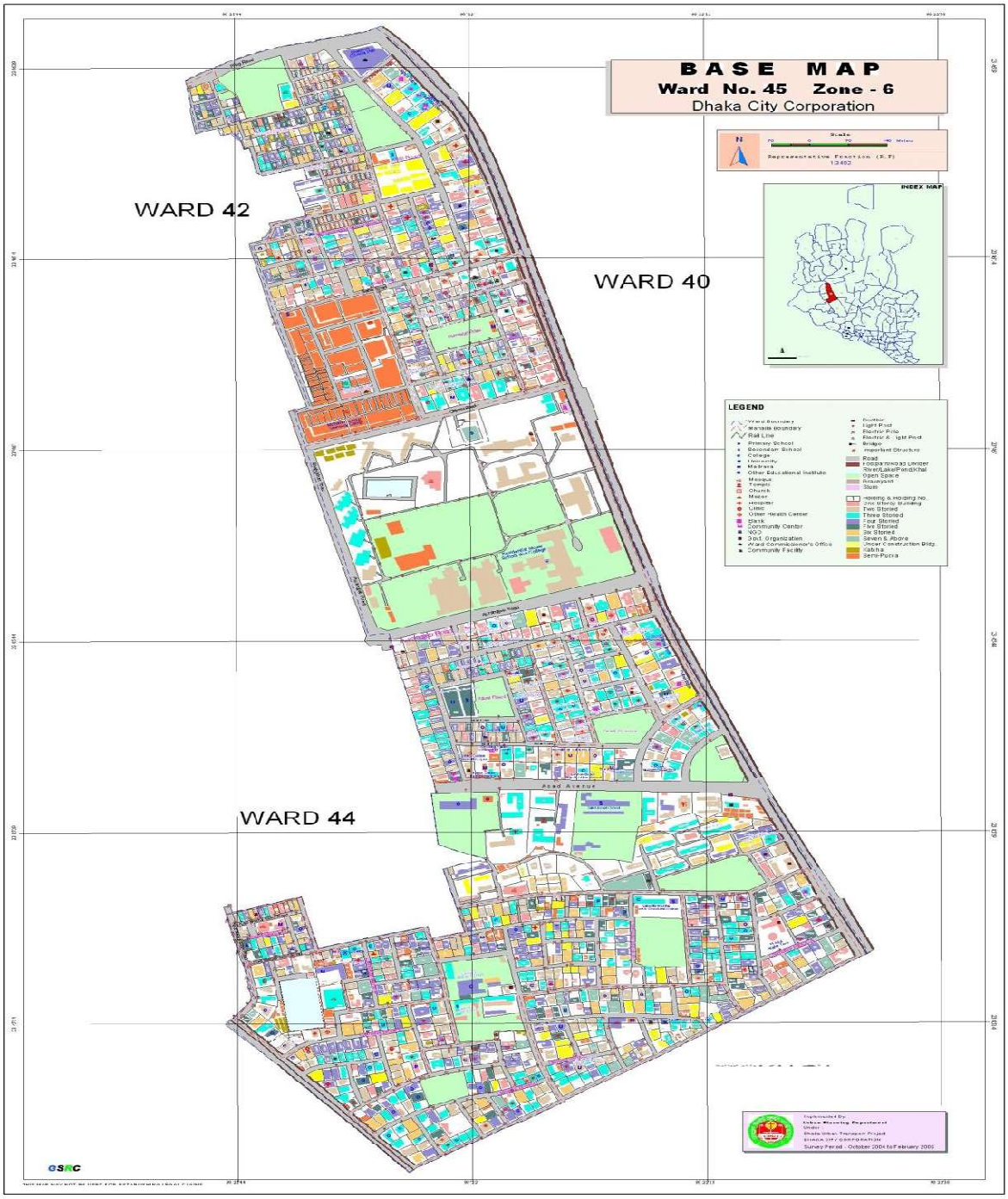
Ward maps of Mohammadpur Thana (ward 42, 44, 45, 46-part,47)



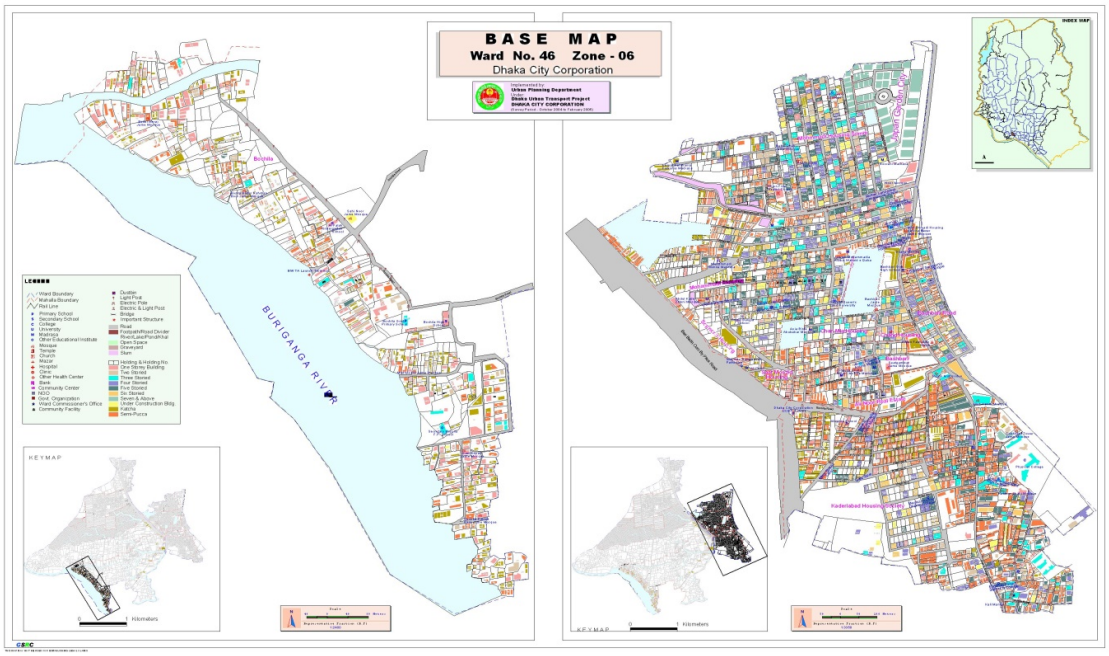
Ward 42


BASE MAP
Ward No. 44 Zone - 6
Dhaka City Corporation
Scale
Representative Fraction (R.F)
INDEX MAP
WARD 42
WARD 45
WARD 46
WARD 45
Asad Avenue
LEGEND
Ward Boundary
Mahalla Boundary
Rail Line
Primary School
Secondary School
College
University
Madrasa
Other Educational Institute
Mosque
Temple
Church
Mazar
Hospital
Clinic
Other Health Center
Bank
Community Center
NGO
Govt. Organization
Ward Commissioner's Office
Community Facility
Dustbin
Light Post
Electric Pole
Electric & Light Post
Bridge
Important Structure
Road
Footpath/Road Divider
River/Lake/Pond/Khal
Open Space
Graveyard
Slum
Holding & Holding No.
One Storey Building
Two Storied
Three Storied
Four Storied
Five Storied
Six Storied
Seven & Above
Under Construction Bldg.
Katcha
Semi-Pucca
Urban Planning Department
DHAKA CITY CORPORATION
GSRC

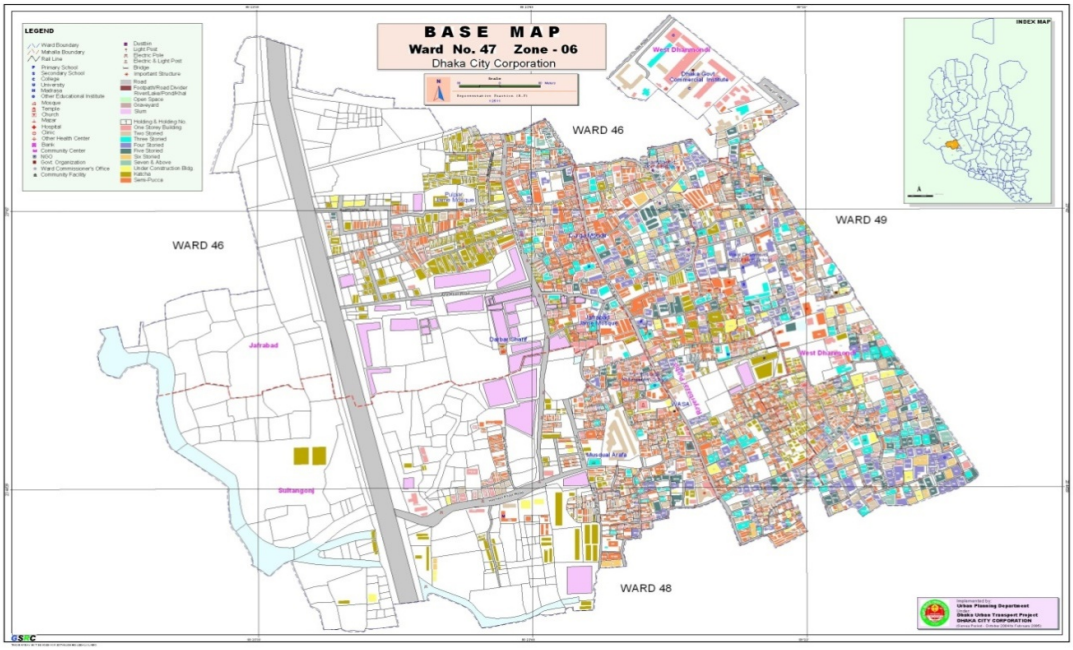
Ward 44


BASE MAP
Ward No. 45 Zone - 6
Dhaka City Corporation
WARD 42
WARD 40
WARD 44
INDEX MAP
LEGEND

Ward 45

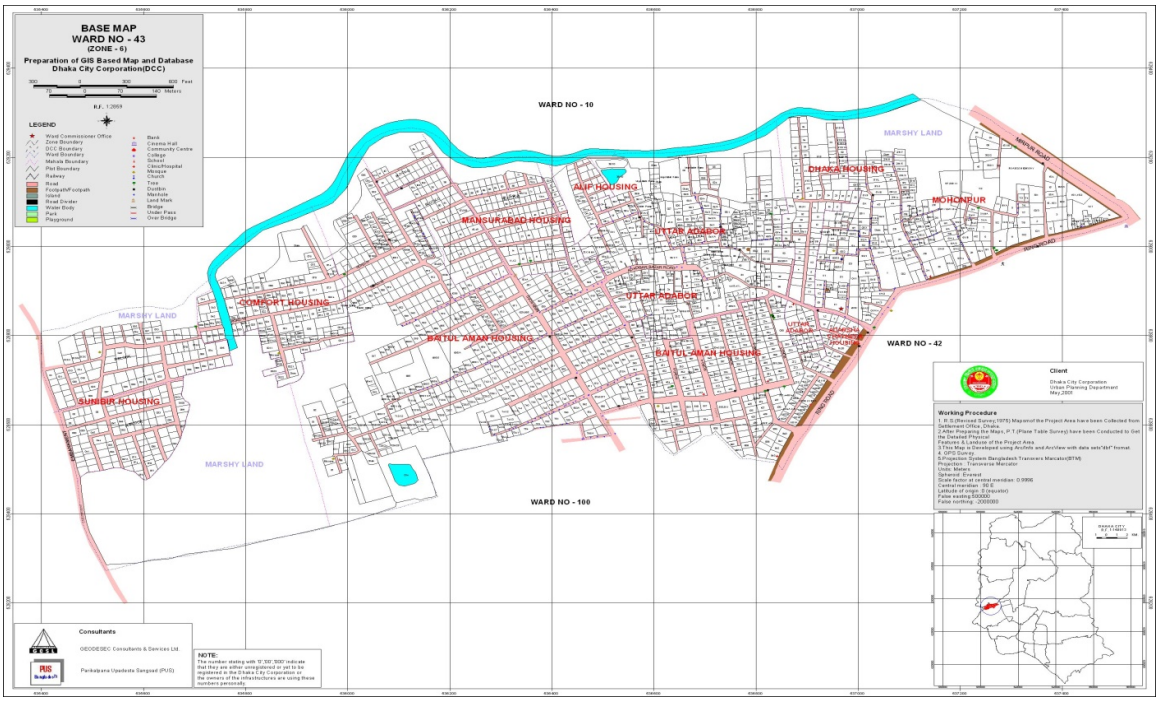


Ward 46 (part-2)

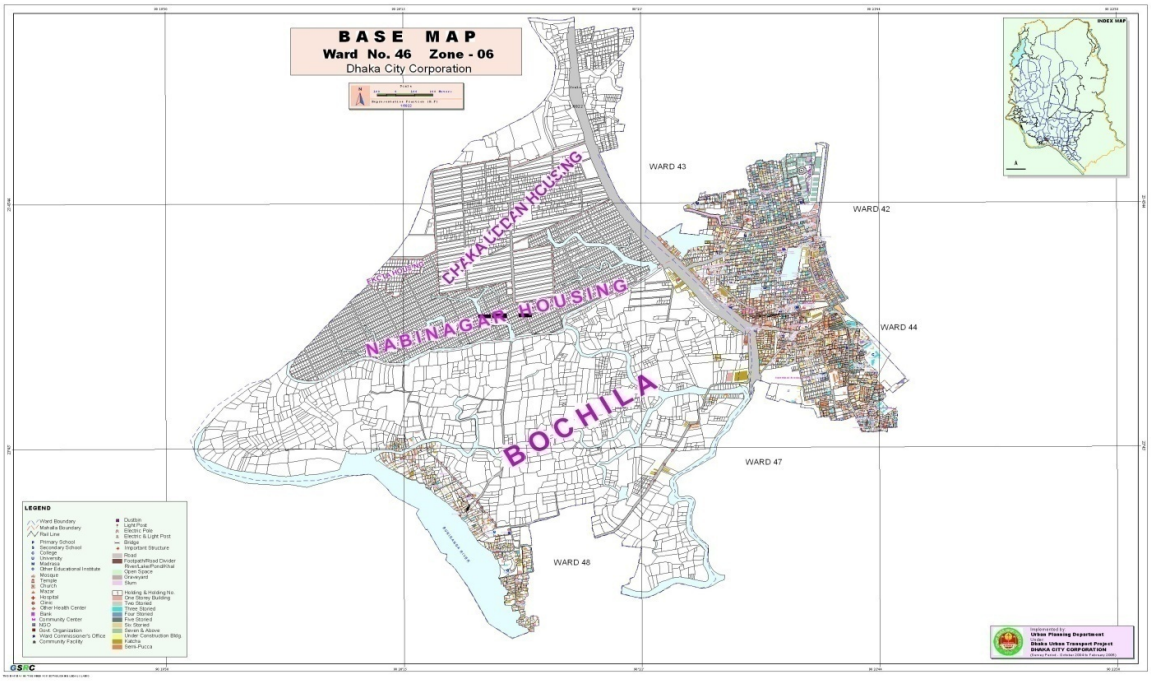


Ward 47

Ward map of Adabor Thana (ward 43, 46-part)

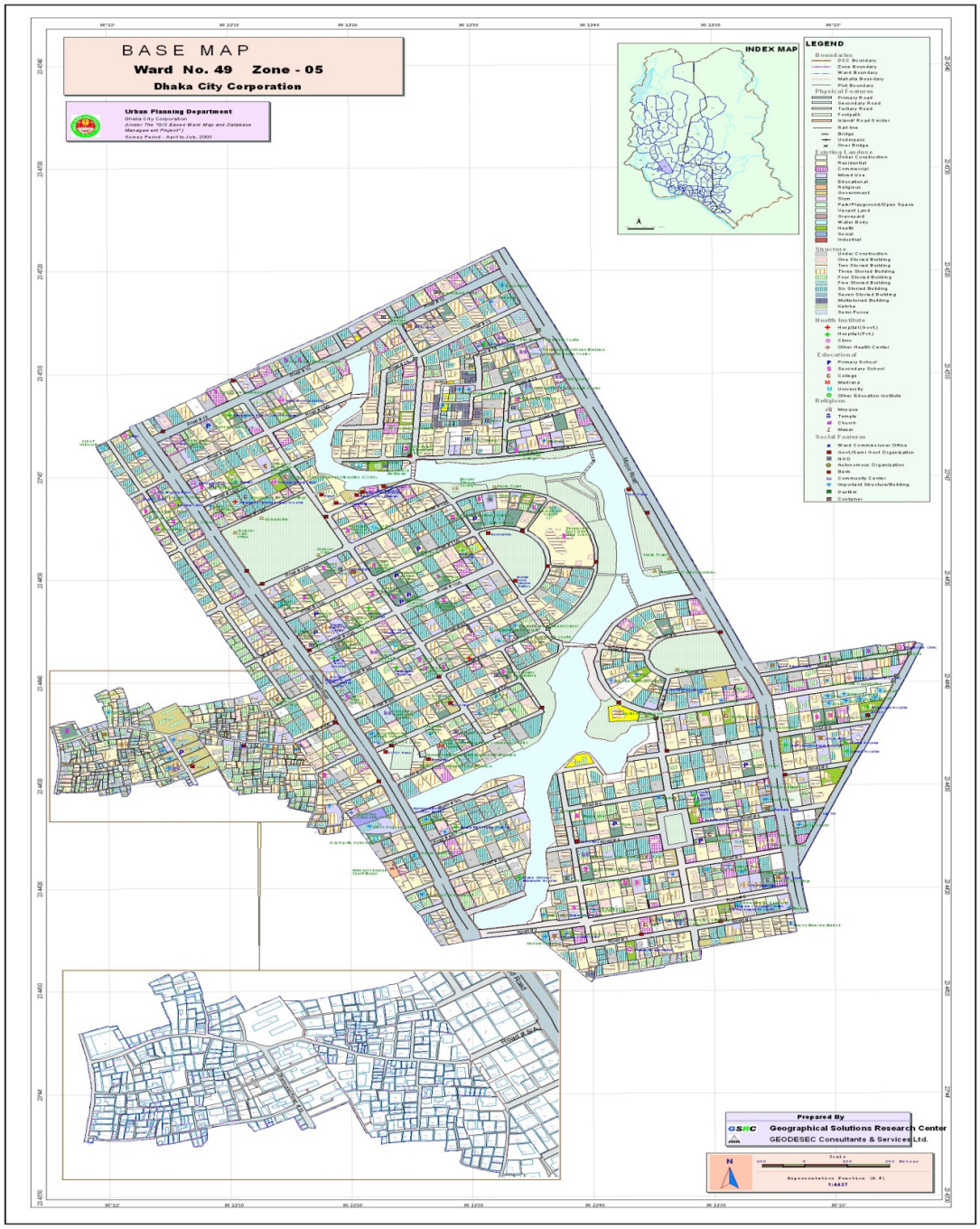


Ward 43



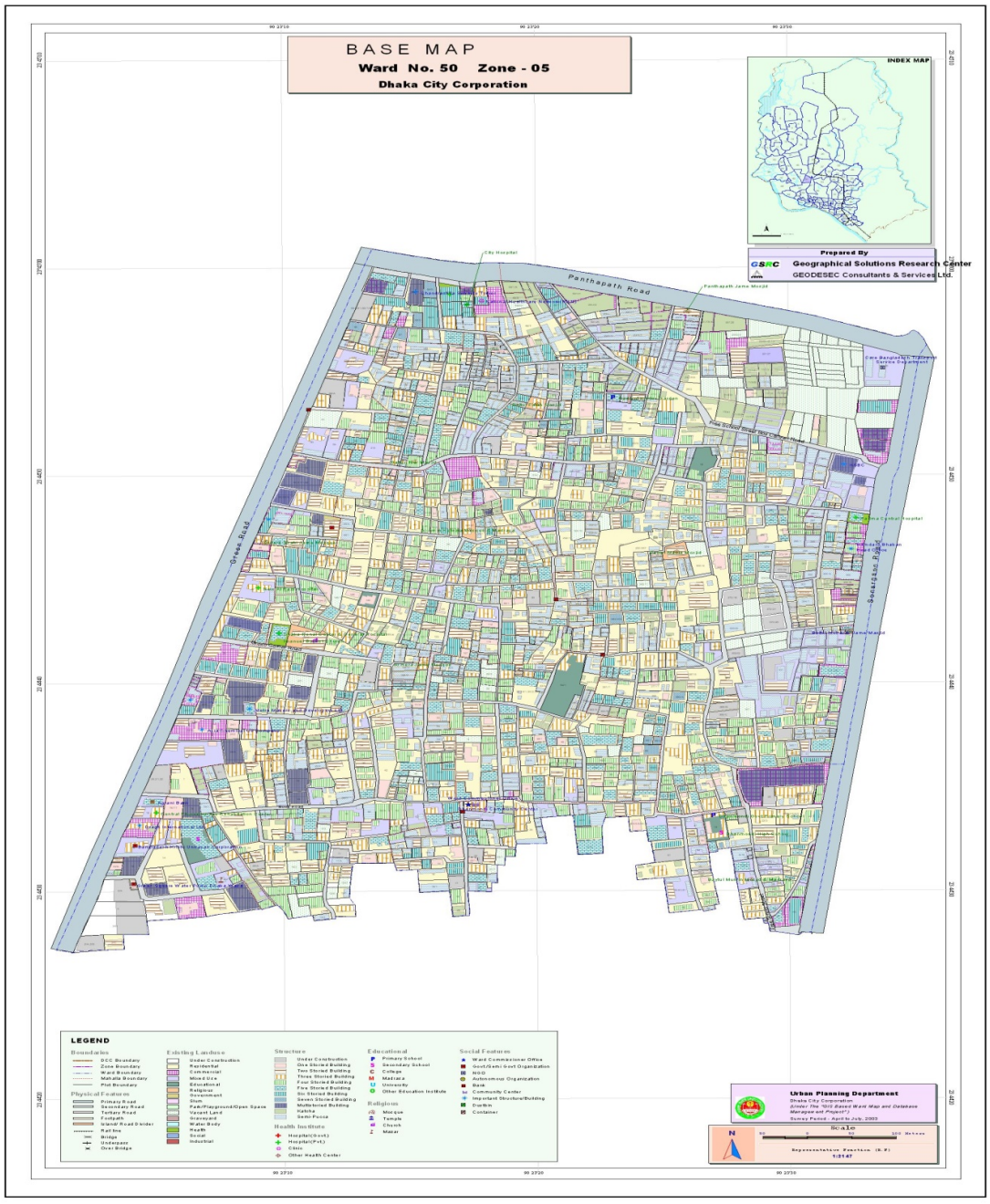
Ward 46 (part-1)

Ward map of Dhanmondi Thana (ward 49)

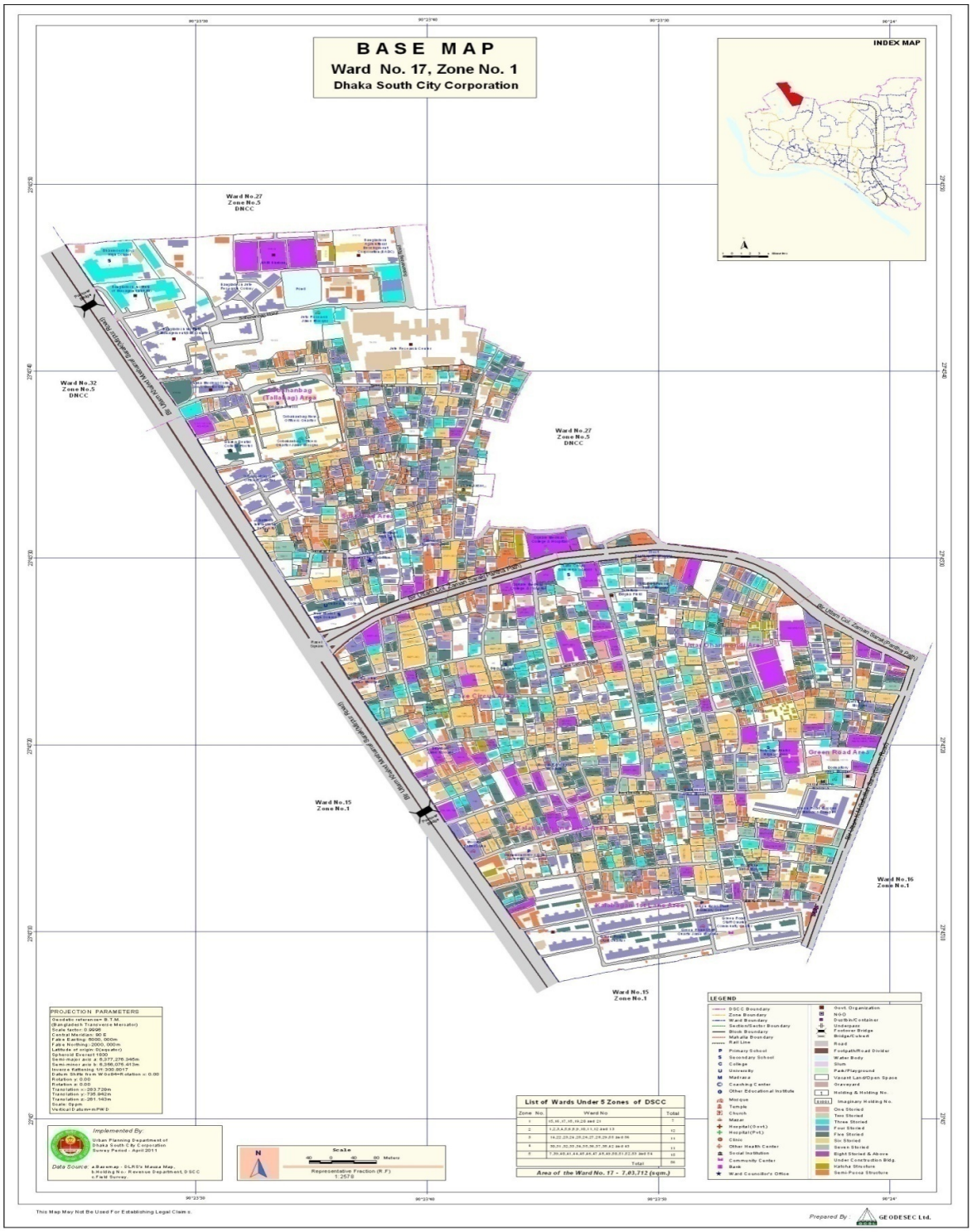

BASE MAP
Ward No. 49 Zone - 05
Dhaka City Corporation
Urban Planning Department
Dhaka City Corporation
(Under The "GIS Based Ward Map and Database Management Project")
Survey Period : April to July, 2003
INDEX MAP
LEGEND
Boundaries
DCC Boundary
Zone Boundary
Ward Boundary
Mahalla Boundary
Plot Boundary
Physical Features
Primary Road
Secondary Road
Tertiary Road
Footpath
Inland Road Divider
Rail line
Bridge
Underpass
Over Bridge
Existing Landuse
Under Construction
Residential
Commercial
Mixed Use
Educational
Religious
Government
Slum
Park/Playground/Open Space
Vacant Land
Graveyard
Water Body
Health
Social
Industrial
Structure
Under Construction
One Storied Building
Two Storied Building
Three Storied Building
Four Storied Building
Five Storied Building
Six Storied Building
Seven Storied Building
Multistoried Building
Kaccha
Semi-Pucca
Health Institute
Hospital(Govt.)
Hospital(Pvt.)
Clinic
Other Health Center
Educational
Primary School
Secondary School
College
Madrasa
University
Other Education Institute
Religious
Mosque
Temple
Church
Mazar
Social Features
Ward Commissioner Office
Govt/Semi Govt Organization
NGO
Autonomous Organization
Bank
Community Center
Important Structure/Building
Dustbin
Container
Prepared By
GSRC
Geographical Solutions Research Center
GEODESEC Consultants & Services Ltd.
N
Scale
Representative Fraction (R.F)
1:4437

Ward 49

Ward map of Sher-e-Bangla Nagar Thana: (ward 50,17)



Ward 50



Ward 17 (previous 51)