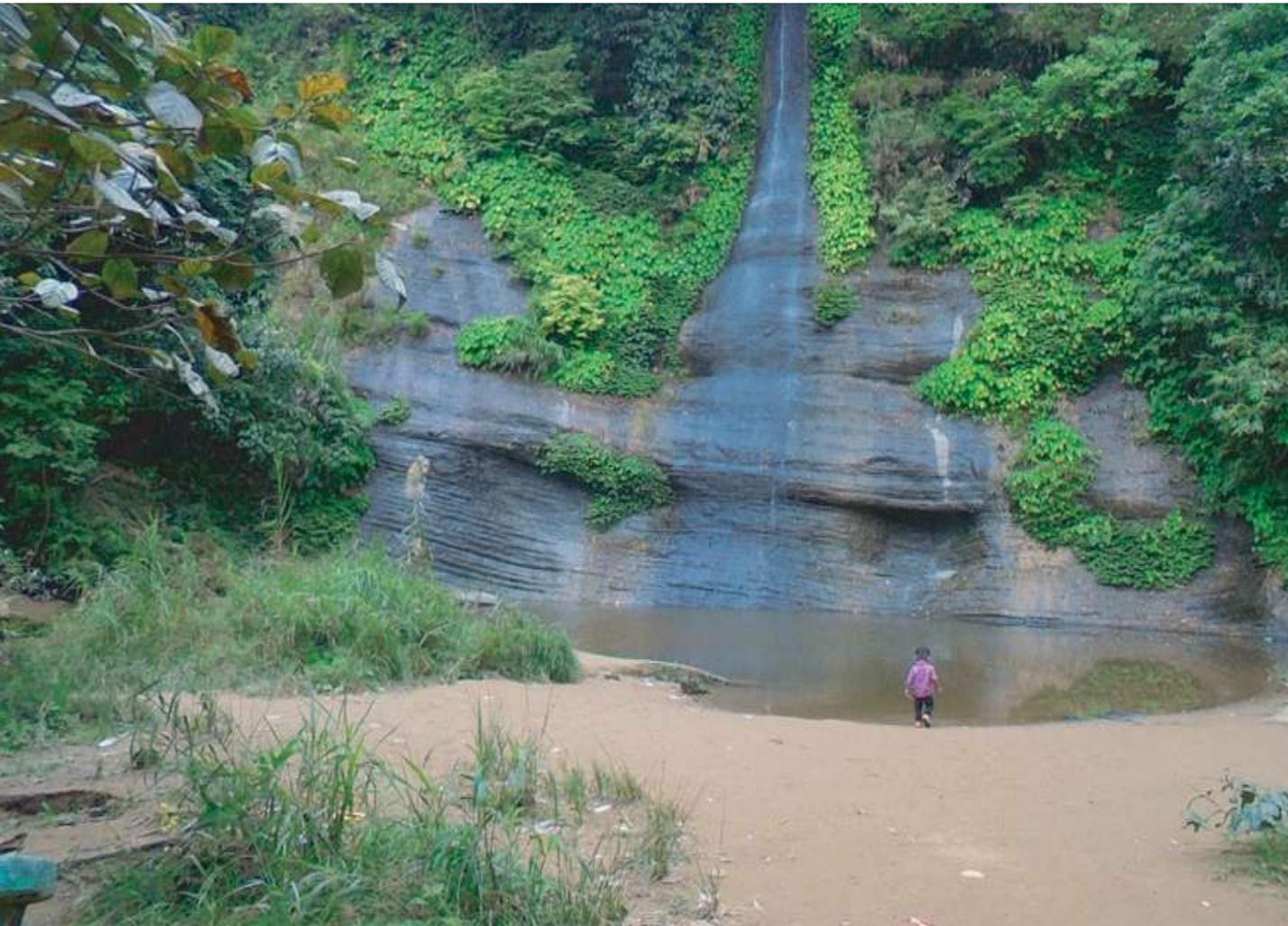


# Valuation of Ecosystem Services in Sitakunda Botanical Garden and Eco-park, Chattogram, Bangladesh

Bulletin 06  
Ecosystem Services Valuation  
Forest Economics Division



Government of the People's Republic of Bangladesh  
Ministry of Environment, Forest and Climate Change  
**Bangladesh Forest Research Institute**

Chattogram  
December 2024



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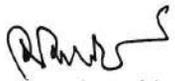
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# Foreword

The concept of ecosystem services, which refers to the benefits that society receives from the environment, is becoming important in scientific and policy-making aspects. These benefits include both productive and non-productive aspects, and it depends on the health of native plants, animals, and their ecological systems. Recognizing the value of ecosystem services has led to a shift in how protected areas are managed, with a focus on intervening in areas like biodiversity, water, primary industries, human settlements, regional planning, and climate change. This concept is also reshaping sustainable environmental management and generating new ideas for managing landscape resilience. While the scientific understanding of ecosystem services is well-developed, there is a lack of information on this topic in Bangladesh.

Bangladesh Forestry Master Plan emphasizes the importance of ecosystem services valuation for decision-making. Despite growing attention in policy documents, scientific literature on ecosystem services valuation in Bangladesh remains limited. Forest-based ecosystem services are highlighted in various policies and plans, including the draft National Forest Policy, Bangladesh Climate Change Strategy, National Adaptation Plan, Coastal Zone Policy, and Land Use Policy. Ecosystem services valuation is likely to become increasingly important for monitoring the progress and impacts of programmatic decisions on ecosystems in Bangladesh. On that note, Sitakunda Botanical Garden and Eco-park, Chattogram, a biodiversity hotspot, provides numerous ecosystem services to surrounding communities.

The valuation of ecosystem services in Sitakunda Botanical Garden and Eco-park is a groundbreaking study that contributes significantly to the forestry sector in Bangladesh. As the second of its kind for a protected area in the country, this research by Bangladesh Forest Research Institute (BFRI) sheds light on the economic value of the park's services. By quantifying these benefits, the study aims to raise awareness among stakeholders and inform policymakers, researchers, and practitioners for more effective management of protected areas. This pioneering work of BFRI is a crucial step towards sustainable conservation and resource management in Bangladesh.



10.12.2024

**Director**

Bangladesh Forest Research Institute  
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# Acknowledgement

We express our gratitude to Allah, the most gracious, benevolent, and merciful, for granting us the energy and good health to undertake the task of evaluating the economic worth of the ecosystem services provided by Sitakunda Botanical Garden and Eco-park in Chattogram, Bangladesh.

We are expressing our deep gratitude and appreciation for your valuable contributions to our research, entitled "Valuation of Ecosystem Services in Sitakunda Botanical Garden and Eco-park, Chattogram, Bangladesh".

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In conclusion, we are vastly expressing our earnest appreciation for all of your support, which has made this study possible. Your steadfast support and unwavering dedication have been indispensable to the success of this endeavor. We firmly believe that the findings of this study will

Sincerely,  
The Authors

## List of Acronyms and Abbreviations

AGB	Above Ground Biomass	IFESCU	Institute of Forestry and Environmental Sciences, University of Chittagong
AVG	Average	KII	Key Informant Interviews
Avg.	Average	MEA	Millennium Ecosystem Assessment
BD	Bulk Density	MoEFCC	Ministry of Environment, Forest and Climate Change
BDT	Bangladeshi Taka	NGO	Non-government Organization
BFD	Bangladesh Forest Department	NPK	Nitrogen, Phosphorus, Potassium
BFRI	Bangladesh Forest Research Institute	NTFP	Non Timber Forest Product
BGB	Below Ground Biomass	PABAT+	Protected Area Benefit Assessment Tool+
CFS	Cubic Feet per Second	PAs	Protected Areas
DBH	Diameter at Breast Height	ppm	Particle per Million
Deci.	Decimal	SBGEP	Sitakunda Botanical Garden and Ecopark.
DoE	Department of Environment	SOC	Soil Organic Carbon
DoL	Department of Livestock	SPM	Suspended Particulate Matter
ES	Ecosystem Service	SPSS	Statistical Package for Social Sciences
EU	European Union	sq.m	Square Meter
FGD	Focus Group Discussion	SRDI	Soil Resource Development Institute
GBH	Girth at Breast Height	TB	Total Tree Biomass
GDP	Gross Domestic Product	TCM	Travel Cost Method
GO	Government Organization	TEV	Total Economic Value
GWP	Global Warming Potential	ULO	Upazilla Livestock Officer
ha	Hectare	UMS	Urea Molasses Straw
HH	Household	UNO	UpazilaNirbahi Officer
IPCC	Intergovernmental Panel on Climate Change	USD	United States Dollar
IUCN	International Union for Conservation of Nature	USFS	United States Forest Service

# Executive Summary

The protected areas assume a pivotal role in safeguarding our invaluable natural resources while also furnishing essential ecosystem services that confer substantial benefits upon human society. However, the economic benefits of these areas are often overlooked in policy and decision-making processes. Despite their importance, few comprehensive studies have been conducted to evaluate the economic benefits provided by forest ecosystems in Bangladesh. To address this gap, a recent study conducted an economic valuation of ecosystem services provided by the Sitakunda Botanical Garden and Eco-park, Chattogram, Bangladesh. The study analyzed the economic value of 27 subcomponents under 22 components of four ecosystem service categories. This study has exclusively focused on their utilitarian value, sidelining the incorporation of non-use values.

This park is one of the most well-known protected areas in Bangladesh and provides numerous ecosystem services such as the supply of NTFPs, fuel woods, water regulation, groundwater discharge, carbon sequestration, air filtration, tourism, biodiversity etc. Data was collected through various methods such as systematic forest survey, household survey, tourist interview, farmer interview, key informant interview, and focus group discussion between July 2020 and June 2022. Various methods were used to value the ecosystem services, depending on the nature of the service. These methods included direct market valuation, zonal travel cost, productivity, replacement cost, compensation cost, alternative cost methods etc.

The forest was found<sup>></sup> to be rich in flora and fauna, with 321 plant species and approximately 3,82,992 trees (DBH > 5 cm) in the park (474 trees per hectare). It also has 161 species of wildlife (Vertebrate). The study estimated a conservative economic benefit of around BDT 6.89 billion (approximately USD 72.48 million) per year generated by the eco-park. This amounts to a benefit of BDT 8.52 million or USD 0.09 million per hectare per annum. To maintain this level of ecosystem services, approximately BDT 1.10 billion (USD 11.58 million) should be allocated for proper management per year. Encroachment was found to be the main barrier to increasing vegetation composition, the main cause of decreasing water flows, and a supreme threat to wildlife conservation. Therefore, immediate action should be taken to halt encroachment to maintain the ecosystem services provided by the eco-park.

In summary, the Sitakunda Botanical Garden and Eco-park provides a significant economic benefit through its ecosystem services. The findings underscore the importance of considering these benefits in policy and decision-making processes to ensure their continued provision. The study also identifies the need for proper management and the protection of these areas to maintain their economic and ecological benefits for future generations.

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## **1. Introduction**

Ecosystems are complex communities that are formed by the interaction between biotic components, such as plants, animals, and microbes, and abiotic components, such as air, water, and mineral soil. The concept of ecosystem services (ES) refers to the various contributions that ecosystems make to human well-being, which can include direct benefits like food, wood, and other raw materials, as well as indirect benefits, like the regulation of ecosystems that perform vital functions such as pollination, soil conservation and water purification (Jalal et al., 2020).

Protected areas play a crucial role in the preservation of biodiversity and the provision of ecosystem services, as they safeguard vital ecosystems, offer safe havens for species, facilitate their migration and mobility, and guarantee the uninterrupted functioning of natural processes throughout the environment. ([www.cbd.int](http://www.cbd.int)). According to the Millennium Ecosystem Assessment (MEA, 2005), PAs are hotspots for various ecosystem services, including biodiversity maintenance, climate regulation, nutrient cycling, flood regulation, wood and food provision, and recreation. People depend on those functioning ecosystems, which provide benefits that support human existence and wellbeing. The relationship between people and nature has been experienced and conceptualized in multiple ways. Recently, ecosystem services (ES) concepts have permeated science, government policies, multi-national environmental agreements, and science-policy interfaces (Kadykalo et al., 2019). Despite the vital ecosystem services forests provide for human well-being, including clean air and water, climate regulation, biodiversity conservation etc. these benefits are frequently overlooked in market transactions. Economic valuation of forest ecosystem services can assign a monetary value to these services, allowing them to be included in the GDP calculation. By incorporating the value of forest ecosystem services in the GDP, policymakers can better understand the economic contribution of forests to the country's overall well-being, and make more informed decisions about the sustainable use and management of forest resources. It can help to ensure that economic growth is not achieved at the expense of environmental degradation, and that forests are managed in a way that supports long-term economic development while preserving their critical ecosystem services. Ultimately, addition of forest ecosystem services in the GDP can promote more sustainable and equitable development practices that account for the full range of economic, social, and environmental considerations.

However, it is important to note that not all ecosystems, habitats, and species are effectively represented in the protected areas of Bangladesh, and declaring a PA alone is not enough to restore an ecosystem. In addition, poor land use planning can reduce the value of ecosystem services. To improve the ecological environment and achieve sustainable development, it is necessary to undertake an assessment of the value of ecosystem services, linking the market value of these services to ecological systems. Moreover, Bangladesh Forest Department is making economic benefits out of the ecosystem services without knowing the optimum limits and how long they can harness the economic benefits. The economic benefits can be drawn from the non-consumptive services like tourism, carbon credit instead of acquiring from the consumable provision services (Uddin et al., 2020). This study helps to conceptualize

the economic and environmental importance of the Sitakunda Botanical Garden and Ecopark ecosystem and undertake future strive towards sustainable management of the ecosystem services.

According to Small et al., (2017), in order to effectively implement the ecosystem approach or ecosystem services paradigm at the national level, it is essential to clarify semantic issues, redefine the concept of cultural services, and provide practical definitions for intangible ecosystem services that are vital to our well-being. This is a crucial step towards identifying appropriate approaches for managing trade-offs and promoting adaptive management. However, it can be argued that ecosystem services should be defined as the interactions (i.e. processes) of the ecosystem that produce a change in human well-being, while ecosystem components or goods, i.e. countable as biomass units, are only proxies in the assessment of such changes (La Notte et al., 2017).

Economic analysis of the role and value of ecosystem services begins through isolating their contribution to welfare bearing goods. This contribution is then valued through the application of a range of methods and techniques ranging from adjustments of market prices to the measurement and valuation of preferences for non-market goods (Bateman et al., 2010). Direct use of ecosystem services is easy to evaluate, and there are some published statistics on the amount and number of these resources, but indirect use is difficult to measure and needs a great deal of time and effort (Al mamun et al., 2017).

The evaluation of the ecosystem service value of protected areas, such as the Sitakunda Botanical Garden and Ecopark, holds immense importance. Within this park, an extensive collection of native angiosperm and gymnosperm plants coexists with introduced exotic species (Dutta et al., 2014). This park provides a wide range of ecosystem services to the people living in adjacent areas, including provisioning, cultural, supporting and regulating services. The study is expected to provide valuable insights into those services and the importance of preserving and conserving the park. It will also deliver a comprehensive understanding of the ecosystem services and their contribution to human well-being, as well as the dependence of local communities on these services. While there have been some studies conducted on the floristic composition of the SBGEP (Nandi, 2009; Dutta et al., 2014; Dutta et al., 2015; Islam et al., 2016) there remains a lack of comprehensive research on the ecosystem services it provides and the extent to which local communities rely on them for their livelihoods. Through the promotion of a rational approach to the monetary valuation of natural resources, this study aims to facilitate the sustainable utilization of land and promote the preservation of these invaluable ecosystems. Moreover, this study has taken initiative to value direct and indirect benefits of the forest. It is also hoped that the findings from this study will provide useful information for policymakers, and raise awareness about the importance of ecosystem services among the general public.

## **2. Objectives of the Study**

The aim of this study is to assess the total economic value of Sitakunda Botanical Garden and Eco-park, Chattogram.

The specific objectives are:

- a) To assess the forest resources of the park.
- b) To estimate total economic value of the identified provisioning, cultural, supporting and regulating services.
- c) To determine the livelihood dependency of local communities on ecosystem services and
- d) To recommend the necessary measures for conservation of the park to sustain the ecosystem services.



### 3. Materials and Methods

#### 3.1. Study Area

##### 3.1.1. Sitakunda upazila (sub-district)

Sitakunda is a Upazila located in Chattogram district, in the southeastern part of Bangladesh. It is situated at the foothills of the Chattogram Hill Tracts, near the Bay of Bengal. Geographically, the location of Sitakunda Upazila lies between 23°29' and 23°42' north latitude, and 90°59' and 91°05' east longitude (<https://sitakunda.chittagong.gov.bd/>), with an average elevation of 40 meters above sea level (<https://en-gb.topographic-map.com/map-pc65gt/Sitakunda>). The Upazila covers an area of approximately 181 square kilometers and is surrounded by hills, forests on the eastern side and the Bay of Bengal on the western side.

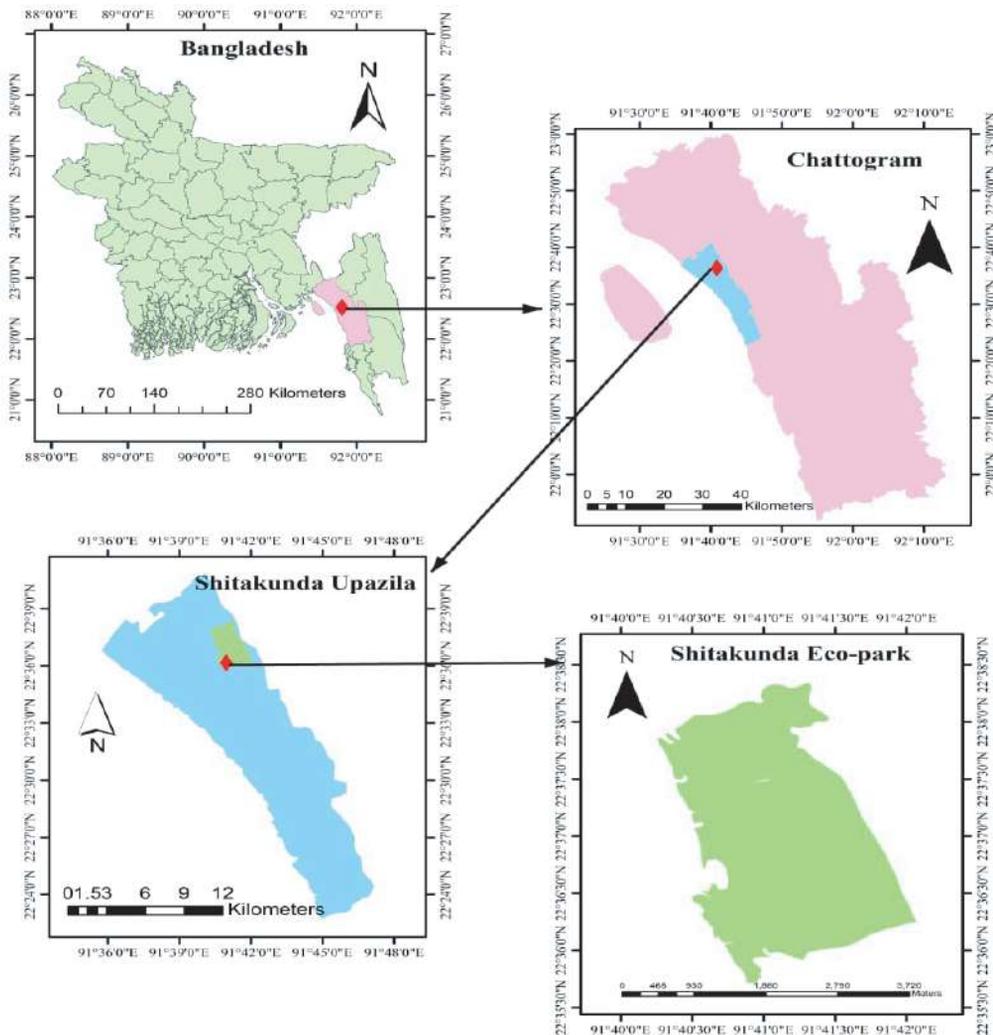


Figure 1: Location of the study area (Source: Dutta and Hossain, 2016)

Sitakunda is located approximately 35 kilometers southeast of Chattogram city, the second-largest city in Bangladesh and a major port city. The sub-district is well-connected to other parts of the country by road, rail, and air, with major highway passing through the area and a railway station located in the nearby town of Sitakunda Bazar. The Bay of Bengal is located to the west and southern west of Sitakunda, and the sub-district is surrounded by hills and the Bay of Bengal. The hills and forests in the area provide a unique and diverse ecosystem, supporting a wide range of plant and animal species (Figure 1).

As an administrative unit, Sitakunda is divided into nine union councils, which are further divided into several villages. The subdistrict is governed by the Upazila Nirbahi Officer (UNO), who is responsible for overseeing the day-to-day administration and development activities.

According to the well-known website Weather and Climate, Sitakunda experiences a tropical climate with an annual high temperature of 30.84°C and an annual low temperature of 24.32°C. The average annual precipitation is 147.13mm. May is the warmest month, reaching 33.98°C, while January is the coldest month, with a temperature of 16.84°C. July receives the highest rainfall, measuring 470.67mm, whereas December is the driest month, with only 2.12mm of rainfall. Rainfall of 1.0 mm or more occurs on 165.33 days (45.3% of the year), while the remaining 199.67 days (54.7%) remain dry. The average humidity in Sitakunda is 81.01% (Source: [www.tcktcktck.org/bangladesh/chittagong/sitakunda#t1](http://www.tcktcktck.org/bangladesh/chittagong/sitakunda#t1)). In addition to the monsoon rains, Sitakunda is also affected by occasional cyclones and storms that form over the Bay of Bengal. The region's hilly terrain and lush vegetation provide some protection from the impacts of these weather events. Overall, the climate of Sitakunda is characterized by high levels of humidity, heat, and rainfall, making it a suitable environment for agriculture and forestry. The presence of numerous hills and waterfalls in the area also attracts tourists and nature enthusiasts.

### **3.1.2. Sitakunda botanical garden and eco-park**

Sitakunda Botanical Garden and Eco-park is a unique natural reserve located in the north-western part of Chattogram district, Bangladesh. It is situated between 22°36'N and 22°39'N latitude, and 91°40'E and 91°42'E longitude, and is nearly 35 kilometers north of Chittagong city and 3 kilometers from the Sitakunda Upazilla headquarter. The eco-park is easily accessible, being located just one kilometer east of the Dhaka-Chittagong highway (Figure 2 & 3).

Established under the Bangladesh Wildlife Preservation (Amendment) Act of 1974 in 1998, this park covers an area of 808.38 hectares, with 405 hectares designated as a botanical garden and the remaining 403.38 hectares serving as an eco-park. The area is divided into two ranges, Porjoton and Punorbashon, and is composed of low, medium, and high hills, numerous gullies, waterfalls, and streams that are fed by the hills. These hills are part of the Garo Hill Range and are subject to moisture stress for about 100 days each year due to the southwest monsoon, which provides the majority of the area's annual rainfall of around 2890 millimeters (Alam, 2001; Misbahuzzaman and Alam, 2006; Dutta et al., 2014).

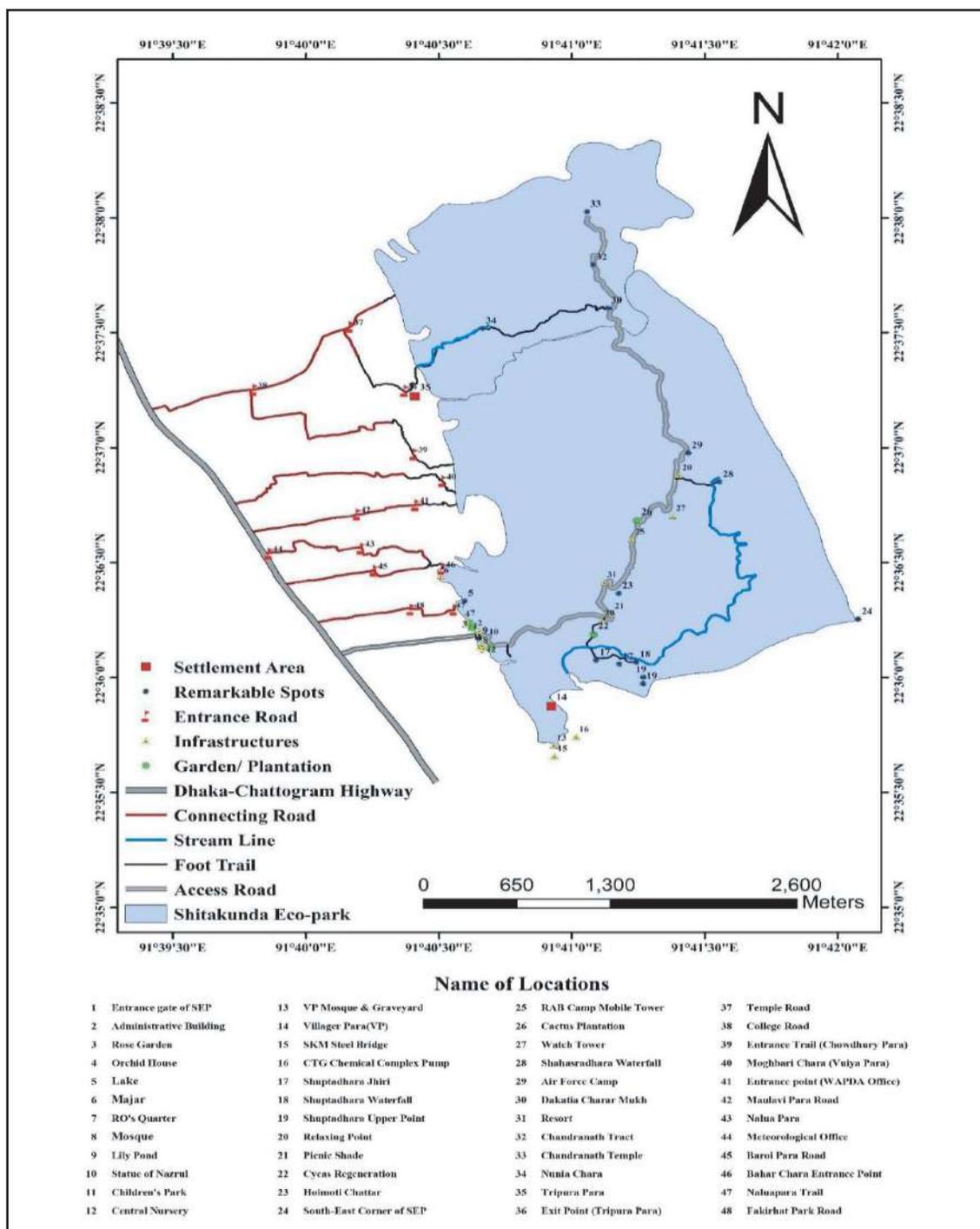


Figure 2: Base map of Sitakunda Botanical Garden and Eco-park, Chattogram



Figure 3: Sitakunda Botanical Garden and Eco-park

The ecopark has a moist tropical climate with a mean annual temperature of 29.6°C and mean monthly humidity levels ranging from 66.5% to 88.6%. This unique combination of geography and climate provides an ideal habitat for a diverse range of plant and animal species, making the Sitakunda Botanical Garden and Ecopark a must-visit destination for nature lovers and conservationists alike Alam, 2001; Uddin et al., 2005; Misbahuzzaman and Alam, 2006; Dutta et al., 2014.

**Table 1:** Distribution of villages adjacent to the Sitakunda Botanical Garden and Eco-park

District	Upazila	Pourashava/Union	Number of Villages	Distance Range from SBGE (Km)
Chattogram	Sitakunda	Sitakunda Pourashava	15	00-10
		Barabkunda Union	20	
		Muradpur Union	17	
		<b>Total</b>	<b>52</b>	

Table 1 is about Sitakunda Upazila in Chattogram, Bangladesh. It lists the number of villages in 3 different unions under the Upazila of Sitakunda that are adjacent (within 0-10 km distance) to Sitakunda Botanical Garden and Eco-park (SBGEP). The total number of villages across all three unions is 52.

**Table 2:** Distribution of number of households (HH) in the adjacent (1-3 km) villages dependent on Sitakunda Botanical Garden and Eco-park.

SI No.	Villages	No. of HH	Pourashava/ Union
1.	Tripura Para	258	Sitakunda Paurashava
2	Sobahanbag	320	Sitakunda Paurashava
3	Nij Taluk Para	210	Sitakunda Paurashava
4	Moulvi Para	210	Sitakunda Paurashava
5	Chowdhury Para	220	Sitakunda Paurashava
6	Nalua Para	210	Sitakunda Paurashava
7	Mohadebpur	395	Sitakunda Paurashava
8	East Mohadebpur	105	Sitakunda Paurashava
9	Edilpur	320	Sitakunda Paurashava
10	Hatilota	428	Barabkunda Union
11	Ali Chowdhury Para	150	Barabkunda Union
12	Vhiarekhil	128	Barabkunda Union
13	Mandaritola	560	Barabkunda Union
14	Anontapur	165	Barabkunda Union
15	Dalipara	340	Muradpur Union
16	Peshker Para	385	Muradpur Union
<b>Total HH</b>		<b>4404</b>	

On the other hand, Table 2 lists the number of households (HH) in 16 different villages in 3 different unions (Figure 4). Those villages are adjacent to the SBGEP and within 0 to 3 kilometers distant from it. All 16 villages consist of 4404 HH (Figure 5). The number of households was determined from the information collected from union councils, municipality, group discussion with local people, key informants and PRA Report of IPAC on Sitakunda Eco-park Site, 2011.

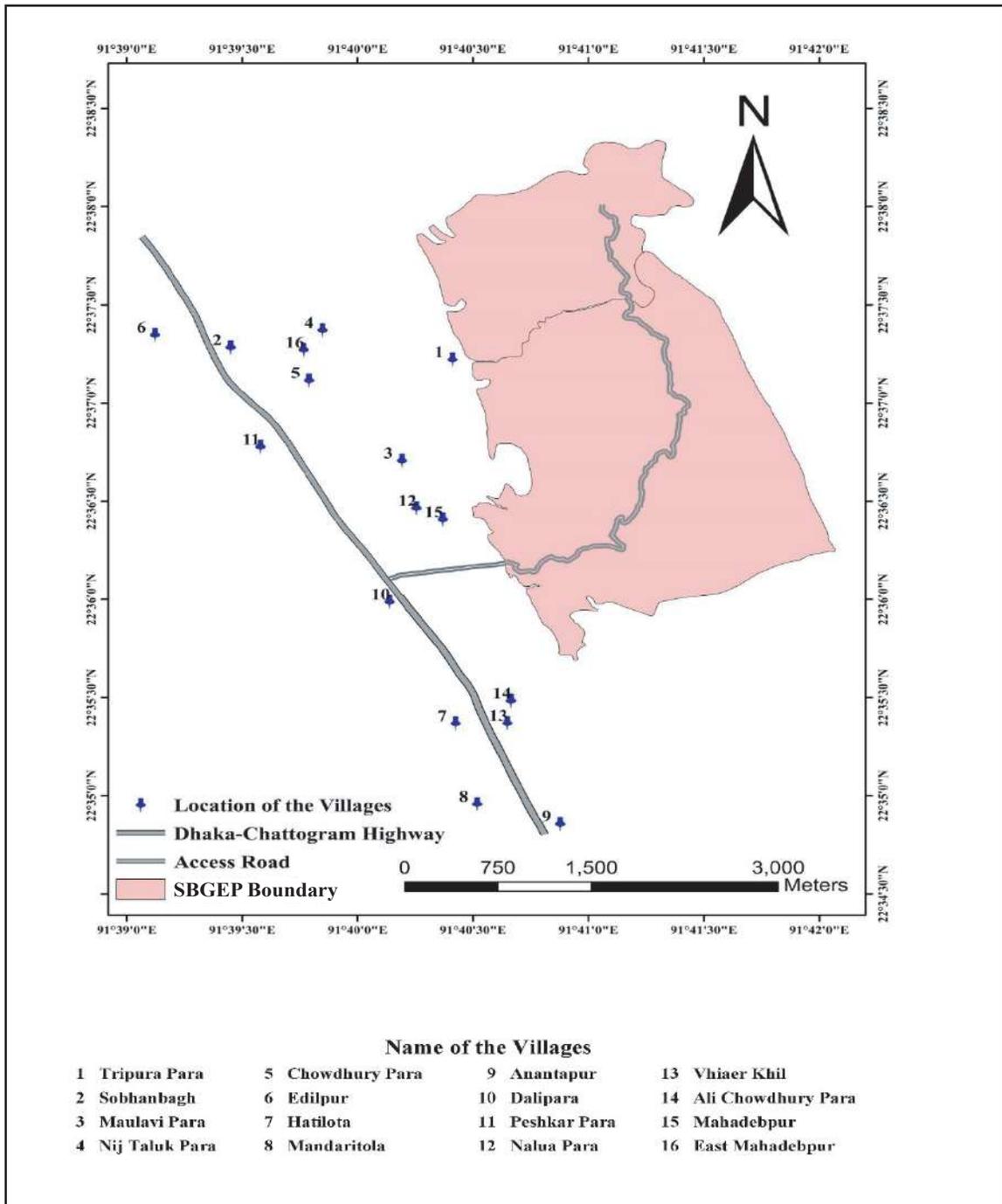


Figure 4: Location of the villages surrounding Sitakunda Botanical Garden and Eco-park

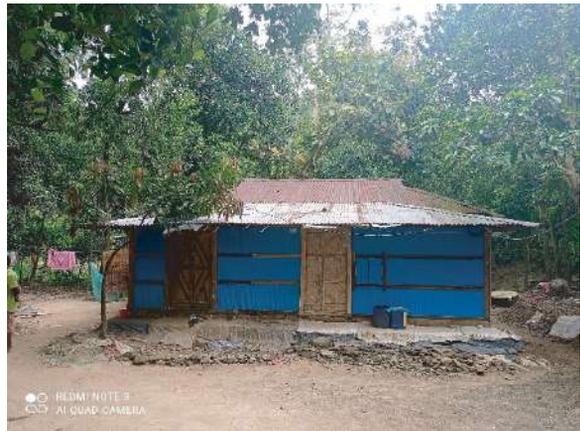


Figure 5: Household pattern of the villages surrounding Sitakunda Botanical Garden and Eco-park

## **3.2. Tools Used for Data Collection**

Some common tools were used for data collection in this study. PABAT+ (2020) tool developed by the International Union for Conservation of Nature (IUCN) was used for assessing the components of ecosystems services. A semi-structured questionnaire survey was used to gather information from a sample of individuals. Key Informant Interviews (KII) involved talking to people who have knowledge or expertise about different services of forest ecosystem. Focus Group Discussion (FGD) involved bringing a group of people together to discuss a particular topic. Face-to-face interviews were conducted in person. Camera trapping included setting up cameras was used to capture images of wildlife. Transect walks was done on pre-determined paths for observing and recording wildlife and vegetation data. Plot sampling was done to assess the abundance and diversity of tree species and collection of soil sample in that area.

## **3.3. Data Collection Methods**

The study conducted multiple surveys, including reconnaissance, vegetation, wildlife, soil sampling, air quality, water body, household, tourist, and market surveys to meet objectives. Ecosystem services were identified through interviews with park management, political leaders, government officers, NGOs and local stakeholders. The study also assessed the livelihood dependency of local communities on the ecosystem services and their value, as well as the importance of the services to the public and decision-makers through FGD and KI meetings.

### **3.3.1. Forest survey**

The forest survey measured woody plants with a diameter at breast height (DBH) of 5cm or greater (Long et al., 2013) from 82 square sample plots (10m × 10m each plot) selected using random sampling method. Saplings with a DBH of 2cm to 5cm were also measured (3m × 3m each plot). Regeneration was measured by counting seedlings with a DBH less than 2cm (1m × 1m each plot). Data on the total height, DBH, and species name of trees and saplings were recorded, as well as species and number of individuals in the regeneration plots (Figure 6 & 7).

### **3.3.2. Soil sampling**

Soil Samples were collected randomly from four types of land i.e. Beside the Streams, Upper Hill, Middle Hill and Lower Hill areas of Sitakunda Botanical Garden and Eco-park (SBGEP). Soil samples from 0-20 cm, 20-40 cm and 40-60 cm depth were collected to measure different parameters. The soil samples were analyzed in Soil Science Division lab of Bangladesh Forest Research Institute (BFRI) and Soil Resource Development Institute (SRDI) lab, Chattogram (Figure 8).

### **3.3.3. Wildlife survey**

The wildlife section of BFRI conducted a survey to identify wildlife in Sitakunda Botanical Garden and Eco-park. Three methods were used in the survey.

1. Transect walks were conducted on foot to estimate wildlife diversity and census. Walking rates were one kilometer per hour in forested areas and two kilometers per hour in open habitat (Figure 9)
2. Camera Traps were set up in different locations of the Park to capture images of nocturnal animals. Six cameras were used and captured images were used to identify the nocturnal wildlife species present.
3. Questionnaire surveys were conducted with farmers, daily laborers and forest department staff. Participants were shown pictures of different wildlife and asked to identify and they had been seen in the forest.

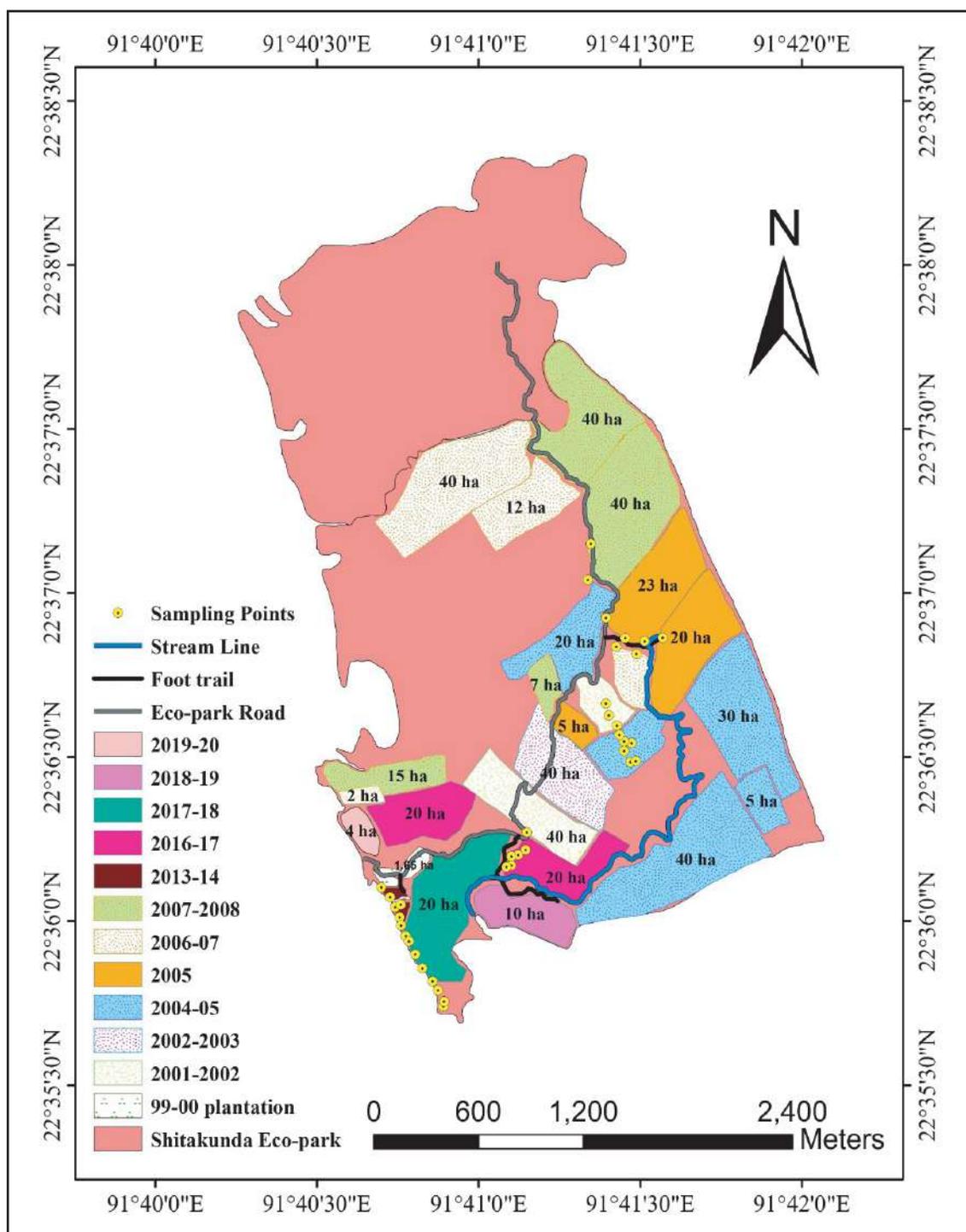


Figure 6: Vegetation survey map including the plantation sites of SBGEP



**Figure 7: Vegetation survey in Sitakunda Botanical Garden and Eco-park**



**Figure 8: Soil sample collection in Sitakunda Botanical Garden and Eco-park**



**Figure 9: Camera trapping and transect walk for wildlife survey in SBGEP**

### 3.3.4. Market survey

The market survey aimed to establish the prices of commercially valuable forest resources, such as timber, fuelwood, bamboo culms, and broom grass, in the areas surrounding the SBGEP. The survey involved visiting nearby sawmills, timber markets and traders to determine the unit prices (Figure 10).

### 3.3.5. Household survey

To survey the households in the adjacent villages of SBGEP, a semi-structured questionnaire was used (Figure 11). The sample size of households was determined using the Cochran (2007) method. To cross-check the data collected from the households, FGD (focus group discussions) and KII were also conducted.

#### *Determination of household sample size*

The sample size was determined by using the following formula (Cochran, 2007).

$$\text{Initial Sample Size } (n_0) = Z^2pq/e^2$$

Here,

$N_0$  = Sample size;  $Z$  = level of confidence (at 95% confidence level)

$p$  = estimated proportion of an attribute that is present in the population ( $p = 0.5$ );  $q = 1-p$

$e$  = Margin of error to be attained (here  $\pm 10\%$ )

$$\text{Final Sample Size} = n_0 / \{1 + (n_0 - 1)/N\}$$

Here,

$N$  = Total household number.

16 villages were selected having 4404 households with 24,222 (Aprx.) people and the determined sample size was 94. However, 110 households were interviewed randomly to ensure the accuracy of the result.

#### *Other surveys*

Other surveys will be described in the "Methods of Valuing Ecosystem Service".

### 3.3.6. Literature review

An extensive literature survey was conducted to gather information from previous studies, establish the scientific basis, and validate the methods used in the study. The sources included research articles, books, reports, manuals, and information from the Forest Working Plans of the Forest Department. The literature was sourced from libraries of BFRI, IFESCU, BFD, Park Management Office and various websites through the internet.

#### *Classification of the ecosystem services*

The classification of ecosystem services has been widely debated in recent years, and many classification schemes have been proposed. One widely recognized scheme was introduced in the Millennium Ecosystem Assessment (2005) and has been adopted in several studies and initiatives. The four ecosystem service categories defined by the Millennium Ecosystem Assessment are (a) Provisioning services, such as food, fuel, and fresh water, (b) Cultural services, such as recreation, tourism, and spiritual values, (c) Regulating services, such as climate regulation, water regulation, and pest control and (d) Supporting services, such as soil formation, nutrient cycling and primary production.

**Provisioning services** are products and materials obtained from ecosystems, including food, fibers, building materials, fresh water, energy, bio-chemicals and genetic resources.

**Cultural services** are non-material benefits obtained from ecosystems that enhance people's lives, such as spiritual and religious values, recreation and tourism, aesthetic value, landscape, inspirational value, education, research, sense of place and cultural heritage.

**Regulating services** are benefits obtained from the regulation of ecosystem processes and the environment, such as climate regulation, disease regulation, water regulation, water purification, pollination, soil protection, carbon sequestration, and protection against natural hazards and extreme events.

**Supporting services** are underlying services that allow other services to function, such as soil formation, nutrient cycling, and primary production.

### **3.3.7. Method of identification of ecosystem services in SBGEP**

Protected Areas Benefit Assessment Tools+ (PABAT+) has been used to identify the ecosystem services of Sitakunda Botanical Garden and Eco-park. But it was not followed fully due to some inevitable circumstances. We used the question pattern and the way of analysis of this tool. A total of 50 KII and face to face interview were conducted to identify the ES of SBGEP. A close-ended questionnaire was prepared following the 29 questions given in the PABAT+ by IUCN. For Example,

1. Is the area important for wild food plants and fungi?
2. Is the area important for recreation and tourism?
3. Can the area contribute to climate change mitigation?
4. Is the area valued for nature conservation?
5. Is the area important for jobs associated with tourism?

Options were,

**YES or NO; If Yes, Then, 1) + / ++    2) \$ / \$\$ / 0    3) P+ / PS**

Here,

**+** = Non-Economic Importance;

**++** = Economic Importance

**\$** = Minor Economic Benefit;

**\$\$** = Major Economic Benefit;    **0** = No benefit.

**P+** = Potential Non-Economic Benefit;    **PS** = Potential Economic Benefit

#### **Box 1: Sample questionnaire for identifying ecosystem services in SBGEP**

### **3.4. Data Analysis**

The collected data was compiled and analyzed using statistical packages such as SPSS 22, STATA 16, Microsoft Office Excel 2016, Google Earth Engine etc.



Figure 10: Market survey in the local markets adjacent to SBGEP



Figure 11: Household survey in the villages adjacent to SBGEP



Figure 12: Methodology review workshop supported by COMPASS program, USFS

### 3.5. Methods of Valuing Provisioning Services

#### 3.5.1. Valuation of forest extractions

The study was primarily based on sample survey of 110 households in the buffer zone of SBGEP and used a combination of direct market price and alternative pricing to determine the economic value of the direct and indirect uses of the ecosystem services provided by SBGEP.

Following the Millennium Ecosystem Assessment's concept of an ecosystem approach, the main ecosystem services considered for valuation included nine provisioning components (including livestock fodder, food, domestic water supply, fuel wood, timber and non-timber forest products) (Figure 13).

The average annual value of directly used forest products per household was estimated on the basis of average quantities harvested, their prices, and associated cost, irrespective of what proportion was sold by following Sharma et al. (2015).

$$TVP_i = \sum_{i=1}^n (\%hh_i \times HH \times NV_i)$$

Where  $i$  = Different provisioning services,

$\%hh_i$  = Percentage of total household dependent on the  $i$ th provisioning service;

HH = Total number of households residing in the buffer zone; and

$NV_i$  = Average annual net benefit per user household calculated by subtracting the annual cost of the products from their respective gross value using the net benefit method (Viboonpun, 2000).

#### 3.5.2. Measuring grazing benefits in SBGEP

To measure the benefit of grazing, we determined first the dependency (%) on grazing in the study area by applying face to face interview using a semi-structured questionnaire through simple random sampling, focus group discussion and key informants interview (Figure 9).

From this, we found the number of households which had cattle, number of cattle and dependency on forest for grazing. From FGD and KII, we determined the cost of rearing cattle with grazing and without grazing, period of grazing (day per year) and crossed checked the data we collected from household interview. Then the difference between those parameter was considered as the value of grazing in SBGEP. That is,

$$V_G = \{(CO - CO_w) \times G_p \times C_n\} - F_v$$

Here,

$V_G$  = Value of grazing per year; CO = Cost of rearing cattle without grazing;

$CO_w$  = Cost of rearing cattle with grazing;  $G_p$  = Grazing period;  $C_n$  = Number of cattle

$F_v$  = Value of fodder

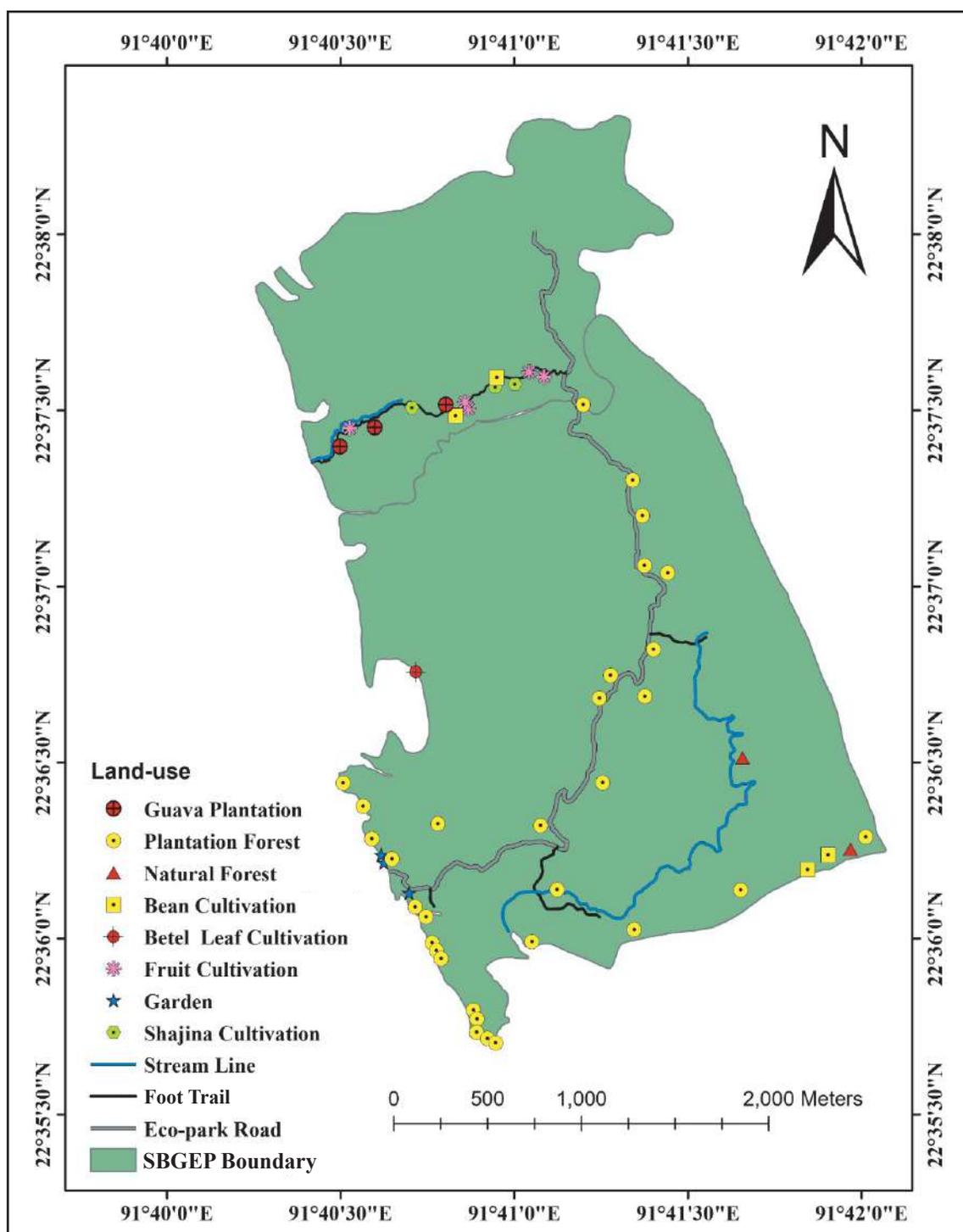


Figure 13: Land use of SBGEP (from where provisioning benefits are obtained)

**Determination of unit price (in BDT) for a cow and a goat**

To determine the cost/day (without grazing) we considered a training manual prepared by Department of Livestock in 2017. In this manual, the cost-benefit for rearing a cow and a goat were calculated per year basis.

**Table 3:** Determination of cow rearing cost without grazing.

Variables	Unit	Value
Increased milk price in 2021	%	10
Rearing cost in 2017	BDT/cow/day	265.20
Increased cost at sitakunda	BDT/cow/day	26.52
Rearing cost in 2021	BDT/cow/day	291.72

This table (Table 3) provides information on variables related to the cost of rearing cows in Sitakunda. Department of Livestock (DoL) published a CIG Refresher Training Manual in 2017 ([www.natpdls.gov.bd](http://www.natpdls.gov.bd)) from which the rearing cost for a cow was collected. Then the cost value was updated for 2021 by taking in consideration the increased milk price in 2021, which is 10%. Thus, the rearing cost calculated for 2021, which was 291.72 BDT for each cow per day.

**Table 4:** Determination of goat rearing cost without grazing. (CIG Refresher Training Manual, 2017 and ULO, Rangamati Sadar, 2022).

Variables	Amount/Goat/Day	Unit Price (BDT)	Total Price
Grainy food	1.50 Kg	35	52.50
Green grass	5.00 Kg	2.5	12.50
UMS (Urea Molasses Straw) (BDT/goat/day)	-	-	1
Medicine and Vaccine (BDT/goat/day)	-	-	1
Maintainaning Cost (BDT/goat/day)	-	-	10
Total Cost (BDT/goat/day)	-	-	77.00

But the estimation for Goat was not acceptable fully to us. Then we consulted with an Upazilla Livestock Officer (ULO) over phone. He gave us an estimation about rearing goat without any grazing in the field. By following his instruction, we prepared an estimation for a goat on daily basis (Table 4). This calculation showed that the total cost for rearing a goat without grazing in the forest is BDT. 77.00 for each goat per day.

**3.5.3. Valuation of wildlife as food**

Valuation of wildlife as food,

$$\Sigma W_{ni} M_n P_i$$

Here, i = wildlife species

W<sub>n</sub> = Number of wildlife i. hunted in a month

M<sub>n</sub> = Number of month of hunting wildlife i.

P<sub>i</sub> = Price per unit of wildlife i.



Figure 14: Focus group discussion on grazing, stream water usage, irrigation etc.



Figure 15: Face to face interview from forest extractors



Figure 16: Farmer interview for collecting agriculture related data

### 3.5.4. Determination of value of the water used for irrigation

Cost of the water used for Irrigation ( $I_v$ )

$$I_v = F_i \times H_f \times C_h$$

Here,

$F_i$  = Number of farmers use water for irrigation.

$H_f$  = Average irrigation hour per farmer per year.

$C_h$  = Average irrigation cost (in BDT) per hour.

### 3.5.5. Determination of value of the stream water consumption for household use

Alternative cost method was applied to find out the value of the water for household use.

The cost of water consumption for household use ( $W_h$ ),

$$W_h = H_h \times W_y \times P_1$$

Here,

$H_h$  = Number of household consume stream water for household use.

$W_y$  = Use of water (in liter) each household per year.

$P_1$  = Unit price of water per liter.

### 3.5.6. Determination of value of the stream water used for drinking purposes

Alternative cost method was applied to find out the value of the stream water for drinking.

Value of stream water for drinking ( $W_d$ ),

$$W_d = I_d \times W_y \times P_1$$

Here,

$I_d$  = Number of Individuals use stream water for drinking.

$W_y$  = Individual use of water (in liter) per year for drinking.

$P_1$  = Unit price of water per liter.

#### ***Determination of unit price of the stream water (Alternative cost method)***

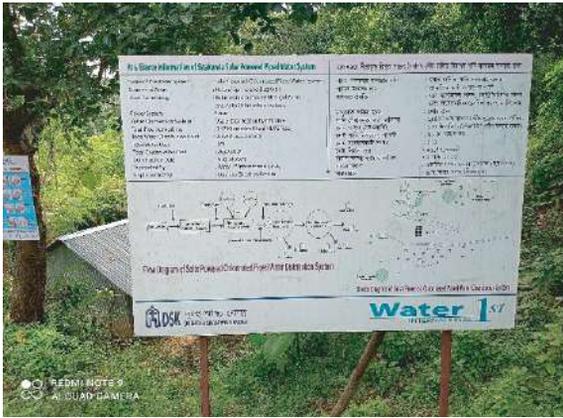
To determine the unit price for water, we considered this project as an indicator. The title of this project is "Power Chlorinated Pipe Water System Project, Tripura Para, SBGEP, Sitakunda". This project was funded by Water 1st International (USA) and materialized by Dustha Swastha Kendra (DSK) and Local People in 2021. Details can be learnt from picture 1 to 6 of figure 17. This project can be an alternative if the stream dries up in the future.

**Table 5:** Determination of unit price of stream water

Variables	Unit	Value
Total plant construction cost	BDT	25,47,000
Total number of household getting benefit	Number	181
Construction cost (for 10 years)	BDT/HH/year	1407.18
Average supply cost	BDT/HH/month	233.19
Average supply cost	BDT/HH/year	2798.28
Total expenditure for water	BDT/HH/year	<b>4205.46</b>
Average household use of water	Liter/year	<b>1,06,312.25</b>
Unit price	BDT/liter	<b>0.04</b>

(Solar Power Chlorinated Pipe Water System Project, Tripura Para, Sitakunda (Picture 1 to 6))

That's why we have considered this project as the best option to keep the water service unchanged. Water, got from this project, is not only be used as daily household chores but also for drinking as the water is chlorinated automatically before reaching to the consumer.



1



2



3



4



5



6

Figure 17: Snaps of Solar Power Chlorinated Pipe Water System Project, Tripura para, Sitakunda

In this plant, a water motor pump is fixed just beside the stream (Picture 2) and the pump is generated by solar energy. The water is chlorinated in the another tank (Picture 2). Then the water is picked up on the hill by the pump again and stored in a plastic tank (Picture 3). After that, the water is supplied from the tank to the pipe and people are using this water for household chores and drinking purpose (Picture 4). There is a meter device for every household where bill per month for water supply is calculated (Picture 5). But the calculation process of the meter was not clear to us. That's why we only considered the average supply cost per household which is BDT. 233.19. Thus, the unit price for water was found BDT. 0.04 per liter (Table 5).

### 3.6. Methods of Valuing Cultural Services

In short, there are two main approaches to estimate demand for recreational sites: revealed preference and stated preference. Under revealed preference, the most commonly used method is the travel cost method (Bharali and Mazumder 2012; Haider et al., 2018). The other three methods under revealed preference approach are market price, cost based and hedonic pricing (Bateman 1993; Bartczak et al., 2008; Alvarez and Larkin 2010, Haider et al., 2018).

The study used the Travel Cost Method (TCM) to assess the benefits of recreation in SBGEP. The TCM involved calculating the recreational value by using the zonal travel cost method and the number of visitors to SBGEP.

The value of the recreational uses (V) for each zone can be calculated followed by the simple equation (Uddin *et al.* 2020):

$$V = \{(T \times w) + (D \times v) + C_a\} \times V_a$$

where T = Travel time (in hours); w = Average wage rate (BDT/hour); D = Distance (in km); v = Marginal vehicle operating costs; C<sub>a</sub> = Cost of admission to asset; and V<sub>a</sub> = Average number of visits per year for each zone. Potential points for cultural services can be identified in Figure 19.

The study employed a simple random sampling technique for the tourist survey, where 150 tourists from 7 divisions were surveyed using a semi-structured questionnaire (Figure 18). The survey resulted in 1504 responses. The individuals were selected randomly in locations where the enumerators were most likely to find them.



Figure 18: Data collection from tourists visiting SBGEP

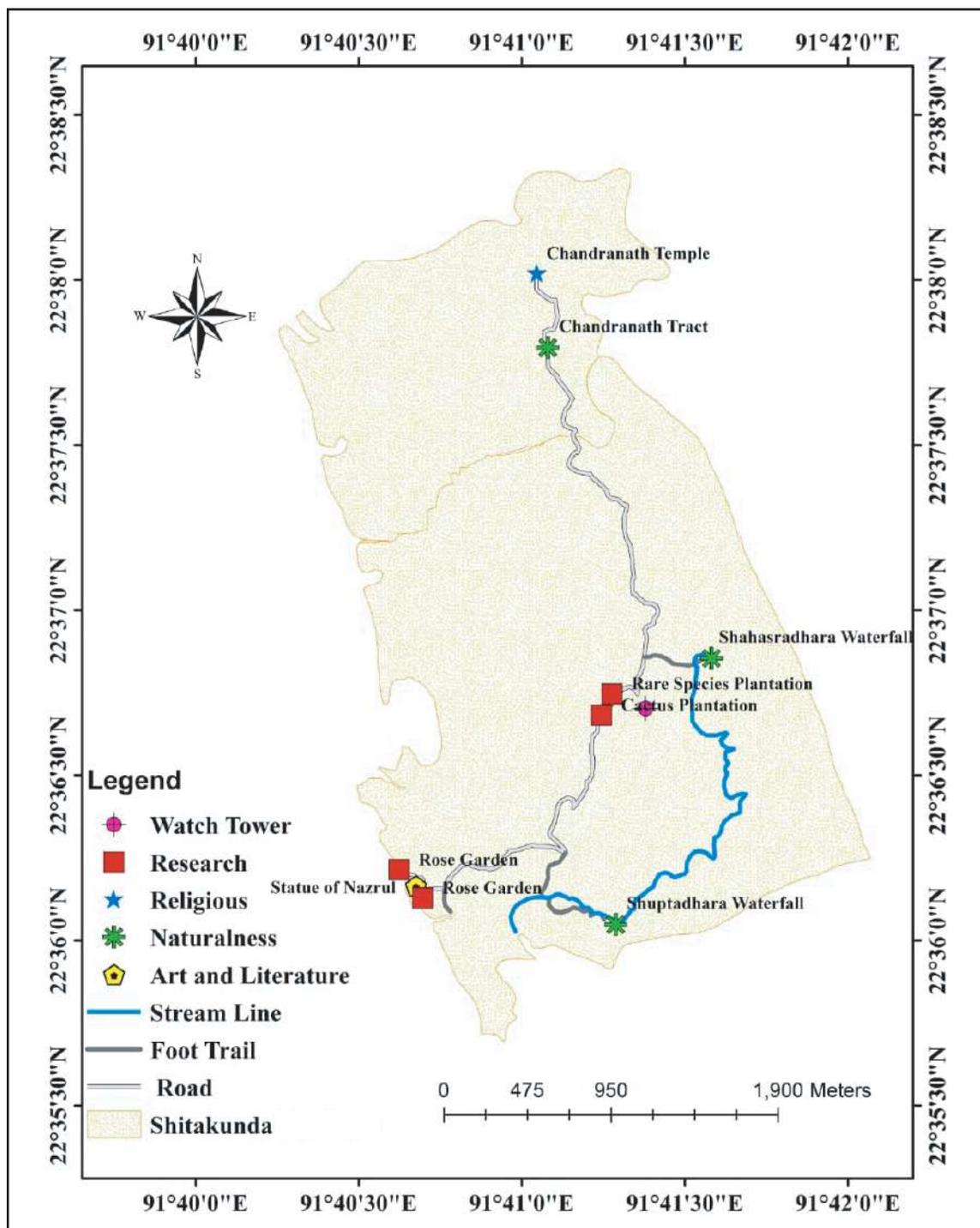


Figure 19: Identified potential points for cultural services in SBGEP

### 3.7. Methods of Valuing Supporting Services

#### 3.7.1. Valuing pollination, nutrient recycling, pest and diseases control, and forest biodiversity

The study used the productivity method to calculate the maximum component excluding Seed Dispersal and Soil Nutrition. The impact of forest and agroecosystem services was estimated using an econometric model and sample statistics.

The study used regression analysis of 11 independent factors with a farmer's agricultural income to determine the increase in crop income per unit increment in crop species density (Crop species richness of agrobiodiversity as measured by the number of major crops) by following Pant et al., 2012. This increase in crop income indicates the combined value of pollination, nutrient recycling, and pest and disease control.

The study used linear regression to estimate the contribution of the agroecosystem and forest ecosystem to household wellbeing, using crop income indices:

$$incrop = \alpha + \beta_1 sppedensity + \beta_2 ecoextent + \beta_3 villtype + \beta_4 age + \beta_5 female + \beta_6 higher + \beta_7 innonagri + \beta_8 agriland + \beta_9 irrigateland + \beta_{10} vlilter + \beta_{11} tripura + \epsilon$$

In the study, the regression equation was used to estimate the contribution of agroecosystem and forest ecosystem to household well-being. The variables are described in Table 6, where the coefficients  $\alpha$  and  $\beta_i$  are estimated using econometric methods. The error term  $\epsilon$  is expected to have a zero mean (unbiased) and constant standard deviation (homoscedastic). The coefficient  $\beta_1$  represents the contribution of the agroecosystem to crop income, while  $\beta_2$  represents the contribution of the forest ecosystem to crop income.

**Table 6:** Variables used in the estimation of supporting services

Variable	Unit	Description
<i>sppedensity</i>	number	Species richness of agrobiodiversity as measured by the number of major crops.
<i>ecoextent</i>	ha	Ecosystem extent as measured by the area of the forest in each Village.
<i>villtype</i>	dummy	Hilly; Yes = 1, No = 0
<i>age</i>	years	Age of respondents
<i>female</i>	dummy	Female respondent = 1, male = 0.
<i>higher</i>	dummy	Respondent above secondary education = 1, otherwise = 0
<i>innonagri</i>	Tk.	Non-agricultural and non-forest income of the household.
<i>agriland</i>	ha	Cultivated agricultural land of the household.
<i>irrigateland</i>	%	Irrigated land of the household as a percentage of the operated agricultural land.
<i>vlilter</i>	%	Average literacy in the village.
<i>tripura</i>	dummy	Tripura = 1, Other = 0.
<i>incrop</i>	BDT	Income from major crops.

### 3.7.2. Valuation method for seed dispersal

The study applied the Replacement Cost Method to value the Seed Dispersal component, following Hougner et al., (2005). The plantation cost of the SBGEP authority over the past 5 years was considered. The relevant data were collected from the Range Office and the cost of planting a seedling was calculated to be BDT 14.98. The regeneration status of SBGEP was measured with the help of the Forest Botany Division of BFRI. Then, the cost of planting seedlings per hectare per year was estimated and subtracted from the replacement cost for seedlings that were regenerated naturally through seed dispersal. It is worth noting that seedlings older than one year were considered in this method to account for the reduced morbidity rate.

## 3.8 Methods of Valuing Regulating Services

### 3.8.1. Method for valuation of carbon regulation

#### *Method for determining tree carbon, oxygen (O<sub>2</sub>) and carbon-di-oxide (CO<sub>2</sub>)*

The measurement of carbon sequestration by trees is tied to the accumulation of tree biomass, which can be determined using the following method (Brown et al., 1989):

$$AGB = \exp(-2.4090 + 0.9522 \ln(D^2HS))$$

The calculation of above ground tree biomass (AGB) in kilograms (kg) using diameter at breast height (DBH) in centimeters (cm), total height (H) in meters (m), and wood density (S) in grams per cubic centimeter (g/cm<sup>3</sup>).

To obtain the total tree biomass, the below-ground biomass (BGB) in kilograms (kg) can be calculated using the ratio of BGB to AGB, which is 0.26 as given. The total tree biomass (TB) can be calculated as:

$$TB (kg) = AGB + BGB$$

$$BGB = 0.26 \times AGB$$

Therefore,

$$TB (kg) = AGB + 0.26 \times AGB$$

$$TB (kg) = 1.26 \times AGB$$

To estimate the total carbon (C) stored in the tree, the total dry weight biomass of the tree can be multiplied by a factor of 0.5, assuming that about 50% of the dry weight is carbon. Therefore, the calculation of total carbon (C) stored in the tree would be:

$$\text{Total C (kg)} = 0.5 \times \text{Total dry weight biomass (kg)}$$

If the above equation was used to estimate the total carbon stored in the trees at SBGEP, then the amount of oxygen provided by SBGEP can be estimated using the following equation-

$$\text{Net O}_2 \text{ release (kg/year)} = \text{net C sequestration (kg/year)} \times 32/12.$$

The sequestered CO<sub>2</sub> equivalent (CO<sub>2</sub> equivalent ton ha<sup>-1</sup>) is estimated as an indicator of global climate regulation ecosystem service by following (Alamgir et al. 2016):

$$CO_2 \text{ equ.} = AGB \times 0.47 \times 3.67$$

The values of 0.47 and 3.67 that were used to convert above-ground biomass (AGB) into biomass carbon storage and carbon storage into CO<sub>2</sub> equivalent, respectively, are recommended by the Intergovernmental Panel on Climate Change (IPCC) for tropical forests (IPCC, 2006).

Overall, the use of these recommended values ensures consistency in carbon accounting and allows for comparison of results across studies (Figure 22). When the wood density of trees in the study area was not available, researchers used a method described by Alamgir and Al-amin (2008) to estimate the carbon content of trees in the park.

#### ***Determination of unit price for carbon (C) and oxygen (O<sub>2</sub>)***

Brown et al., (1989) proposed an equation for estimating Above Ground Biomass (AGB) in tropical forests, which was found to be reliable. The global market value of carbon dioxide was used to determine the value of the forest for carbon sequestration. The market price per ton of carbon is 15 USD, which is used in the analysis of the total monetary service of the forest for global climate regulation, following Uddin et al. (2020). The amount of Oxygen (O<sub>2</sub>) production per year in SBGEP was determined by following Luckow et al., (2015).

Table 7 provides valuable information for determining the market price of oxygen gas, which is a critical component of the global climate regulation. The market price of oxygen gas was determined by following way:

**Table 7:** Monetary value of oxygen gas in Bangladesh (2022)

<b>Variable</b>	<b>Value</b>
1 kg oxygen (BDT) (refill price)	25
1000kg or 1 ton oxygen (BDT)	25000
Value in USD (1 USD = 95 BDT)	263.16

Table 7 presents the monetary value of oxygen gas in Bangladesh for the year 2022. It shows that one kilogram of oxygen costs 25 Bangladeshi Taka (BDT), while a metric ton (1000 kg) is priced at 25,000 BDT. Converting this to US dollars, based on an exchange rate of 95 BDT per USD, a metric ton of oxygen is valued at approximately 263.16 USD. The refill price of oxygen was likely considered in this table because it represents the most common and accessible form of oxygen purchase for consumers and small-scale users in Bangladesh.

### **3.8.2. Method for determining and valuing soil carbon**

Soil Organic Carbon was determined with the help of Soil Science Division of BFRI and Soil Resource Development Institute (SRDI), Chattogram (Figure 21).

#### ***Method for determining and valuing the soil organic carbon (SOC)***

In this study, Soil Organic Carbon (ton/ha) was determined by measuring three parameters: Bulk Density (BD) and SOC (%) and soil depth.

#### ***Method for assessing soil pH***

The soil pH was measured electrochemically with the help of glass electrode pH meter (Model: TOA-TDK. Japan) maintaining the ratio of soil to water 1:2.5 and times of shaking was approximately 30 minutes as suggested by Jackson (1958).

**Method of measuring soil BD (g/cc)**

The soil BD was measured by core method as described by Blake and Hartge (1986).

Bulk Density of Soil is calculated by using following formula:

$$\text{BD} = \text{Wo.d} / \text{V}$$

Here, BD = Bulk Density of Soil in g/cc; Wo. d = Oven-dry weight (g) of the soil filled in the core sampler.; V = Volume of soil sample (cc).

**Method of determining MC (%)**

The soil MC was measured by Gravimetric Method as described by Blake (1965).

$$\text{MC (\%)} = \{(W_2 - W_3) / (W_3 - W_1)\} \times 100$$

Here,

W<sub>1</sub> = Weight of empty cup (g)

W<sub>2</sub> = Weight of cup (g) + moist soil (g)

W<sub>3</sub> = Weight of cup (g) + oven-dry soil (g)

**Method of determining SOC (%)**

The Soil Organic Carbon (%) was determined by Walkley and Blake (1934) Wet Oxidation Method.

$$\text{Percentage of Organic Carbon} = \{(B - T) \times f \times .003 \times 1.3 \times 100\} / W$$

Here,

B = Amount of N FeSO<sub>4</sub> (ml) solution required in blank experiment.

T = Amount of N FeSO<sub>4</sub> (ml) solution required in experiment with soil.

f = Strength of N FeSO<sub>4</sub> solution (from blank experiment)

W = Weight of soil (g) used.

(1 ml of N K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution = .003g Carbon. It has been estimated that only about 77% Carbon in soil is oxidized by normal K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution. So, 0.003 should be multiplied by 1.3 to get the percentage of total carbon present in the soil.)

**Method of calculating SOC (ton/ha)**

SOC (ton/ha) was calculated by multiplying BD (g/cc) with SOC (%) and depth (cm)

**Valuation of soil organic carbon (SOC)**

The market price per ton of carbon USD 15 was determined for valuation of SOC following Uddin et al., (2020).



**Figure 20: Data collection for measuring carbon in litter and undergrowth in SBGEP**



**Figure 21: Lab test for assessing SOC and soil nutrient (N, P, K) in SBGEP**



**Figure 22: Tree data collection for measuring tree carbon in SBGEP**

### 3.8.3. Method for measuring and valuing carbon in litter and undergrowth

Carbon in litter and undergrowth were assessed by ash method following Allen et al., (1986) (Figure 20).

$$\text{Percent of organic matter} = \{(W_1 - W_2) / W_1\} \times 100$$

Here,

$W_1$  = Oven-dry weight of sample

$W_2$  = Ash-weight after heating in furnace

Organic matter contains 58% organic carbon.

So, percent of organic carbon = percent of organic matter x 0.58

#### *Valuation of carbon in litter and undergrowth*

The market price per ton of carbon USD 15 was determined for valuation of carbon in litter and undergrowth following Uddin et al., (2020).

### 3.8.4. Method for measuring and valuing soil fertility or nutrition

The soil nutrient levels of SBGEP were assessed using the services of the Soil Resource Development Institute (SRDI), Chattogram. The Kjeldahl Method was used to determine the soil nitrogen content, while the Molybdophosphoric Blue Color Method was used to determine the amount of phosphorus present. The analysis of the soil samples was carried out by the SRDI.

#### *Unit price determination of soil nutrients*

In order to calculate the value of the soil nutrients, the prevailing market prices in 2021 at Sitakunda for direct sale of the individual nutrients were used. For example, the market price for nitrogen was taken to be 25 BDT per kilogram, while the prices for phosphorus and potassium were 31.33 BDT per kilogram and 25 BDT per kilogram, respectively.

#### *Valuation of soil fertility in SBGEP*

The direct market price method is an approach to determining the monetary value of soil nutrition, and it involves assessing the market price of the fertilizers that provide the nutrients in question (N, P, K) and multiplying it by the amount of the nutrients present in the soil. Here are the steps involved in the direct market price method by following Ninan and Kontoleon (2016):

*Soil nutrient analysis:* Soil samples are analyzed to determine the amount of nutrients (N, P, K) present in the soil.

*Fertilizer prices:* The current market prices of fertilizers that provide the required nutrients are determined.

*Calculation of the value of nutrients:* The amount of each nutrient in the soil is multiplied by the market price of the corresponding fertilizer, giving the value of each nutrient.

*Total value of soil nutrition:* The values of each nutrient are added to give the total value of soil nutrition.

This method provides an estimate of the economic value of soil nutrition based on the market prices of the fertilizers that provide the required nutrients. However, it does not account for other factors that may influence the actual value of soil nutrition, such as the availability of alternative

nutrient sources, the cost of fertilizer application, and the interaction between soil nutrients and other factors that affect crop growth and yield.

### 3.8.5. Method for valuing water regulation

#### *Description of the streams*

The study aimed to evaluate the impact of Sitakunda Eco-park on the adjacent watershed by analyzing the surface water flow (Discharge) and infiltration rate (Recharge) of Supthadhara and Shahradhara streams. The watershed was divided into two segments: inside (2.92 km) and outside (2.78 km) the Eco-park, with a total length of 5.7 km from the Supthadhara stream to the Bay of Bengal. Only the main stream was considered for data collection (Figure 23).

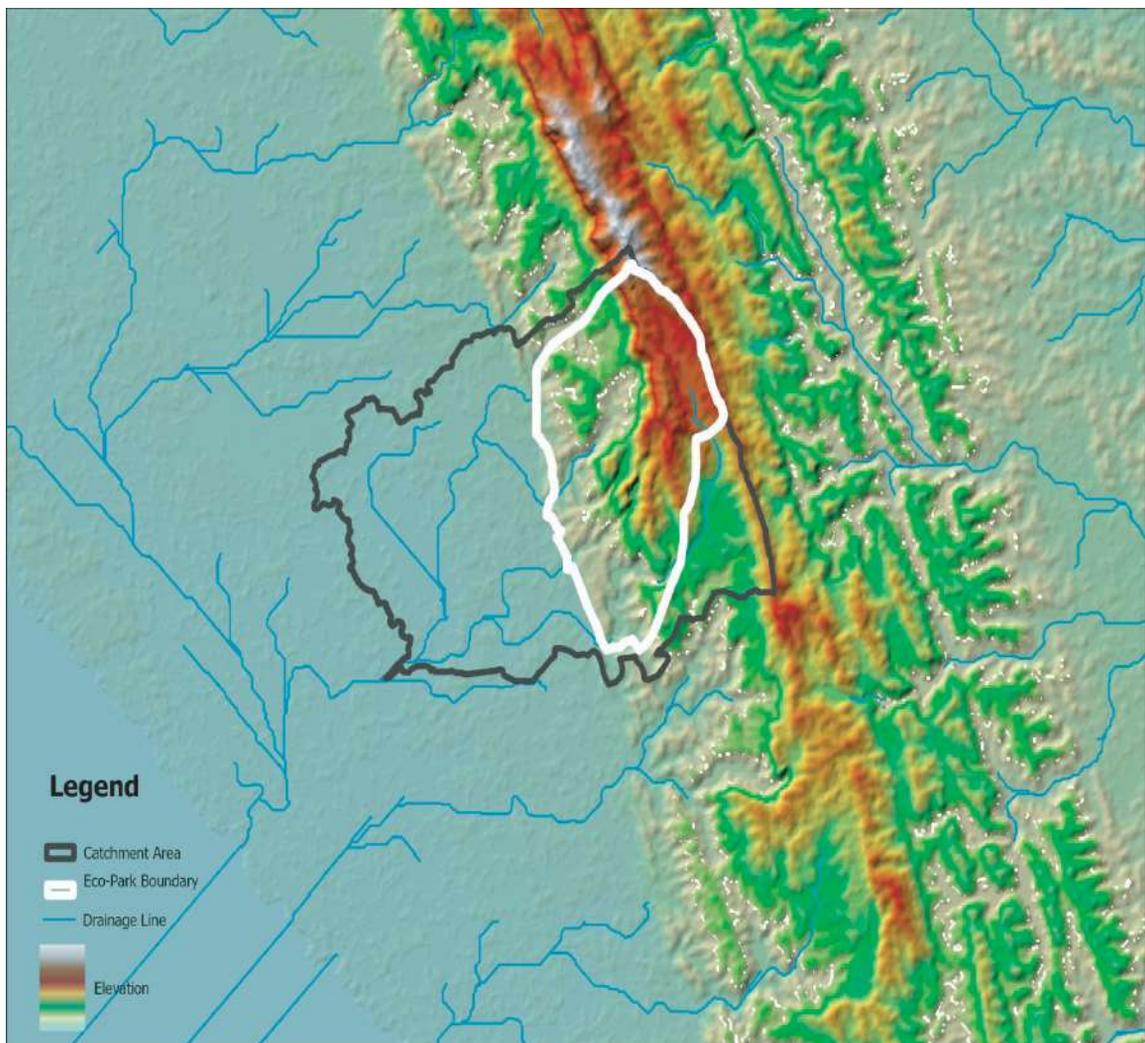


Figure 23: Catchment area of Sitakunda Botanical Garden and Eco-park streams



Figure 24: Data collection for measuring water discharge rate of the streams in SBGEP



Figure 25: Data collection for measuring water infiltration rate in SBGEP stream area



Figure 26: Data collection from local people about water regulation by SBGEP

**Selection of sampling sites**

The entire watershed was divided into 7 stations randomly and from each station, 3 sampling plots were selected (Table 8). Water samples were collected from these plots (Figure 24 & 26).

**Table 8:** List of plots where data was collected

Location	Name of the Stream	Station No	Plot No
1) Inside Eco-park	1.1 Supthadhara	1	Plot: 1 (N: 22.60086; E: 91.68790)
			Plot: 2 (N: 22.601529; E: 91.684895)
			Plot: 3 (N: 22.60179 ; E: 91.68457)
		2	Plot: 4 (N: 22.60152 ; E: 91.68484)
			Plot: 5 (N: 22.60075; E: 91.68311)
			Plot: 6 (N: 22.599677; E: 91.683583)
	3	Plot: 7 (N: 22.598665; E: 91.683798)	
		Plot: 8 (N: 92.59688 ; E: 91,68393)	
		Plot: 1 (N: 22.61442; E: 91.69305)	
1.2 Shasradhara	4	Plot: 2 (GPS was not available)	
		Plot: 3 (GPS was not available)	
2) Outside Eco-park	2.1 Supthadara	5	Plot:1 (GPS was not available)
			Plot:2 (GPS was not available)
			Plot:3 (GPS was not available)
		6	Plot:1 (GPS was not available)
			Plot:2 (GPS was not available)
			Plot:3 (GPS was not available)
	2.2 Guptakhali	7	Plot: 1 (N: 22.58338; E: 91.67806)
			Plot: 2 (N:22.58720; E: 91.65942)
			Plot: 3 (N: 22.578753; E 91.643638 )

**Formula for determining water discharge (Open channel flow: float method)**

Cubic feet per second (CFS) = A x V (area multiplied by velocity)

- A (Area) = Width of channel (feet) x Depth of water (feet)
- V (Velocity) = Distance traveled / time to travel (feet traveled divided by seconds)

- Measure the average surface velocity of the flowing water using the float technique
- Velocity 1 \_\_\_\_\_ ft/s (feet per second)
- Velocity 2 \_\_\_\_\_ ft/s
- Velocity 3 \_\_\_\_\_ ft/s
- Add the three float timed velocity values together then divide that number by 3 = Average Velocity AVG Velocity \_\_\_\_\_ ft/s
- Multiply the AVG Velocity by 0.85 to get the adjusted velocity \_\_\_\_\_ ft/s
- The Area is calculated using the table below: CFS = AREA x AVG. VELOCITY

**Box 2: Float discharge technique worksheet**

### ***Infiltration rate measurement by double ring infiltrometer***

#### **Apparatus**

The double ring infiltrometer is a tool used to measure water infiltration in soil. The set consists of three pairs of inner and outer stainless steel rings with diameters of 28 cm, 30 cm, and 32 cm and a height of 25 cm (Figure 25). Other components include a driving plate, an impact-absorbing hammer, measuring bridges and measuring rods with floats. The double ring limits the lateral spread of water after infiltration and the rings are partially inserted into the soil and filled with water to measure the speed of infiltration.

#### **Procedure**

Here is a summary of the procedure for using the double ring infiltrometer to measure infiltration rate:

- 1) Place the inner ring with the cutting edge facing down on the ground, and remove any obstacles.
- 2) Put the driving plate on top of the inner ring, fitting the ring over, between, or within the pins on the plate, depending on its diameter.
- 3) Use the impact-absorbing hammer to insert the infiltration ring about 5 cm vertically into the soil, being careful not to disturb the soil too much.
- 4) Remove the driving plate from the inserted ring.
- 5) Insert the rings below any particular top layer that may interfere with the measurement, such as a disturbed or crusted layer or layer with macro-pores.
- 6) Place the outer ring with the cutting edge facing down around the inner ring, and put the driving plate on top of it.
- 7) Repeat steps 3-6.
- 8) The standard double ring infiltrometer set allows simultaneous measuring in threefold, so place the rings 2-10 m apart, depending on the field situation.

### **3.8.6. Valuation method of air dust control by SBGEP**

The measurement of air dust was conducted by the Department of Environment (DoE) in Chattogram aimed to assess the level of air dust within and outside of the SBGEP (Figure 27). Seven key locations within the SBGEP were selected to gather data on air dust, specifically in areas where people frequently move. Additionally, seven places outside of the park within a 1 km radius were chosen as reference points to account for other factors that may affect air dust (PM 10 & 2.5) levels. The data collected were used to determine the difference in air dust levels between the SBGEP and the surrounding areas. The valuation of air dust control by SBGEP was done by following compensation cost method based on the study by Dechezleprêtre et al., (2020). To estimate the economic impact of 1 ton of PM<sub>2.5</sub> dust on Bangladesh's Real GDP, we assume uniform dispersion of PM<sub>2.5</sub> in the atmosphere. Considering the surface area of Bangladesh (147,570 km<sup>2</sup>) and a mixing layer height of 1 km, the volume of air is  $147.57 \times 10^{12}$  m<sup>3</sup>. Distributing 1 ton (10<sup>9</sup> μg) of PM<sub>2.5</sub> over this volume results in an increase of approximately 0.0068 μg/m<sup>3</sup>. Given that a 1 μg/m<sup>3</sup> increase in PM<sub>2.5</sub> causes a 0.8% reduction in GDP (Dechezleprêtre et al., 2020), as 0.0068 μg/m<sup>3</sup> increase would reduce GDP by 0.00544%. With

Bangladesh's Real GDP at USD 222.726 billion in 2022, this reduction amounts to approximately USD 12.12 million. Therefore, removing 1 ton of PM2.5 dust per year would economically benefit Bangladesh by about USD 12.12 million.



Figure 27: Data collection for measuring air dust control by SBGEP with the help of Department of Environment, Chattogram

### 3.9 Forest Ecosystem Services (Stock and Flow)

Forests provide a vast array of benefits, known as ecosystem services. These services can be categorized as stocks and flows, highlighting the ongoing processes within a healthy forest.

**Stock:** A resource or monetary asset held at a specific point in time. For instance, Standing timbers, carbon fixation (in trees, undergrowth, and soil), soil fertility, oxygen production etc.

**Flow:** The movement of a resource or service between stocks over time. For example, of a flow would be the harvesting of timber from a forest over a one-year period. Water infiltration, air dust removal, ecotourism, recreation etc. can be considered as a flow of ecosystem services as those can be measured in one-year period.

#### *Conversion of stocks into flow*

In this study, we aim to measure the value of the components in per year basis. For this, it is needed to convert some stock components like: tree and soil carbon storage, undergrowth carbon, soil fertility, climate regulation service (oxygen production and carbon-di-oxide equivalent) into flow in per year basis. This study initially quantified data as a stock and subsequently converted it to a flow format. Users can employ their preferred method to reconvert the provided stock data into flow values as needed. The conversion methods applied in this study has been given below:

***Tree and soil organic carbon, and soil fertility:*** This study intended to estimate annual carbon and soil fertility flow in Sitakunda Eco-park. Precise stand age data is unavailable (for naturally grown trees), but a 25-year average is adopted based on park establishment (1998) and documented restoration efforts. This age aligns with peak carbon sequestration in young forests. Lacking of exact stand age, we utilize the park's documented establishment and ongoing restoration focused on native and slower-growing species (Nath and Alauddin, 2006; Misbahujjaman and Alam, 2006). Prior to this (1980s-1999), the area likely held short-rotation plantations of Eucalyptus and Acacia species, harvested before 2000 (Alam, 2001). These fast-growing species are typically cut within a 5-10-year rotation, suggesting the current tree cover is not remnant from those plantations. This suggests a young forest structure (post-2000) with an average stand age of 25 years, suitable for annual carbon flow estimation. The study acknowledges limitations due to estimated stand age. The 25-year stand age assumption, based on documented history and restoration practices, provides a reliable framework for analysis. Transparency regarding limitations strengthens the research and advances understanding of carbon and soil fertility dynamics in young restored forests.

***Undergrowth carbon:*** The average age of undergrowth is 2-4 years in a temperate forest which was reported by Matveeva et al., (2018). While precise undergrowth age data is unavailable, existing literature suggests faster growth rates in tropical plants compared to temperate ones (openaccessgovernment.org, 2022). Considering this and potential faster growth in our tropical study area, we conservatively adopt an average undergrowth age of 2 year. For this, we have divided the total undergrowth carbon with 2 to find the flow of 1 year. Acknowledging the limitations, the adjusted average age assumption (2 years) offers a starting point for estimating undergrowth carbon flow in the context of our tropical study area. Future research efforts could focus on acquiring more specific data on the undergrowth species composition and their growth rates to refine these estimates.

### **3.10. Total Economic Value (TEV) of SBGEP**

In this study, the Total Economic Value (TEV) of the SBGEP was determined by considering only the use values of the ecosystem services provided by the park. The use values were divided into four categories: Provisioning services, Cultural services, Supporting services, and Regulating services. The monetary value of each category was calculated in both BDT and USD. The total value of the ecosystem services was obtained by adding the monetary sub-totals of each category to find the overall TEV of the SBGEP.



**Figure 28: Natural beauty of Sitakunda Botanical Garden and Eco-park**

## 4. Results and Discussion

Results of the study are presented by categorizing them into four major groups, such as, provisioning, cultural, regulating and supporting services. It is to be noted that the value presented here has been evaluated following a conservative approach. The real value of the services obviously will be much higher than the estimations here.

### 4.1. Identification of Ecosystem Services (ES) in SBGEP

A total of 32 components from four ecosystem services categories were identified from SBGEP (Table 9). This table is showing the percentage of "Yes" for different components and their respective services provided by the SBGEP ecosystem.

**Table 9:** Ecosystem Services (ES) from Sitakunda Botanical Garden and Eco-park

ES	Components	(Yes%)	ES	Components	(Yes%)	
Provisioning	Food	100	Cultural	Tourism	100	
	Timber	100		Job from tourism	100	
	Fuel Wood	100		Cultural Identity & heritage	100	
	NTFPs	100		Peace and Stability	40	
	Fodder	75		Aesthetic Values	100	
	Genetic Resources	20		Education and Research	100	
	Hunting of Wildlife	30		Spirituals and Religious	100	
	Ornamental Resources	10		Mental Health	75	
	Agricultural lands	40		Supporting	Biodiversity Conservation	100
	Drinking Water	40			Soil Formation	60
	Hunting of Wildlife	30			Nursery Habitat	40
Regulating	Climate Regulation	40	Nutrient Cycling		80	
	Noise Control	40	Soil Nutrition		80	
	Soil Erosion Control	100	Pollination		30	
	Carbon Sequestration	100	Seed Dispersal		75	
	Soil Nutrition Control	80	Pest and Diseases		20	
	Water Regulation	100				
	Air Quality Control.	100				

In the Provisioning category, 100% of the services provided by environment are related to food, timber, fuel wood, non-timber forest products (NTFPs), Services such as drinking water and hunting of wildlife have a lower percentage of "Yes". In the Cultural category, highest perception was found in tourism, job creation from tourism, cultural identity and heritage, aesthetic values, education and research, spirituality & religion and mental health. In the Regulating service, climate regulation, air quality control, soil erosion control, carbon sequestration, and water regulation got maximum interest among others. In the Supporting category, all components have a lower percentage of "Yes" with the exception of biodiversity conservation.

### 4.2. Importance of Ecosystem Service Components of the Park to Public

These charts given below can help in understanding the public's priorities and preferences in Importance, Economic Benefit and Potentiality (Total Marks 50) towards the different benefits provided by the ecosystem.

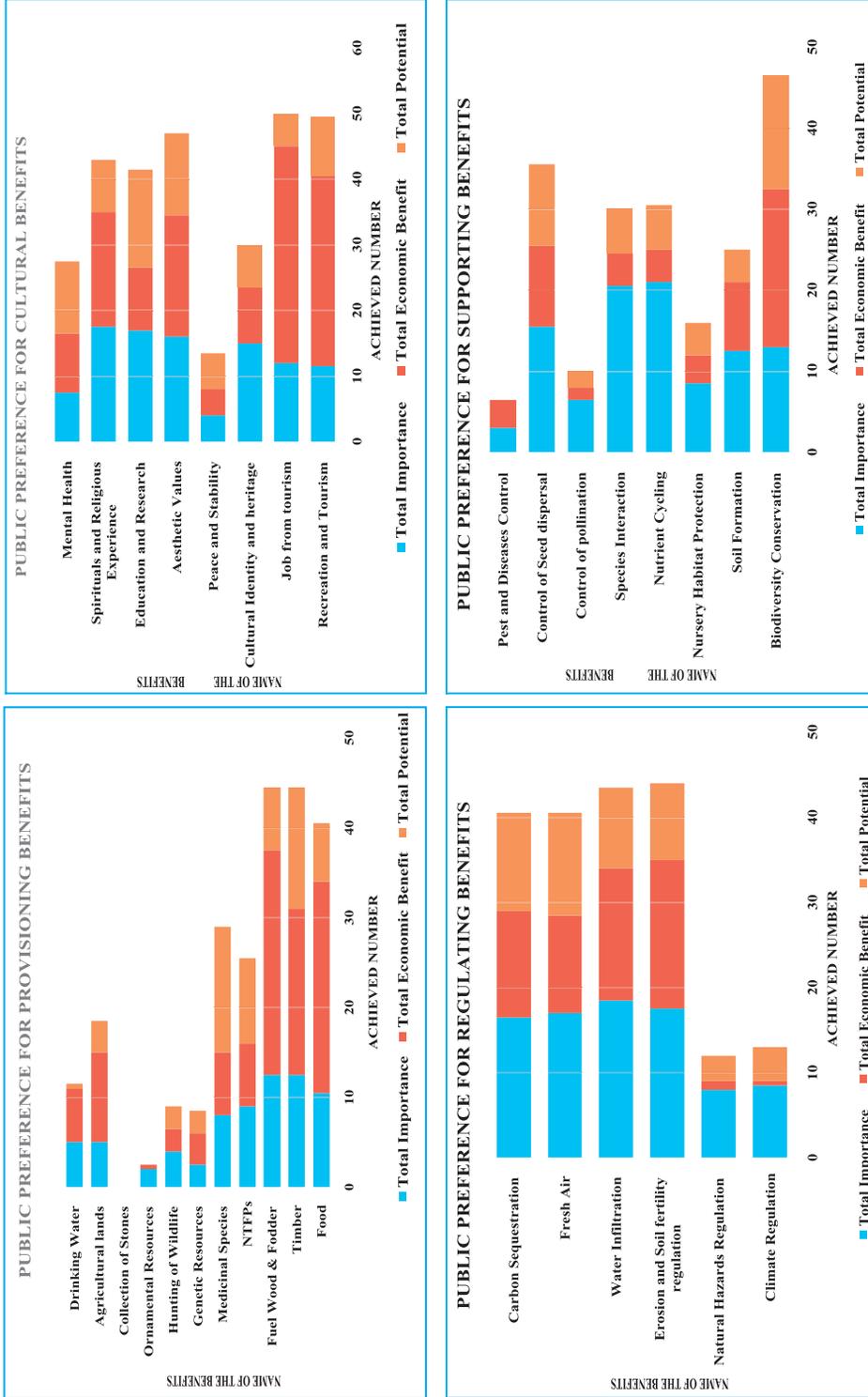


Figure 29 (Chart 1-4: Clockwise): Public's priorities and preferences towards the different benefits provided by the ecosystem

These four graphical charts represent the public preferences of benefits provided by the ecosystem. In figure 29, chart 1 shows that the most preferred provisioning benefits among the public are fuelwood, fodder, and timber. These are followed by medicinal and NTFPs. The second chart illustrates the most preferred cultural benefits among the public are job creation from tourism and recreation. The third one describes that the most preferred supporting benefits among the public are biodiversity conservation and control of seed dispersal which are followed by species interaction and nutrient cycling and the last one shows most preferred regulating benefits among the public which are erosion and soil fertility regulation. These are followed by water regulation and fresh air. These charts can help in understanding the public's priorities and preferences towards the different benefits provided by the ecosystem and can be used in decision making related to conservation and management of these ecosystems.

The workshop organized by BFRI in partnership with Compass Program, USFS was focused on reviewing the methodology for valuing ecosystem services at the Sitakunda Botanical Garden and Eco-park (Figure 12). It was attended by approximately 30 scientists from various organizations such as IFESCU, BFD, USFS and BFRI. The final list of components for valuation was selected based on suggestions from the participants and included nine components under provisioning service, one from cultural services, and six from supporting and regulating services respectively (Table 10).

**Table 10:** Selected Ecosystem Services (ES) components from Sitakunda Botanical Garden and Eco-park

<b>Ecosystem Services</b>	<b>Ecosystem Service Components</b>	
<b>Provisioning Services</b>	Food	Fodder
	Round Log	Water Harvesting
	Fuel Wood	Irrigation
	NTFPs	Grazing
	Medicinal Species	
<b>Cultural Services</b>	Ecotourism	
<b>Supporting Services</b>	Nutrient Cycling	Biodiversity
	Pollination	Seed dispersal
	Pest and Diseases Control	Soil Nutrition
<b>Regulating Services</b>	Soil Fertility Control	Climate Regulation
	Water Regulation	Carbon Regulation
	Air Quality Control	Soil Erosion

### 4.3. Forest Resources of the Park

#### 4.3.1. The conservation status of the SBGEP's vegetation

Though vegetation resources are generally considered as the forest resource, we included the wildlife (vertebrates) in this list. Approximately, 3,82,992 trees (DBH  $\geq$  5 cm) were found in the Sitakunda Botanical Garden and Eco-park. This calculation was based on a 0.1% area of vegetation survey, which covered 0.81 hectares.

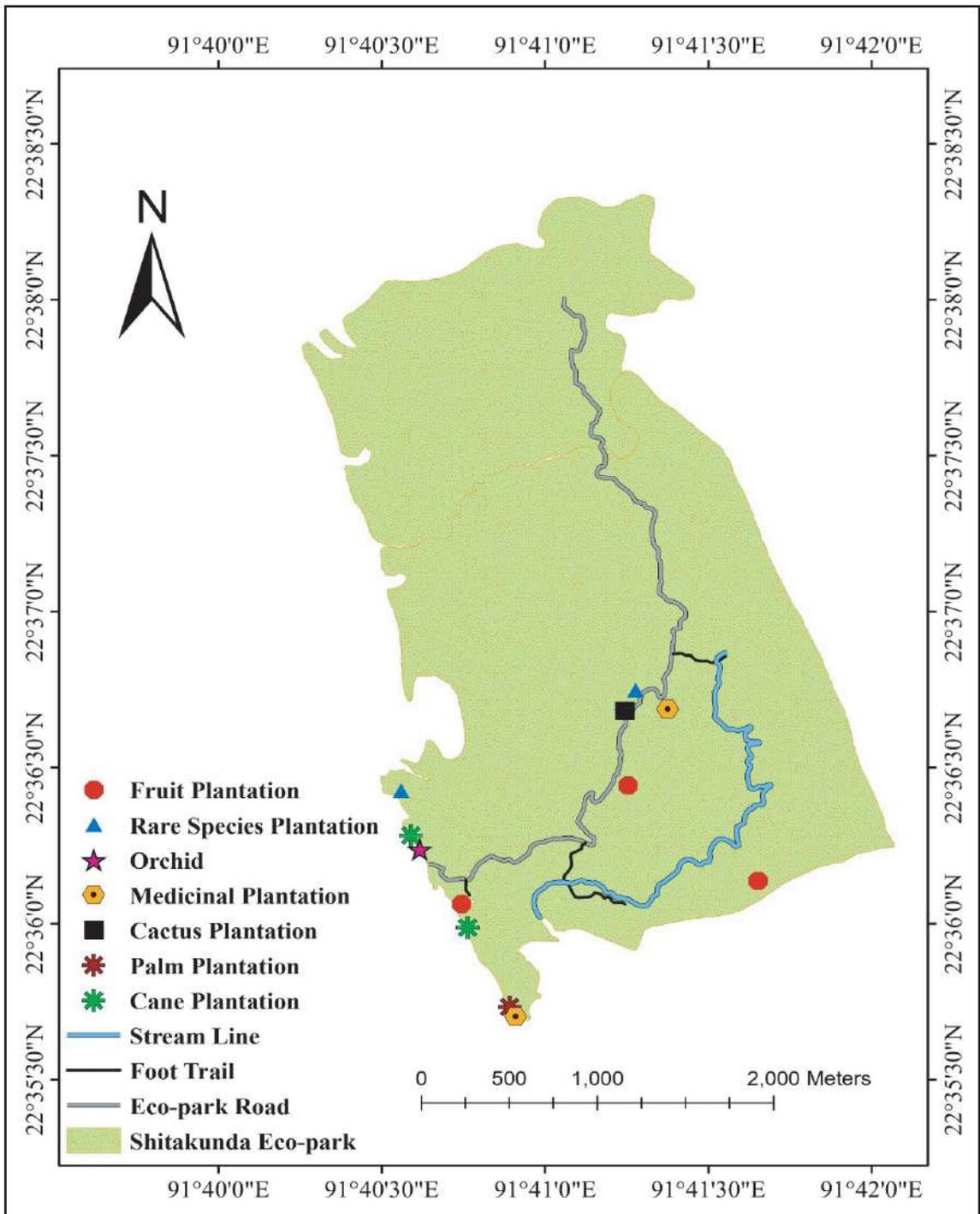


Figure 30: Genetic resources map of SBGEP

There were 82 sampling plots, and 384 trees were found in these plots, with a density of 474 trees (DBH  $\geq$  5 cm) per hectare. The total number of trees in the SBGEP was calculated based on this information.

The Sitakunda Botanical Garden and Eco-park is known for its high diversity of vegetation, with 321 species identified in the area. A small portion (0.1%) of the park was surveyed with the assistance of the Forest Botany Division of BFRI, and the vegetation status of the forest has been recorded (Table 11).

**Table 11:** Type of plants and number of species found in the park

SI No.	Type of Plants	Number of Species	SI No.	Type of Plants	Number of Species
01.	Tree	157	04.	Fern	08
02.	Shrub	59	05.	Epiphyte	02
03.	Herb	72	06.	Climber	23
<b>Total Plant Species</b>		<b>321</b>			

The above table shows the different types of plants found in SBGEP and the number of species under each category. There are 157 tree species, 59 shrub species, 72 herb species, 8 fern species, 2 epiphyte species, and 23 climbing plant species, making a total of 321 plant species (For details See Annex 1 and Figure 31).

The people in the area surrounding the Sitakunda Botanical Garden and Eco-park use the plants for a variety of purposes, including obtaining wild fruits, vegetables, medicines, fuelwood, and fodder. This study has identified the species of plants that are used for people's livelihood.

**Table 12:** Number of species according to the use

SI No.	Use Pattern	Number of Species (Apprx.)	SI No.	Use Pattern	Number of Species (Apprx.)
01.	Round Log	39	07.	Vegetables	28
02.	Fodder	09	08.	Bamboo	14
03.	Fuel Wood	45	09.	Sun grass	01
04.	Medicinal	72	10.	Broom Stick	02
05.	Edible fruit	36	11.	Economic Plant	16
06.	Avenue Plants	51			

Most of the vegetation species (72) used as medicinal purpose followed by avenue plants (51), fuel wood (45). A significant amount of species is used as round log and edible fruit purposes (Table 12). (For details, Annex. 1 and Figure 30)

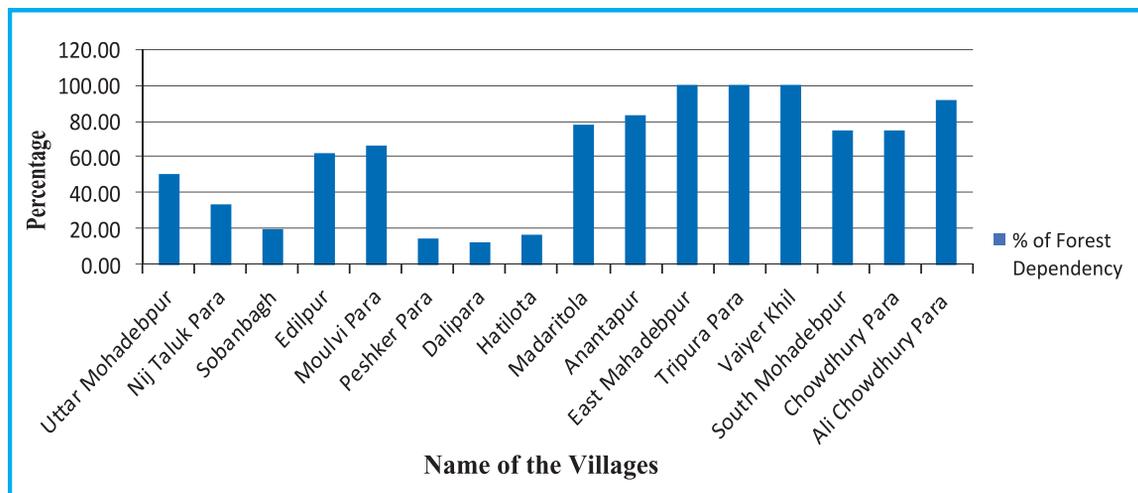
#### 4.3.2. The conservation status of SBGEP's wildlife

The current condition of the wildlife (Vertebrate) in Sitakunda Botanical Garden and Eco-park was assessed to determine its conservation status. The Sitakunda Botanical Garden and Eco-park is rich in wildlife, with a total of 161 vertebral species identified. This includes 27 mammal species, 20 reptile species, and 102 bird species, as well as 12 amphibian species (For details, Annex. 2 and Figure 34 & 35).



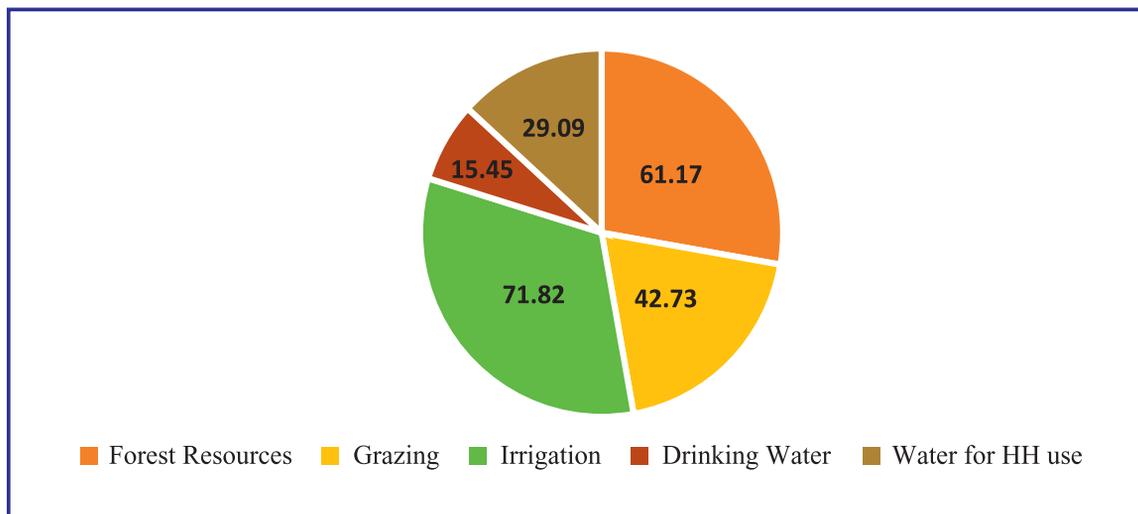
**Figure 31: Vegetative diversity of Sitakunda Botanical Garden and Eco-park**

#### 4.4. Livelihood Dependency of Local Communities on Ecosystem Services



**Figure 32: Dependency rate (%) of villages adjacent to SBGEP**

Local community are more or less dependent on these services, with three villages named: East Mahadebpur, Tripura Para, and Vaiyer Khil expressed 100% dependency on the forest resources, water resources, and other ecosystem services (Figure 32).



**Figure 33: Dependency rate (%) of villagers on the provisioning services**

According to Figure 33, the majority of villagers in the area primarily rely on irrigation for water due to the intense agricultural activity. Streams surrounding the forest serve as the main source of water for irrigation. Forest resource collection is the next significant source, followed by grazing and water for household use.



Figure 34: Image of wildlife captured by camera trapping in SBGEP



Figure 35: Image of wildlife captured by transect walk in SBGEP

## 4.5. Valuation of the Identified Provisioning, Regulatory, Cultural and Supporting Services

The study found 16 villages located near the eco-park and a total of 4404 households residing there. Over 61% of these households, or which in number 2687, have direct dependence on forest resources. The dependency of the households on forest resources provided valuable information (i.e. amount of extraction, income from forest resources, usage etc.) on the provisioning and supporting services provided by the forest. Data were collected from the SBGEP and surrounding areas to determine the value of other services.

### 4.5.1. Valuation of provisioning services

Provisioning services are the most important services provided by the eco-park. A total of 09 different types of components were identified listed in table 10, which were used to determine the value of the provisioning ecosystem services. Furthermore, the component "Food" includes subcomponents such as vegetables, wild fruit, fish, kankra, and fritters, while the component "Water Harvesting" encompasses both domestic and drinking purposes. These subcomponents were used to calculate the overall value of each component. The figure 36 to 38 and 40 to 46 indicate different provisioning benefits of SBGEP.

#### *Water for household use*

The value of water for household use was determined by calculating the value of consumption of stream water in the SBGEP.

**Table 13 :** Monetary value of consumption of water for household use per year in SBGEP

Variables	Unit	Value
Average consumption of water for household use	Liter/Household/Year	99,506.25
Total consumption of water for household use	Liter/Year	12,74,83,789.09
Unit price	BDT/Liter	0.04
Total value of household usage water	BDT/Year	50,42,958.56

It was found that over 29.08% of total households living near the forest use the stream water for their daily needs. This benefit is enjoyed by 6994 people from 1281 households each year. The average household water usage is 272.61 liters per day. Table 13 presents the monetary value of water consumption for household use in SBGEP. The average consumption per household is 99,506.25 liters/year, resulting in a total consumption of 127.48 million liters/year. The local price of water is BDT 0.04 per liter, and as a result, the total value of the water used for daily needs from the stream is more than BDT 5.04 million.

#### *Extraction of forest resources*

In this study, 18 different types of forest resources were listed under the components of food, round log, fuel wood, NTFPs, and medicinal species. The value of each type of forest product was determined through a market survey by asking sellers about the actual price paid by extractors. The net profit earned by extractors from the forest products was calculated, revealing that the yearly value of these extracted products was BDT 6.40 million (equivalent to USD 0.067 million). The highest value was found from fuelwood, with a value of BDT 3.31 million (Table

**Table 14:** Annual financial values of major forest resource extraction from Sitakunda Botanical Garden and Eco-park

Sl No.	Extraction of Forest Resource	Total amount Extracted (Unit/Yr)	Unit	Average Price of Resource (BDT/Unit)	Net Profit (BDT)	*HH Collected Resources (Number)	HH (%)	Total HH (Number)	Provisioning value (BDT)
1	Round Log	117.57	CFT	250.00	8392.50	4.00	4.00	99.00	2,07,712.29
2	Fuel Wood	1333.00	Mound	120.00	7050.00	51.00	46.00	1262.24	33,09,289.35
3	Bamboo	542.00	Culm	60.00	10020.00	23.00	21.00	569.24	2,47,992.52
4	Nalkhagra & Muli Bamboo	189.00	Bundle	150.00	5850.00	23.00	21.00	569.24	1,44,786.05
5	Broom Stick	3042.00	Culm	0.80	1183.60	44.00	40.00	1088.99	29,293.81
6	Sun Grass	66.00	Bundle	150.00	2400.00	7.00	6.00	173.25	59,399.40
7	Fodder	585.00	Bundle	80.00	6800.00	7.00	6.00	173.25	1,68,298.31
8	Edible Wild Fruit	340.00	Kg	52.19	16243.75	8.00	7.00	198.00	4,02,028.79
9	Vegetables	2658.25	Kg	21.88	49149.22	13.00	12.00	321.75	12,16,430.98
10	Medicinal Plants	172.00	kg	50.00	5600.00	4.00	4.00	99.00	1,38,598.61
11	Fritter	150.00	Kg	50.00	6525.00	0.00	0.00	0.00	6525.00
12	Turtle	32.00	Number	200.00	5900.00	0.00	0.00	0.00	5900.00
13	Kankra	400.00	Dozan	155.00	59656.25	0.00	0.00	0.00	59,656.25
14	Honey	0.62	Mound	40000.00	19550.00	4.00	4.00	7.42	36,289.32
15	Deer	2.00	Number	36000.00	69750.00	0.00	0.00	0.00	69,750.00
16	Wild cock	4.00	Number	833.79	2585.14	0.00	0.00	0.00	2585.14
17	Wild boar	8.00	Number	30000.00	228750.00	0.00	0.00	0.00	2,28,750.00
18	Fish	2.00	Mound	4800.00	2100.00	18.00	16.00	445.50	51,974.48
<b>Total (in BDT)</b>									<b>63,85,260.30</b>
<b>Total (Million USD)</b>									<b>0.067</b>
									(1 USD = 95 BDT)

\*HH= Household.

**Table 15:** Value of drinking water per year in SBGEP

Variables	Unit	Value
HH use water for drinking purpose	%	15.45
People use water for drinking purpose	Number	3715.30
Volume of water	Liter/Head/Year	900.00
Volume of water	Liter/Year	3343770.98
Unit price	BDT/Liter	0.04
Total value of drinking water	BDT/Year	<b>1,32,271.71</b>

Table 15 shows the value of drinking water per year in SBGEP. It reveals that 15.45% of households use water for drinking, with a total of 3,715.30 people relying on it. On an average, each person consumes 900.00 liters of water annually. It was found that people living in the buffer zone of SBGEP consuming about 3.35 million liters of drinking water per year from the streams. The total value of the drinking water consumed per year is about BDT 0.13 million.

**Table16:** Monetary value of water for irrigation per year in SBGEP

Variables	Unit	Value
Irrigation Dependency	%	71.82
Farmers (Approx.)	Number	385.00
Farmers use water for Irrigation	Number	276.51
Average Irrigation Cost	BDT/ hour	183.81
Water use for Irrigation	hour/Farmer/year	69.55
Cost of Irrigation	BDT/Farmer/Year	12783.99
Total Price of Water for Irrigation	BDT/Year	<b>35,34,901.08</b>

The agricultural activities was found involved 385 farmers in the study area. Of these farmers, around 277 (about 72%) utilize water for irrigation. The average irrigation cost is 183.81 BDT per hour, and each farmer irrigates for about 69.55 hours per year. Consequently, the total price of water for irrigation reaches approximately BDT3.54 million per year (Table 16).

### *Valuation of grazing*

Table 17 highlights the importance of forests and grazing to the local households in SBGEP and provides insight into the livelihoods and resource dependency of the communities in the area. The percentage of households that are dependent on grazing is about 43%. The total number of households that are dependent on grazing is about 1153.

**Table 17:** Number of the household dependent on SBGEP for grazing

Variable	Unit	Value
Grazing Dependency	%	42.92
Household having Forest Dependency (on forest resources)	Number	2686.44
Household having Grazing Dependency	Number	1152.76

With a cost of 100.84 BDT for each cow per day for grazing and 318.24 BDT for each cow per day without grazing, the value of grazing is calculated at 190.88 BDT for each cow per day (Table 18)."Value of Grazing" represents the difference between the cost with grazing and the cost without grazing and shows the value of grazing for each cow per day.

**Table 18:** Monetary value of grazing cow in SBGEP

Variable	Unit	Value
Cost with grazing	BDT/Cow/Day	100.84
Cost without grazing	BDT/Cow/Day	291.72
Value of grazing	BDT/Cow/Day	190.88
Grazing Period	Day/Year	82.43
Household having cow	Number	213.17
Average number of cow	Cow/Household	1.12
Total cow	Number	238.75
Monetary Value of grazing for cow	BDT/Year	<b>37,56,555.72</b>

Grazing Period of cows is about 82 days. The number of households that have cows is about 213. The total number of cows found in the area is 239. Consequently, the annual monetary value of grazing for cow amounts to approximately BDT 3.76 million (Table 18).

Table 19 shows information about the cost of grazing goats and the monetary value of it in SBGEP. The cost of rearing a goat per day with grazing, which is BDT 36.21 and without grazing is BDT 77.00.

**Table 19:** Monetary value of grazing goat in SBGEP

Variable	Unit	Value
Cost with grazing	BDT/Goat/Day	36.21
Cost without grazing	BDT/Goat/Day	77.00
Value of grazing	BDT/Goat/Day	40.79
Grazing Period	Day/Year	83.33
Household having goat	Number	362.22
Average number of goat	Goat/Household	1.70
Total Goat	Number	615.77
Monetary Value of grazing for goat	BDT/Year	<b>20,93,034.73</b>

"Value of Grazing" represents the difference between the cost with grazing and the cost without grazing and shows the value of grazing per goat per day, which is BDT 40.79. The total number of goats in the area is 616. The total monetary value of grazing for all goats in the area in BDT per year is about 2.09 million (Table 19).

Table 20 highlights the importance of grazing for farmers in SBGEP, showing the economic value that it adds to the farmers' livelihoods. Gross monetary value of grazing shows the total monetary value of grazing cows and goats is BDT 14.64 million per year.

**Table 20:** Monetary value of grazing in SBGEP

Variable	Unit	Value
Gross monetary value of grazing	(BDT/Year)	58,49,590.45
Net monetary value of fodder (-)	(BDT/Year)	1,68,298.31
Net nonetary value of grazing	(BDT/Year)	<b>56,81,292.14</b>

Net monetary value of fodder shows the cost of the fodder that was deducted from the total value of grazing. Finally, the Net monetary value of grazing was found after deducting the cost of fodder is BDT 5.68 million per year.

**Table 21:** Monetary values of the provisioning services from Sitakunda Botanical Garden and Eco-park

Name of the Component	Subcomponents	Provisioning Value (BDT)	Total (BDT)
Food	Edible Wild Fruit	4,02,028.79	20,43,600.64
	Vegetables	12,16,430.98	
	Fritter	6525.00	
	Turtle	5900.00	
	Kankra	59,656.25	
	Deer	69,750.00	
	Wild cock	2585.14	
	Wild boar	2,28,750.00	
	Fish	51,974.48	
Round Log	-	-	2,07,712.29
Fuel Wood	-	-	33,09,289.35
NTFPs	Bamboo	2,47,992.52	5,17,761.10
	Nalkhagra & Muli Bamboo	1,44,786.05	
	Broom Stick	29,293.81	
	Sun Grass	59,399.40	
	Honey	36,289.32	
Medicinal Species	-	-	1,38,598.61
Fodder	-	-	1,68,298.31
Water Harvesting	Drinking Water	1,32,271.71	51,75,230.27
	Water for HH Use	50,42,958.56	
Irrigation	-	-	35,34,901.08
Grazing	Cow	37,56,555.72	56,81,292.14
	Goat	20,93,034.73	
<b>Total Provisioning Value of SBGEP (in BDT)</b>			<b>2,07,76,683.79</b>
<b>Total Provisioning Value of SBGEP (in million USD)</b>		(1 USD = 95 BDT)	<b>0.22</b>

\* Net profit of people received from the SBGEP provisioning ecosystem services was counted as provisioning value.

\* The value of fodder was deducted from the total value of grazing to avoid overlapping of benefits.

Table 21 indicates a comprehensive view of the components and subcomponents of the SBGEP ecosystem services, along with their respective provisioning values in both BDT and USD. The food category encompasses a variety of food items, including edible wild fruits, vegetables, fritter, turtle, kankra, deer, wild cock, wild boar, and fish, with a total provisioning value of BDT 2.04 million. The provisioning value for round logs is BDT 0.21 million, while fuel wood holds a value of BDT 3.31 million. Non-Timber Forest Products such as bamboo, nalkhagra and muli bamboo, broomstick, sun grass, and honey, have a combined provisioning value of BDT 0.52 million. The provisioning value of medicinal species is BDT 0.14 million, and that of fodder is BDT 0.17 million. The combined value of drinking water and water for household use is BDT 5.18 million, and that of irrigation is BDT 3.53 million. Finally, the provisioning value of grazing cattle is BDT 5.68 million. It can be seen that the highest benefit was received from irrigation and the lowest benefit was received from medicinal species. The total provisioning value of the SBGEP program is BDT 20.77 million which is equivalent to USD 0.22 million. Figure 36 to 46 representing the evidence of receiving provisionary benefits from SBGEP.



Figure 36: Round log extraction from Sitakunda Botanical Garden and Eco-park

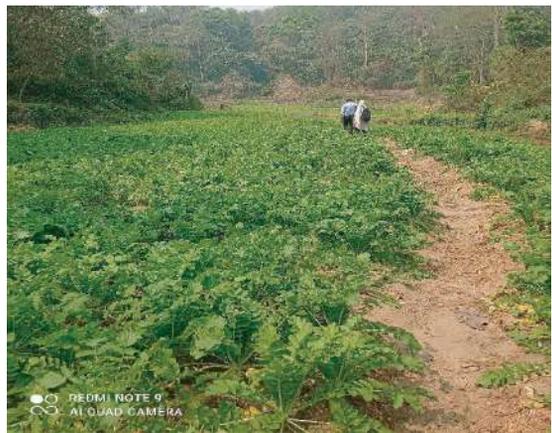
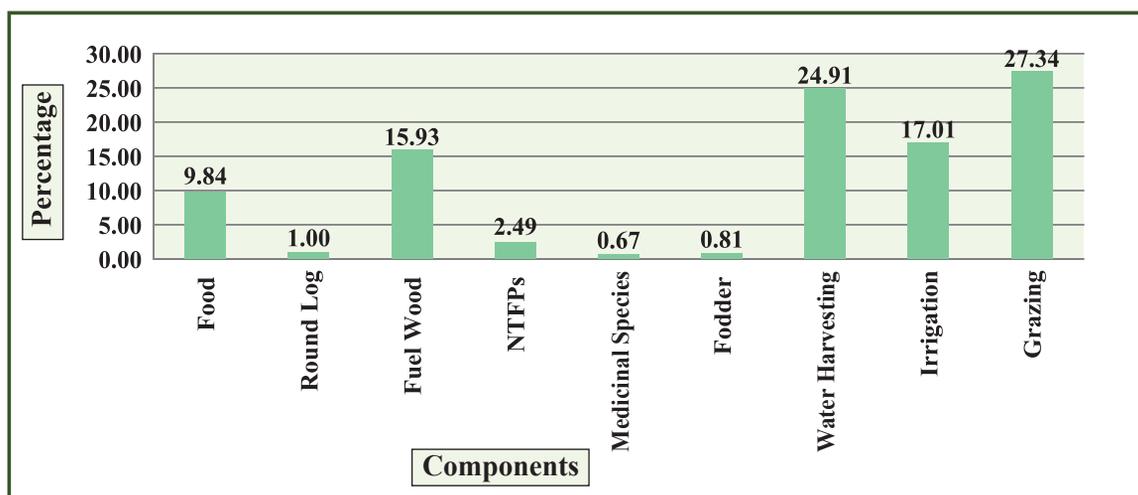


Figure 37: Fruit and vegetables production in Sitakunda Botanical Garden and Eco-park



Figure 38: Fuel wood collection from Sitakunda Botanical Garden and Eco-park



**Figure 39: Contribution (%) of components in provisioning services of SBGEP**

Figure 39 presents the contribution of different components to the total monetary value of provisioning services. The component with the highest contribution is grazing, which accounts for nearly 28% of the total value. Water harvesting (drinking water + water consumption for household use) contributes 24.91%, irrigation contributes about 17% and fuel wood subsidizes nearly 16%. The remaining components have a low influence compared to these four.

These findings suggest that grazing, water harvesting and irrigation play a significant role in determining the overall provisioning value. The other components, while still important, have a lower impact on the total value. This information would be useful in prioritizing resources and making decisions regarding the management and use of stream water and the ecosystem as a whole.



**Figure 40: Honey and sun grass extraction from Sitakunda Botanical Garden and Eco-park**



**Figure 41: Fodder collection from Sitakunda Botanical Garden and Eco-park**



**Figure 42: Bamboo collection from Sitakunda Botanical Garden and Eco-park**



**Figure 43: Broom grass collection from Sitakunda Botanical Garden and Eco-park**



Figure 44: Household use of stream water in Sitakunda Botanical Garden and Eco-park



Figure 45: Irrigation from stream water in Sitakunda Botanical Garden and Eco-park



Figure 46: Grazing in Sitakunda Botanical Garden and Eco-park

#### 4.5.2. Valuation of cultural service

The cultural values of a natural ecosystem can include a variety of values such as aesthetic, artistic, educational, spiritual, and scientific. In this study, only tourism, specifically ecotourism, was considered as a cultural ecosystem service. The study was conducted using a sample of 150 tourists, predominantly composed of males. The tourists were selected randomly in locations where the enumerators were most likely to encounter them. Almost all the respondents were male and came from different parts of Bangladesh. This information provides insight into the methods used for the study and helps to contextualize the results.

**Table 22:** Determination of zone wise information for individual tourist

Zone	Round Travel time (Hour)	Income (BDT)/Hour	Distance (Km)	Transportation Cost (Per Km)	Ticket Price (BDT)
Dhaka	11	155	228.10	6.41	30.00
Chattogram	4	97	55.41	9.21	30.00
Khulna	22	108	404.43	4.73	30.00
Rajshahi	21	149	407.50	3.67	30.00
Barisal	22	58	264.50	5.62	30.00
Sylhet	22	156	336.50	2.64	30.00
Mymensingh	18	111	338.00	3.96	30.00

Table 22 shows the travel time, income, distance, transportation cost, and ticket price for different zones in Bangladesh. The zones listed are Dhaka, Chattogram, Khulna, Rajshahi, Barishal, Sylhet, and Mymensingh. For each zone, the round travel time in hours, the income in BDT per hour, the distance in km and the transportation cost in BDT per km are given.

**Table 23:** Determining the number of tourists (zone wise) visit SBGEP per year

Zone	Avg. Number of Tourists/Day	% of Tourists	Tourists/Year
Dhaka	104	7	40,276
Chattogram	1169	78	4,52,714
Khulna	94	6	36,403
Rajshahi	49	3	18,976
Barisal	36	2	13,942
Sylhet	20	1	7745
Mymensingh	32	2	12,393
<b>Avg. Number of Tourists</b>	<b>1504</b>	<b>100</b>	<b>5,82,448</b>

The distribution of tourists among different zones in Bangladesh has been shown in Table 23. As per the data, it can be seen that the South-Eastern zone of Bangladesh (Chattogram Division) has the highest number (78%) of visitors, followed by the Dhaka Division and the Khulna Division. The other zones, such as Rajshahi, Barishal, Sylhet, and Mymensingh, have relatively fewer visitors. Additionally, the data shows that there were no foreign visitors. Moreover, no visitor from the Rangpur Division recorded during the study period.

**Table 24:** Determination of zonal travel cost of tourism in SBGEP

Zone	Income /Hour	Time Cost (BDT) inside the Park	Time Cost (BDT) outside the park	Distance Cost (in BDT)	Time Cost for the Eco-park (BDT)	Distance Cost for the Eco-park (BDT)	Partial Travel Cost (BDT)
Dhaka	154.58	510.13	1773.07	2925.00	864.74	585.00	5,95,97,470.94
Chattogram	96.91	319.81	389.23	1020.78	397.65	204.16	28,60,27,999.00
Khulna	107.74	355.54	2367.16	3828.57	828.97	765.71	5,91,43,297.86
Rajshahi	149.31	492.71	3100.58	2993.33	1112.82	598.67	3,30,46,583.88
Barisal	58.33	192.50	1280.42	2975.00	448.58	595.00	1,49,67,441.99
Sylhet	156.25	515.63	3382.81	1775.00	1192.19	355.00	1,22,15,820.55
Mymansingh	110.83	365.75	1941.80	2680.00	754.11	536.00	1,63,59,477.22
<b>Travel Cost (BDT/Year)</b>							<b>48,13,58,091.44</b>

Table 24 provides information on the travel cost for tourists visiting from seven different zones in Bangladesh. For each zone, the table includes the hourly income of tourists, time cost inside and outside the park, distance cost, time cost for the eco-park, distance cost for the eco-park, and partial travel cost. The time cost inside the park is calculated by multiplying the hourly income by the time a tourist spends inside the park. The time cost outside the park is calculated in the same manner, but it takes into account the time a tourist spends outside of the park. The distance cost represents the cost of transportation to and from the park for a visitor, while the time cost for the eco-park takes into account the total time a tourist passes inside the park. This study found that all in average a tourist passes 3.30 hours in the park. The distance cost for the eco-park represents the cost of transportation specifically to and from the eco-park. Finally, the partial travel cost is the sum of the time and distance costs for the eco-park and multiplication with the number of visitors visit every year from the respective zone. In total, the travel cost for all seven zones is BDT 481.36 million per year (Table 24).

**Table 25:** Value of ecotourism of SBGEP

Variable	Unit	Value
Travel Cost	BDT/Year	48,13,58,091.44
Vehicle Toll/year	BDT/Year	28,30,670.00
Total income of CNG taxi drivers from tourism	BDT/Year	30,24,000.00
Income of Shopkeepers	BDT/Year	25,27,200.00
<b>Value of Ecotourism</b>	<b>BDT/Year</b>	<b>48,97,39,961.44</b>
<b>Value of Ecotourism</b>	<b>Million USD</b>	<b>5.16</b>

\*1 USD = 95 BDT

About 5,82,448 tourists visit this park per year. Since, there was a car parking area, the toll collected from the tourists' vehicles were included in this study. About 41,637 number (in an Average) of different vehicles are being parked there every year. Not only that, there were 18 CNG Taxis and 11 shops which are completely dependent on the tourists. So, the yearly average income from those tourist services were included in this valuation. The information regarding the total number of tourists, income from ticket selling and vehicle toll were collected from Range Office of SBGEP. Total monetary benefit from ecotourism component of cultural service is BDT. 489.74 million (USD. 5.16 million) (Table 25). Figure 34 to 36 are representing ecotourism benefits in SBGEP.

This information can be used to compare the popularity of tourism of SBGEP and to analyze trends in the tourism industry in the country. This result can also be used to make informed decisions about investments in the tourism industry and to allocate resources effectively.



**Figure 47: Tourists are visiting Sitakunda Botanical Garden and Eco-park**



**Figure 48: CNG taxi drivers and shopkeepers providing service to the tourists of SBGEP**



**Figure 49: Vehicle toll is being collected from the parking lot of SBGEP**

### 4.5.3. Valuation of supporting services

The economic value of supporting services provided by the Sitakunda Botanical Garden and Eco-park, such as crop diversity (which relates pollination, nutrient recycling, pest and disease control), forest biodiversity, seed dispersal, and soil nutrition, helps to maintain the health and productivity of the ecosystem (Figure 51). These services play a crucial role in ensuring the sustainability of the environment, and their estimated monetary value gives an indication of their economic importance.

#### *Valuing pollination, nutrient recycling, pest and diseases control and forest biodiversity*

The productivity method is a commonly used approach to calculate the maximum components like pollination, nutrient recycling, pest and diseases control, forest biodiversity etc. of ecosystem services. This method estimates the value of the services based on the increase in productivity that they provide to economic activities. In this approach, the value of the ecosystem services is estimated by calculating the increase in the economic output resulting from the provision of the service.

**Table 26:** Descriptive statistics of independent and dependent variables

Variable	Mean	Std. Error	95% Confidence Interval	
			Lower	Upper
<i>incrop</i>	7952.5455	661.79582	6870.0809	9198.2431
<i>sppdensity</i>	5.7818	.34665	5.1093	6.5199
<i>ecoextent</i>	.6323	.06007	.5423	.7548

Here, crop income represents the annual financial returns obtained by farmers or agricultural producers from the harvest and sale of their cultivated crops. The average crop income of the sample households was about BDT. 7953 (Table 26) and this figure was used to extrapolate total crop income. This study found that almost all households in the sample are dependent on crop income in some way. Some households have members engaged in agriculture, either within the buffer zone of the SBGEP or by leasing their agricultural land to others. Rest of them produce vegetables for their own consumption at their household premises. Average crop species density of this area is 6 per household and in average 0.63 ha land of a village is in the forest area (Table 26). The study estimates that the total crop income in the study area is BDT 35.02 million. Detail table can be seen in Annex 3.

**Table 27:** Effects of crop diversity and forest area on crop income of the farm households

Model	coefficient	Standard Error	t	P >  t	95% Conf. Interval	
					Lower Bound	Upper Bound
(Constant)	-2134.55	2968.253	-0.72	0.474	-8024.951	3755.851
<i>sppdensity</i>	715.5112	173.0308	4.14	0.000	372.1372	1058.885
<i>ecoextent</i>	3120.273	1282.532	2.43	0.017	575.1298	5665.417

Note: Number of observations (households) = 110; Population size = 4404; prob > F = 0.000; R<sup>2</sup> = 0.336; P < 0.05).

The study recognizes that the SBGEP provides benefits to agriculture in the form of pollination, soil nutrition, soil formation, pest and disease control, among others. However, it is not possible

to measure the extent of these benefits, the study estimated the intangible values of crop and forest diversity to find the real benefits that people received from the SBGEP. The study used the species density coefficient per household and the average species density to estimate the intangible (aggregate) value of crop diversity on crop income (Table 27). See full table in Annex 4 and for more information follow Annexes. 5 and 6.

**Table 28:** Crop income from agricultural activities in the villages adjacent to the SBGEP

Variable	Unit	Value
Crop income	BDT/HH	7953.00
Average crop Species density	No./HH	6
Average area of the forest in each Village	ha	0.63
Increased crop income for each unit increases in the crop Species Density	BDT/HH	716.00
Increased crop income for each unit (ha) increases in the ecosystem extent	BDT/HH	3120.00
Total Household adjacent to the SBGEP	No.	4404
Intangible value of crop diversity per year	BDT	1,89,19,584.00
Intangible value of Forest biodiversity per year	BDT	86,88,105.50

The species density coefficient per household was multiplied by the average species density and the total number of households to estimate the intangible value of crop diversity across the study area. The estimated intangible value of crop diversity was found to be BDT 18.91 million (Table 28).

The study estimated the intangible value of the supporting services of forest biodiversity on household income by multiplying the ecosystem extent coefficient by the average ecosystem extent and the total number of households. The estimated intangible value of forest ecosystem services across the study area was found to be BDT 8.69 million (Table 28).

### **Valuation of deed dispersal**

Seed dispersal is a benefit that a forest management body receives from the ecosystem of the forest. It is the process by which seeds are transported away from their parent plant to a new location where they can germinate and grow into new plants. This process is essential for the survival and reproduction of many plant species in the forest ecosystem. Monetary valuation of seed dispersal benefits can help to ensure that the full value of the ecosystem services provided by the ecosystem is recognized and incorporated into decision-making processes.

**Table 29:** Valuation of seed dispersal in Sitakunda Botanical Garden and Eco-park

Variable	Unit	Value
Plantation cost of park authority in last 05 years (2016-2020)	BDT	23,60,000.00
Total Seedling Planted	No.	1,57,500
Cost of seedling	BDT	14.98
Average number of seedlings planted in 05 years	No./ha	2018
Average plantation cost	BDT/ha/year	30,235.83
No of Seedlings (one year old natural regeneration)	No./ha	6011
Replacement Cost	BDT/ha/year	90,073.33
Money saved due to natural regeneration by seed dispersal	BDT/ha/year	59,837.51
<b>Total Value of Seed Dispersal</b>	<b>BDT/year</b>	<b>4,83,96,574.59</b>

Table 29 provides information about the valuation of seed dispersal in the Sitakunda Botanical garden and Ecopark using the replacement cost method. The total cost of park authority from 2016-2019 is shown to be BDT 2.36 million. During this period, the park authority planted a total of 1,57,500 seedlings, with a cost of BDT 14.98 per seedling. This results in an estimated cost of BDT 30,235.83 per hectare per year for seedling plantation. The table also provides information about the estimated number of seedlings per hectare for natural regeneration which is 6,011. The replacement cost per hectare per year was estimated to be BDT 90,073.33. This means that the park authority saved BDT 59,837.51 per hectare per year through natural regeneration. The total value of seed dispersal was calculated to be BDT 48.40 million, which represents the economic benefits of the seed dispersal services provided by the forest ecosystem in the SBGEP.

#### **Determination of monetary value of soil nutrition (N, P, K)**

Though determining the monetary value of soil nutrition (N, P, K) involves assessing the economic benefits that these nutrients provide to agricultural production. In this study, we went through direct market price method. Using the direct market price method to determine the monetary value of soil nutrition (N, P, K) involves assessing the amount of these nutrients in the soil and then multiplying it by the market price of the fertilizers that provide these nutrients. It is important to note that this approach provides an estimate of the economic benefits of soil nutrition and does not account for non-market benefits, such as the ecological benefits of nutrient cycling in the soil.

**Table 30:** Amount of soil nutrition (Nitrogen, Phosphorus, Potassium) in SBGEP

Variable	Values	SD	SE
Amount of Nitrogen (N) (kg/ha)	2574.70	0.37	0.07
Amount of Phosphorus (P) (kg/ha)	40.12	0.01	0.00
Amount of Potassium (K) (kg/ha)	697.71	0.18	0.04
<b>Total amount of N (kg)</b>			<b>20,80,357.60</b>
<b>Total amount of P (kg)</b>			<b>32,412.32</b>
<b>Total amount of K (kg)</b>			<b>5,63,743.50</b>

Table 30 provides information about the amount of nitrogen (N), phosphorus (P), and potassium (K) present in the SBGEP area. The values listed in the table are in kilogram (kg). The SBGEP area has 2574.70 kg/ha of nitrogen, a total of 2081 thousand kg; 40.12kg/ha of phosphorus and a total of 32 thousand kg; 697.71 kg/ha of potassium and a total of 563 thousand kg. The data on soil nutrient content in the SBGEP area provides an estimate of the soil's fertility and helps in determining the health and productivity of the ecosystem. By knowing the amount of nutrients such as nitrogen, phosphorus, and potassium present in the soil, it is possible to assess the soil's ability to support plant growth and overall ecological health.

**Table 31:** Monetary value of soil nutrition (N, P, K) in SBGEP

Variable	Values
Value of N (BDT)	5,20,08,940.00
Value of P (BDT)	10,15,478.032
Value of K (BDT)	1,40,93,587.36
<b>Value of Total Soil Nutrition (BDT)</b>	<b>6,71,18,005.39</b>
<b>Value of Total Soil Nutrition (BDT/year)</b>	<b>6,71,180.10</b>

\*1 USD = 95 BDT

Table 31 shows the monetary value of soil nutrition (N,P,K) in the SBGEP area. The values are given in Bangladesh Taka (BDT) and Million US dollars (USD). The value of nitrogen is BDT 52 million, the value of phosphorus is BDT 1.02 million, and the value of potassium is BDT 14.10 million. The total value of soil nutrition in BDT is 67.12 million. Unfortunately, we cannot directly measure the yearly increase of soil nutrients. To address this limitation, we divided the total value of BDT 67.12 million by 25. This is because the park was designated a protected area approximately 25 years ago (established in 1998) relative to our data collection year (2022). While this approach provides a tentative annual value of BDT 2.70 million (or USD 0.023 million) for soil nutrients, it's important to acknowledge the limitations. These values give an estimate of the monetary value of soil nutrients in the SBGEP area, which is important in evaluating the economic impact of soil nutrient loss and soil degradation.

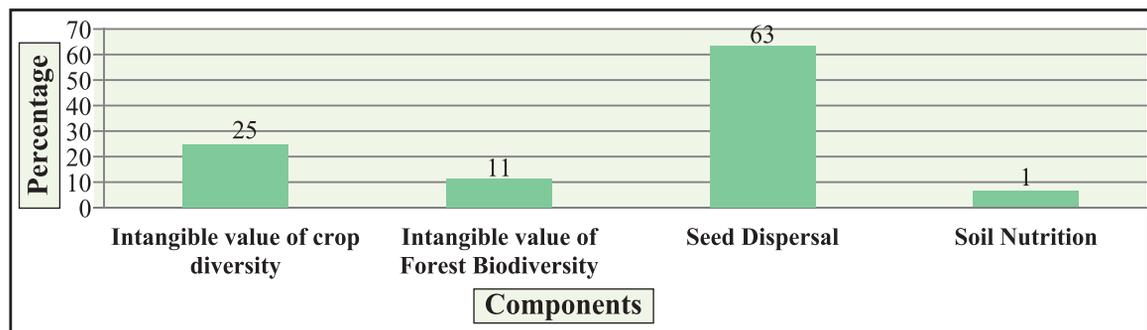
**Table 32.** Valuation of supporting services in Sitakunda Botanical Garden and Eco-park

Components		Unit	Value
Intangible value of crop diversity	Pollination	BDT	1,89,19,584.00
	Nutrient Recycling		
	Pest & Diseases Control		
Intangible value of Forest Biodiversity		BDT	86,88,105.50
Seed Dispersal		BDT	4,83,96,574.59
Soil Nutrition		BDT	6,71,180.10
<b>Total Monetary Value</b>		BDT	<b>7,66,75,444.19</b>
		<b>Million USD</b>	<b>0.81</b>

\*1 USD = 95 BDT

Table 32 shows the valuation of supporting services (per year basis) in the Sitakunda Botanical Garden and Eco-park. The intangible value of crop diversity, which includes pollination, nutrient recycling, and pest and disease control, is about BDT 19.00 million. The intangible value of forest biodiversity is BDT 8.69 million. The value of seed dispersal which is maximum among the other components is BDT 48.40 million. The value of soil nutrition is BDT 288.80 million. The total monetary value of supporting services in Sitakunda Botanical Garden and Eco-park is BDT 76.66 million, which is equivalent to USD 0.81 million per year.

These values give an estimate of the economic value of supporting services provided by the Sitakunda Botanical Garden and Eco-park, which are essential for maintaining the health and productivity of the ecosystem.



**Figure 50:** Contribution(%) of components in supporting services of SBGEP

Figure 50 presents the contribution of different components to the total monetary value of supporting services in the Sitakunda Botanical Garden and Eco-park. The component with the highest contribution is seed dispersal, which accounts for 63% of the total value. Crop diversity contributes 25%, forest biodiversity contributes 11%, and soil nutrients contributes nearly 1%. It suggests that seed dispersal plays a significant role in determining the overall value of supporting services in the Sitakunda Botanical Garden and Eco-park. The other components, while still important, have a lower impact on the total value. This information is useful in prioritizing resources and making decisions regarding the management of the ecosystem.



Figure 51: Intangible benefit in crop diversity and biodiversity from supporting service

#### 4.5.4. Valuation of regulating services

We identified 6 components that can help to evaluate of the regulating service (Table 10). Each of these 6 components has its own subcomponents that contribute to the overall value of the regulating ecosystem services. The total number of subcomponents is 11. By valuing these 6 components and their subcomponents, it is possible to estimate the economic value of this ecosystem services. This information is useful in making informed decisions about the management and protection of this critical services. The goal is to ensure that the regulating ecosystem services continues to provide essential benefits to people and the environment.

##### Valuing carbon regulation

This component has four subcomponents i.e. tree (or vegetation) carbon, soil organic carbon, soil carbon control and carbon from litter and undergrowth. These subcomponents help to provide a more detailed understanding of the carbon sequestration component and its contribution to the overall value of the ecosystem. By accounting for these subcomponents, it is possible to develop an accurate estimates of the economic value of carbon sequestration and make solidified decisions about how to manage and protect important ecosystem services.

**Table 33:** Valuation of carbon regulation in SBGEP

Subcomponents	Production (ton)	Value (USD)	Value USD/year	Value BDT/year	Total value (million USD)
Tree Carbon	1,04,872.56	15,73,088.37	62,923.54	59,77,736.30	<b>0.10</b>
Soil Carbon	34,602.51	5,19,037.65	20,761.51	19,72,343.45	
Carbon in Litter and undergrowth	1510.78	22,661.66	11,330.83	10,76,428.85	
<b>Total</b>	<b>1,40,985.85</b>	<b>21,14,789.68</b>	<b>95,015.88</b>	<b>90,26,508.60</b>	

Table 33 shows the production and market value of the subcomponents of carbon regulation in the SBGEP area. The unit price of carbon (USD 15.00) for each subcomponent was fixed based on the study conducted by Uddin et al., 2020. The values are shown in million USD, with tree (DBH ≥ 5cm) carbon being the highest contributor at USD 1.57 million, followed by soil carbon at USD 0.63 million and carbon in litter and undergrowth at USD 0.02 million. The total value of carbon regulation in SBGEP is estimated to be USD 2.23 million. This information provides an estimate of the economic value of carbon regulation in SBGEP and can be used to inform decision-making about the management and protection of this ecosystem services.

**Table 34:** Monetary value of soil carbon control in SBGEP

Variable	Unit	Values	SD	SE
Soil C. in SBGEP	ton/ha	42.82	25.80	4.96
Soil C. outside of SBGEP	ton/ha	36.60	9.46	4.23
<b>Value of Controlled Soil Carbon (C)</b>				
Control of Soil C by SBGEP	ton/ha			6.22
Control of Soil C by SBGEP	ton			5033.27
<b>Value of Controlled Soil C</b>	USD			75,499.05
	<b>USD/year</b>			<b>3019.96</b>
	<b>BDT/year</b>			<b>2,86,896.40</b>
	<b>million USD</b>			<b>0.003</b>

The study of the difference in soil organic carbon within the boundaries of a protected area (SBGEP) and outside of it provides information about the control that the park exerts on SOC and the role it plays in soil carbon conservation. By comparing the SOC levels, researchers can determine if the park has had a positive or negative impact on soil carbon and how effective it has been in conserving this important resources. This information can help to guide future conservation efforts and policies.

The difference in soil organic carbon levels between the protected area and outside of it is summarized in table 34. The data shows that the SOC inside SBGEP is 42.82 ton/ha, while the SOC outside of SBGEP is 36.60 ton/ha. The control of soil carbon by SBGEP, which is calculated as the difference between these two values, is 6.22 ton/ha, or 5033.27 tons. The calculated value in BDT is 7.17 million, while the value in million USD is 0.08 (Table 34). If we convert this stock account to the flow account dividing by 25 to find the value per year basis, it shows BDT 0.29 million (USD 0.003 million). These values represent the monetary value of the soil carbon that is being conserved by the protected area.

This table helps to demonstrate the importance of protected areas in conserving soil carbon and the monetary value that is associated with these conservation efforts. The data can be used to prioritize and allocate resources for soil carbon conservation and to make decisions about the management of protected areas.

### ***Valuing climate regulation***

The global climate regulation is an important component of the natural environment and its value is assessed by measuring two subcomponents: oxygen production and carbon sequestration. This assessment is based on the methods developed by Nowak et al., 2007 and Alamgir et al., 2016.

The unit price for carbon was determined using the study conducted by Uddin et al., 2020 and the unit price for oxygen was followed from table 7. This unit price allows for the calculation of the value of oxygen production and carbon sequestration and helps to understand the role of the natural environment in regulating the global climate.

**Table 35:** Valuation of global climate regulation in SBGEP

<b>Ecosystem Components</b>	<b>Production (ton)</b>	<b>Market value ( USD/ton)</b>	<b>Value (USD)</b>	<b>Value (USD/year)</b>	<b>Value (million USD/yr)</b>
Oxygen production	5,00,380.12	263.16	13,16,78,977.78	52,67,159.11	5.27
CO <sub>2</sub> Sequestration	1,87,642.54	15.00	28,14,638.15	1,12,585.53	0.12
<b>Total</b>	<b>6,88,022.66</b>		<b>13,44,93,615.93</b>	<b>5379744.64</b>	<b>5.39</b>

Table 35 provides information on the valuation of the global climate regulation in the SBGEP. The oxygen production in the SBGEP is more than 500 thousand tons, with a market value of USD 263.16 per ton. The total value of oxygen production in the SBGEP is calculated by multiplying the production (in tons) by the market value (in USD/ton), resulting in a value of USD 5.27 million per year. Similarly, the carbon sequestration in the SBGEP is more than 187 thousand tons, with a market value of USD 15.00 per ton. The total value of carbon sequestration in the SBGEP is calculated by multiplying the production (in tons) by the market value (in USD/ton), resulting in a value of USD 0.12 million per year. The total value of the global climate regulation in the SBGEP is calculated by adding the value of oxygen production and carbon sequestration, which results in a total value of USD 5.39 million per year.

This information provides a valuable understanding of the role of the SBGEP in regulating the global climate and highlights the importance of conservation and protection efforts aimed at maintaining the stability of these vital ecosystem services. The total value of the global climate regulation can be used to prioritize and allocate resources for conservation and protection efforts, as well as to inform policy decisions aimed at ensuring the continued health and stability of the natural environment.

**Valuation of soil fertility regulation**

The component of soil regulation in Sitakunda Botanical Garden and Eco-park (SBGEP) was evaluated by considering two subcomponents: soil fertility control and soil erosion. The valuation of soil fertility control was based on the comparison of the amount of nutrients (N,P,K) in the soil of SBGEP and a fellow land. The value of soil erosion was estimated by considering the height increase in the agricultural land around SBGEP as reported by farmers in a survey.

**Valuing soil nutrition control by SBGEP**

The soil fertility component was determined by comparing the amount of nutrients (nitrogen, phosphorus, and potassium) in the soil of a land near the SBGEP area. The value of this component was calculated by adding the value of nitrogen and phosphorus and subtracting the value of potassium. The final value represents the difference in soil fertility between inside and outside of the park.

**Table 36:** Monetary value of soil nutrition control of SBGEP

Soil Nitrogen Control		Soil Phosphorus Control		Soil Potassium Control	
“N” (kg/ha) in SBGEP	2574.7	Soil P (kg/ha) in SBGEP	40.11	Soil K (kg/ha) in SBGEP	697.70
“N” (Kg/ha) outside of SBGEP	1732.22	Soil P (Kg/ha) outside of SBGEP	18.91	Soil K (Kg/ha) outside of SBGEP	312.65
Control of Soil “N” (Kg/ha) by SBGEP	842.48	Control of Soil P (Kg/ha) by SBGEP	21.20	Control of Soil K (Kg/ha) by SBGEP	385.05
Control of Soil N (kg) by SBGEP	680723.84	Control of Soil P (kg) by SBGEP	17121.95	Control of Soil K (kg) by SBGEP	311121.01
Monetary Value (BDT)	1,70,18,096.0	Monetary Value (BDT)	5,36,430.91	Monetary Value (BDT)	77,78,025.26
Monetary Value (million USD)	0.18	Monetary Value (million USD)	0.0056	Monetary Value (million USD)	0.082
<b>Total Value of Soil Nutrition Control (BDT)</b>	<b>= 1,70,18,096.0+ 5,36,430.91 + 77,78,025.26</b>			<b>2,53,32,552.17</b>	
<b>Total Value of Soil Nutrition Control (BDT/Year)</b>					<b>10,13,302.10</b>
<b>Total Value of Soil Nutrition Control (million USD/Year)</b>					<b>0.011</b>

The table 36 compares the amount of soil fertility (nitrogen, phosphorus, and potassium) in the SBGEP with that of a neighboring land. The comparison shows that the SBGEP is controlling more nitrogen (842.48 kg/ha), phosphorus (21.20 kg/ha) and potassium (385.05 kg/ha) than the neighboring land. The valuation of the control of soil nutrition was calculated by adding the value

of nitrogen, phosphorus and potassium. This resulted in a total value of BDT 25.33 million. However, our study aimed to determine the annual value of the park's components, including soil nutrients. Unfortunately, we cannot directly measure the yearly increase of soil nutrients. To address this limitation, we divided the total value of BDT 25.33 million by 25. This is because the park was designated a protected area approximately 25 years ago relative to our data collection year (2022). While this approach provides a tentative annual value of BDT 1.02 million (or 0.011 million USD) for soil nutrients, it is important to acknowledge the limitations. This information provides insight into the role of the SBGEP in controlling soil fertility and the impact it has on the health and productivity of the surrounding lands.

### ***Valuation of soil erosion***

The calculation of soil erosion was based on the statements made by the farmers who were surveyed. According to their statements, their agricultural lands are periodically flooded by the stream, leading to an upward growth of their lands by one inch every year. This observation suggests that soil erosion from the forest is providing additional nutrients to the agricultural lands and contributing to the fertility of the soil. The survey results indicate that farmers in the area have noticed an increase in soil fertility on their agricultural lands as a result of soil erosion from the forest. This is due to the fact that the stream periodically floods their lands, bringing with it nutrient-rich soil from the forest. As a result, the farmers have observed an upward growth of their lands by one inch every year and an increase in agricultural production.

Given the benefits observed by the farmers, the soil erosion from the forest has been included as an ecosystem services rather than a disservice. This highlights the important role that forests play in providing essential ecosystem services, such as soil fertility, to surrounding lands and communities. The inclusion of soil erosion as an ecosystem services in this context provides an important insights for policy and decision makers, who can use this information to prioritize conservation and management efforts aimed at preserving and promoting the health of forest ecosystems and the services they provide.

**Table 37:** Value of soil erosion in SBGEP

<b>Variables</b>	<b>Unit</b>	<b>Value</b>
Height of Agri-land increase	m/Deci./Year	0.0254
Soil disposition	m <sup>3</sup> / Dec./ Year	1.03
Soil disposition	m <sup>3</sup> / Acre/ Year	102.79
Agri-land on which Soil disposed around SBGEP	Acre	26.41
Total Soil Disposed on land around SBGEP	m <sup>3</sup> /Year	2714.78
Total amount of soil Eroded from SBGEP	m <sup>3</sup> /Year	2714.78
Price of Soil per Cubic meter	BDT	382.5
<b>Value of Soil Erosion of SBGEP</b>	<b>(BDT/Year)</b>	10,38,404.98
	<b>(Million USD/Year)</b>	0.01

The financial value of soil erosion in SBGEP was calculated in table 37. The calculation was done by measuring the height increase of agricultural land around SBGEP due to soil deposition from the park. The height increase was reported by farmers who told that their lands grow upward for 0.0254 meters per decimal per year. Based on this information, the soil disposition was calculated as 1.03 cubic meters per decimal per year. To find the total soil disposed on the

agricultural land, the soil disposition was multiplied by the total number of acres (26.41 acres) of agricultural land around SBGEP. This calculation provides us a total of 2.71 thousand cubic meters of soil disposed on the land per year. Finally, the value of soil erosion was calculated by multiplying the total soil disposed with the price of soil per cubic meter (BDT 382.5). The result shows that the value of soil erosion in SBGEP is BDT1.04 million per year, which is equivalent to USD 0.01 million per year (Table 37).

However, this calculation was done only on the basis of farmers' statement. Further research is needed to find out more accurate result of soil erosion and the benefit that the surrounding agricultural lands getting from the nutrients washed out from the hill with rain water.

### ***Valuation of water regulation***

The water discharge and water infiltration (recharge) subcomponents are important in determining the value of the water regulating services provided by SBGEP. This study focused on the recharge rate in the surroundings of the water body area rather than the whole park area, as there was a lack of rainfall information. The park is home to two waterfalls, Shuptodhara and Shahasradhara, that discharge and recharge a significant amount of water each year. This water flows through numerous streams, with a combined area of 10.52 ha, that are the main source of livelihood for human settlements around the park. SBGEP helps to maintain the flow of water from these waterfalls, making it necessary to measure the discharge and recharge rates of the streams.

### ***Determination of stream area inside and outside of SBGEP***

To determine the stream area, length and width of streams were measured from four points. The table 38 is showing the process of finding the total area of the stream. The value in this table represents the total area of the streams in SBGEP calculated by multiplying the length and width of the streams and then summing up the resulting areas of individual streams. The unit of area is in hectares (ha). The total stream area in SBGEP is 10.52 ha.

**Table 38:** Determination of stream area

<b>Sl. No</b>	<b>Stream Area</b>
<b>01</b>	Length is (l) = 5.7 km; Avg. Width (w) = 15 m = 0.015 km; Total area = 0.0855 Sq. Km = 85500 sq. m
<b>02</b>	Length is (l) = 2.7 km; Avg. Width (w) = 5 m = 0.005 km; Total area = 0.0135 Sq. Km = 13500 sq. m
<b>03</b>	Length is (l) = 1.5 km; Avg. Width (w) = 3 m = 0.003 km; Total area = 0.0045 Sq. Km = 4500 sq. m
<b>04</b>	Length is (l) = 1.2 km; Avg. Width (w) = 1 m = 0.001 km; Total area = 0.0012 Sq. Km = 1200 sq. m
<b>05</b>	Length is (l) = 0.900 km; Avg. Width (w) = 0.5 m = 0.0005 km; Total area = 0.00045 Sq. Km = 450 sq. m
	<b>Grand Total = 1,05,150 sq. m (10.52 hectare).</b>

### ***Determination of discharge rate***

The data collected from 14 sampling points were used to determine the discharge rate of the streams in SBGEP during the dry and monsoon seasons. The discharge rate was calculated by following the methodology described in the study before, and the results were recorded in table 39. This information helps to understand the flow of water in the streams during different seasons and the role of SBGEP in maintaining the water flow.

**Table 39:** Determination of discharge rate (\*CFS) in two streams of SBGEP

Name of the stream	Plot No	Discharge rate (In Dry Season)	Discharge rate (In Monsoon)
		(CFS)	(CFS)
Shahasradhara	Plot No 1	0.394	4.455
	Plot No 2	0.384	4.650
	Plot No 3	0.254	3.250
Supthadhara	Plot No 1	0.440	4.609
	Plot No 2	0.473	5.535
	Plot No 3	0.489	9.080
	Plot No 4	1.091	6.254
	Plot No 5	0.686	7.286
	Plot No 6	0.704	7.775
	Plot No 7	0.639	7.895
	Plot No 8	0.440	7.800
Gupthakhali khal	Plot No 1	0.434	3.825
	Plot No 2	0.800	9.500
	Plot No 3	3.355	8.275
<b>Average Discharge rate (Q)</b>		<b>0.755</b>	<b>6.45</b>
<b>SE</b>		<b>0.21</b>	<b>0.55</b>

\*CFS = Cubic feet per second

Table 39 shows the determination of discharge rate of two streams in the SBGEP, which are Shahasradhara and Supthadhara. The discharge rate is expressed in cubic feet per second (CFS). Data were collected from 14 sampling points of the streams in two seasons, which are the dry season (December to March) and the monsoon (April to October). The discharge rate of each sampling point was recorded and the average discharge rate was calculated for each stream in each season. It has been found that the average discharge rate of those falls is 0.76 CFS in dry season and 6.45 CFS in Monsson.

#### **Valuation of water discharged by the streams**

The table 40 provides information on the valuation of water discharged by streams in a 10.52 ha area in SBGEP. The data is presented for two seasons: dry season and monsoon.

**Table 40:** Valuation of water discharged by the streams in SBGEP per year

Water Discharge	Unit	Amount
Average Discharge rate in Dry season	cubic ft./second	0.76
Total Discharge of a day	cubic ft./day	65,664
Average Stream Flow in Dry season (120 days)	cubic ft.	78,79,680
Amount of water flows	Liter/Dry Season	22,31,52,537.60
Average Discharge rate in Monsoon	cubic ft./second	6.45
Total Discharge of a day	cubic ft./day	5,57,280.00
Average Stream Flow in Monsoon (245 days)	cubic ft.	13,65,33,600.00
***Amount of water flows	Liter/Monsoon	1933,31,57,760.00
Total Amount of water discharged	Liter/Year	1955,63,10,297.60
Unit Price of Water	BDT/Liter	0.04
<b>Value of Water flow</b>	<b>BDT/Year</b>	<b>78,22,52,411.90</b>
	<b>Million USD/ Year</b>	<b>8.23</b>

The average discharge rate in the dry season is 0.76 cubic feet/second and the total discharge of a day is about 66 thousand cubic ft. By multiplying these values by the number of days in the dry season (120 days), the average stream flow in the dry season is calculated to be 7.88 million cubic feet. This value is then converted to liters which is 223.15 million liters in dry season. Similarly, for the monsoon season, the average discharge rate is 6.45 cubic feet/second and the total discharge of a day is 557.30 thousand cubic ft. By multiplying these values by the number of days in the monsoon season (245 days), the average stream flow in the monsoon season is calculated to be 136.53 million cubic feet. This value is then converted to liters (19.33 billion liters).

*(\*\*\*It is to be noticed that we measured the flow rate in the two seasons but it was not possible to measure the rate in deep monsoon. Therefore, we multiplied the total amount of water with 05 to take into account the water flows in the stream during heavy rainfall.)*

Finally, the total amount of water is 19.55 billion liters per year. The value of the water flow per year is then estimated to be BDT 782.26 million (or USD 8.23 million).

**Valuation of water recharged (Ground water infiltration)**

The infiltration rate represents the rate at which water enters the ground from a specific source, and the cumulative infiltration represents the total amount of water that has entered the ground over a given period of time. Ground water infiltration provides a number of essential services to communities, including supplying fresh water for irrigation, drinking, and other daily use, replenishing streams and supporting local ecosystems. It is an important resource that needs to be managed sustainably to ensure that future generations can continue to benefit from its many benefits.

Table 41 presents the valuation of water recharged by the stream. The infiltration rate ranges from 0.58 liter per hour which is 359.07 thousand liters per hectare per year. The unit price of water is given as BDT 0.04 per liter and stream area inside the park is 2.07 ha.

**Table 41:** Valuation of water recharged by the stream water

Variable	Unit	Value
Average Infiltration rate Surrounding the Stream	Liter/hour	1.16
	Liter/m <sup>2</sup> /year	35,906.71
	Liter/ha/year	35,90,67,137.81
Total Infiltration	Liter/year	74,32,68,975.27
Unit Price of Water	BDT/Liter	0.04
<b>Value of Water Infiltrated</b>	<b>BDT/year</b>	<b>2,97,30,759.01</b>
	<b>Million USD/year</b>	<b>0.31</b>

Total infiltration and the value of the water recharged by the stream are calculated by multiplying the infiltration rate by the unit price of water. The total infiltration is 743.27 million liters per year, and the value of the water is BDT 29.73 million per year (or USD 0.31 million).

**Comparison of infiltration rate**

Table 42 compares the infiltration rates of three different sources, the Supthadhara, Sahasradhara, and outside park sources. The infiltration rate is given in inches per hour, and the cumulative infiltration is given in inches.

**Table 42:** Comparison of infiltration rate of three different sources

	<b>Supthadhara</b>	<b>Sahasradhar</b>	<b>Outside park</b>
Infiltration rate (Inch/hour)	0.89	0.47	0.57
Cumulative infiltration (Inch)	32	15	23

Based on the data presented in the table, it appears that the average infiltration rate inside the park (represented by the Supthadhara and Sahasradhar sources) is higher than that outside of the park (represented by the outside park source). This information can provide valuable insight into the water management practices within the park and their effectiveness in maintaining and increasing the infiltration rate.

### ***Valuation of water recharge controlled***

Knowing the amount and monetary value of infiltrated water controlled by the SBGEP can help in making reasonable decisions about water management and conservation efforts. It can provide a clear understanding of the economic value of water and the importance of maintaining and improving the infiltration rate to maximize its benefits.

Table 43 presents the valuation of water recharge controlled by SBGEP. It provides a comparison of the water recharge and its value for both inside and outside of the park, and can be used to evaluate the effectiveness of water management practices within the park and to make logical decisions about water conservation efforts.

**Table 43:** Valuation of water recharge controlled by SBGEP

<b>Variable</b>	<b>Unit</b>	<b>Inside SBGEP</b>	<b>Outside SBGEP</b>	<b>Control Value</b>
Average Controlled Infiltration rate Surrounding the Stream	Inch/hour	0.85	0.57	0.28
	Liter/hour			0.50
	Liter/m <sup>2</sup> /Year			15,561.19
	Liter/ha/Year			15,56,11,907
Total Infiltration	Liter/Year			32,21,16,647.51
Unit Price	BDT/Liter			0.04
<b>Value of Water</b>	<b>BDT/Year</b>			<b>1,28,84,665.90</b>

This information from the table 43 provides an estimate of the amount of water being helped to recharge by the park, and the monetary value of that water. The infiltration rate of 0.28 inches per hour or 0.50 liters per hour controlled by the park is used to calculate the total infiltration of 0.322 billion liters per year. This value is then multiplied by the unit price of water (BDT 0.04 per liter) to estimate the monetary value of the water, which is BDT 12.88 million per year. It highlights the importance of maintaining the park and increasing the infiltration rate to maximize the benefits of the water recharge.

### ***Valuation of air dust control by SBGEP***

Table 44 provides information about air dust levels in and around the SBGEP area. Data were collected by the Department of Environment (DOE) in Chattogram, and the average air dust level was determined for each collection point. The table lists the data collection points and the levels of Suspended Particulate Matter, which is expressed as the average SPM per day.

**Table 44:** Air dust control in SBGEP

Data Collection Points	Average SPM /Day	SD	SE	P (2-tailed)	Control of Air Dust /Day
Within the SBGEP	111	22.83	8.63	0.02	65.5
Outside of the SBGEP	176.5	4.95	3.50		

\*\*\*Unit of Suspended particulate Matter (SPM) is microgram per cubic meter. Here, SPM means PM10 and PM2.5 both

The control of air dust per day is also given, with a value of 65.5  $\mu\text{g}/\text{m}^3$  being controlled by SBGEP in one day. It is clear from the table that the highest levels of air dust are found outside the SBGEP area, with the highest levels recorded at Fakirhat Bazar and the Highway beside eco-park gate.

**Table 45:** Monetary value of air dust control in SBGEP

Variable	Unit	Value
Air dust removed by SBGEP	$(\mu\text{g}/\text{m}^3)/\text{year}$	2,39,075
	ton/year	4.30
Monetary benefit from Air Dust removal	million USD/ton	12.12
Total Benefit gained from Air Dust removal	million USD/year	52.12
	billion BDT/year	4.95

\*Volume of air dust removal = Area of SBGEP (808 ha)  $\times$  Average height of trees (8.11m)

\*\* 1 USD = 95 BDT

Table 45 provides information on the monetary value of air dust control in SBGEP. The air dust removed by SBGEP per year is 4.30 tons. The monetary benefit from air dust removal (USD 12.12 million per ton) is multiplied with the air dust removed by SBGEP per year. This gives a value of USD 52.12 million per year or BDT 4.95 billion.

The calculation assumes uniform dispersion of air dust across Bangladesh, a simplified atmospheric model with a fixed mixing layer height, and a linear relationship between SPM concentration and GDP impact, which may not reflect real-world complexities. It overlooks localized effects, other economic factors, long-term impacts, and global influences. Additionally, the precision of the input data and the single-year focus limit the accuracy and relevance of the results. These limitations suggest that more detailed models and localized studies are needed for a comprehensive assessment. Despite its limitations, the calculation provides a useful first approximation of the economic impact of PM10 and PM2.5 pollution on Bangladesh's GDP. It offers a starting point for understanding the potential scale of the economic losses due to air pollution, highlighting the significance of environmental issues in economic terms. While the assumptions simplify a complex reality, the result can help to raise awareness and guide policy discussions. Accepting this result, with an understanding of its limitations, allows for sound decision-making and sets the stage for more detailed, localized studies that can refine these estimates and lead to more effective environmental and economic policies.

Table 46 provides information on the monetary value of the regulating services provided by SBGEP in BDT. It includes various components and subcomponents of regulating services such as soil fertility regulation, water regulation, air dust control, climate regulation, and carbon regulation.

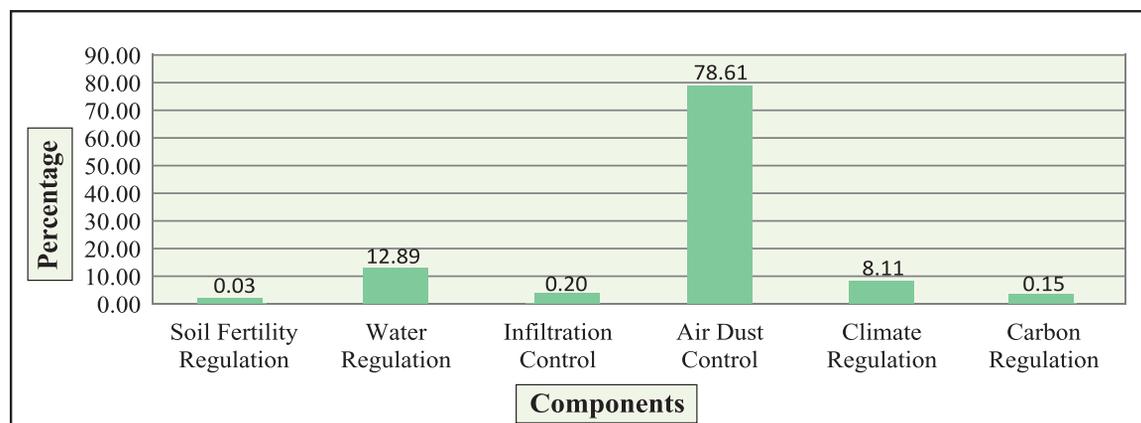
**Table 46:** Monetary value of regulating service of SBGEP

Component	Subcomponent	Regulating Value (BDT/Year)	Total Regulating Value (BDT/Year)
Soil Fertility Regulation	Soil Nutrition Control	10,13,302.10	20,51,707.08
	Soil Erosion	10,38,404.98	
Water Regulation	Water Discharge	78,22,52,411.90	81,19,83,170.91
	Water Infiltration	2,97,30,759.01	
Infiltration Control	-		1,28,84,665.90
Air Dust Control	-		495,14,00,000.00
Climate Regulation	Oxygen production	50,03,80,115.45	51,10,75,740.80
	CO <sub>2</sub> Sequestration	1,06,95,625.35	
Carbon Regulation	Soil Carbon Control	2,86,896.40	93,13,405.00
	Tree Carbon	59,77,736.30	
	Litter and undergrowth C	10,76,428.85	
	Soil Carbon	19,72,343.45	
<b>Total Regulating Value (BDT)</b>			<b>629,87,08,689.69</b>
<b>Total Regulating Value (million USD) (1USD = 95 BDT)</b>			<b>66.30</b>

For each subcomponent, the regulating value in BDT per year is given, and the total regulating value for each component is calculated and shown. Table 46 also provides the total regulating value for all components in BDT which is 6.30 billion and in USD 66.30 million, which is calculated by converting BDT to USD using the exchange rate of 1 USD = 95 BDT.

#### *Graphical presentation of contribution (%) of components in regulating services*

Figure 52 is presented as the percentage contribution of each component to the total regulating service and helps to understand the relative importance of each component in regulating services and its overall impact.

**Figure 52:** Contribution (%) of components in regulating service.

The maximum contribution is about 78.61% from the air dust control component and the minimum contribution is 0.03% from the soil fertility regulation. In other words, the air dust control component contributes the most to the total regulating service while the soil fertility regulation component contributes the least.

These findings provide a perspective on the relative importance of each component in regulating services and highlight the significant impact that climate regulation has on the overall value of regulating services.

#### 4.6. Total Economic Value (TEV) of Sitakunda Botanical garden and Eco-park

Table 47 represents the Total Economic Value (TEV) of Sitakunda Botanical Garden and Eco-park. TEV is a measure of the monetary value of all the benefits (services) that the ecosystem provides to the society. The table is organized into four categories of ecosystem services: provisioning, cultural, regulating and supporting. Each category has different components, and the value of each component is expressed in BDT per ha. per year, Total BDT per year, and million USD per year.



Figure 53: Land encroachment through horticulture and agriculture in SBGEP



Figure 54: Pesticides are being prepared for using in horticultural and agricultural Purposes in SBGEP

**Table 47:** Total Economic Value (TEV) of Sitakunda Botanical Garden and Eco-park

Ecosystem Service	Components	BDT/ha/Year	Total BDT/Year	Million USD/Year
Provisioning	Food	2529.21	20,43,600.64	0.022
	Round Log	257.07	2,07,712.29	0.002
	Fuel Wood	4095.66	33,09,289.35	0.035
	NTFPs	640.79	5,17,761.10	0.005
	Medicinal Species	171.53	1,38,598.61	0.001
	Fodder	208.29	1,68,298.31	0.002
	Water Harvesting	6404.99	51,75,230.27	0.054
	Irrigation	4374.88	35,34,901.08	0.037
	Grazing	7031.31	56,81,292.14	0.060
	<b>Sub Total</b>	<b>25,713.72</b>	<b>2,07,76,683.79</b>	<b>0.22</b>
Cultural	Ecotourism	6,06,113.81	48,97,39,961.44	5.16
	<b>Sub Total</b>	<b>6,03,270.43</b>	<b>48,97,39,961.44</b>	<b>5.16</b>
Supporting	Nutrient Cycling	23,415.33	1,89,19,584.00	0.199
	Pollination			
	Pest and Diseases Control			
	Biodiversity	10,752.61	86,88,105.50	0.091
	Seed dispersal	59,896.75	4,83,96,574.59	0.509
	Soil Nutrition	830.67	6,71,180.10	0.007
	<b>Sub Total</b>	<b>94,895.35</b>	<b>7,66,75,444.19</b>	<b>0.807</b>
Regulating	Soil Fertility Regulation	2539.24	20,51,707.08	0.022
	Water Regulation	1004929.67	81,19,83,170.91	8.547
	Air Dust Control	61,27,970.30	495,14,00,000.00	52.120
	Climate Regulation	6,32,519.48	51,10,75,740.80	5.380
	Carbon Regulation	11,526.50	93,13,405.00	0.098
	Water Infiltration Control	15,946.37	1,28,84,665.90	0.136
	<b>Sub Total</b>	<b>77,95,431.55</b>	<b>629,87,08,689.69</b>	<b>66.302</b>
<b>Grand Total</b>		<b>85,22,154.43</b>	<b>688,59,00,779.11</b>	<b>72.483</b>

Sitakunda Botanical Garden and Eco-park is a valuable resource for the society, providing multiple economic benefits. According to the table 47, the highest value is being generated from the regulating services of the park, which includes ecosystem functions such as carbon sequestration, water regulation etc. The park is contributing BDT 6.30 billion annually in economic benefits from this service alone. In addition, the park also provides cultural services such as ecotourism, as well as provisioning services such as food, NTFPs, wood production etc. and supporting services like soil nutrition, seed dispersal etc. These services, combined with the regulating services, result in a total accumulated economic value per year of BDT 6.89 billion (USD. 72.48 million). Thus, the park is providing an economic value yearly of BDT 8.52 million per ha., demonstrating its high economic efficiency.

The SBGEP is a prime example of how protected areas can provide substantial economic benefits to the society, while also conserving biodiversity and promoting sustainable development.

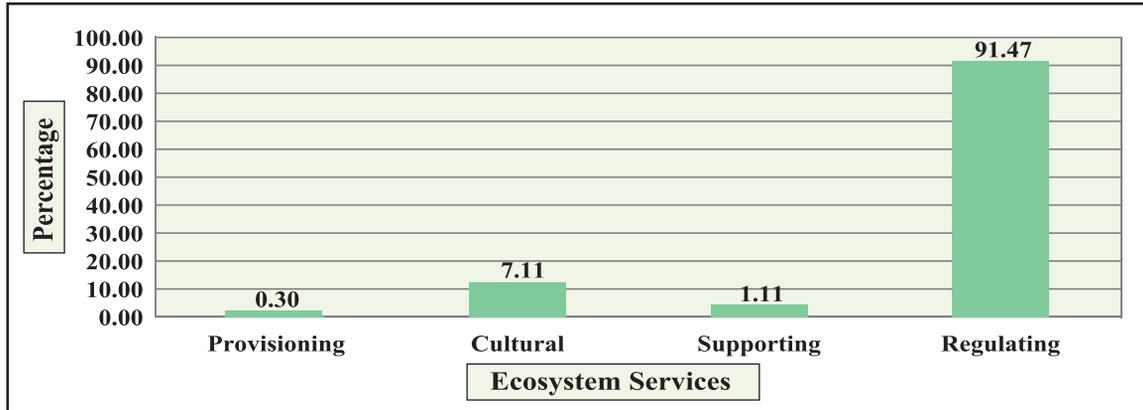


Figure 55: Contribution (%) of four ecosystem services

Figure 55 shows that maximum benefits are generating from regulating ecosystem service of the park. The contribution of other services is very little comparing to the regulating benefits. This presentation implies that indirect services of regulatory components are very much higher which is more than 90% of total ecosystem benefit.

#### 4.7. Discussion

Assessing the total economic value of ecosystem services in forest ecosystems is a complex undertaking due to the multitude of interconnected services they provide. In this study, only use values were taken into consideration. The study took a cautious approach by presenting conservative values for the identified components of the four ecosystem services, all of which were directly measured in the field. The study conducted on Sitakunda Botanical Garden and Eco-park in Chattogram revealed its significant contribution to the national GDP. The park boasts a diverse range of tree species, with 157 species and an average of 474 trees (DBH  $\geq$  5 cm) per hectare, indicating a healthy tree stock. The valuation of ecosystem services estimated the total market value to be around USD 72.48 million per year, underscoring the economic importance of the park's ecological contributions.

In the study by Uddin et al. (2020), the market value of Lawachara National Park was calculated approximately USD 80.14 billion or BDT 6411.20 billion. They considered five components and the average market value per component was BDT 1282.24 billion. Similarly, Jalal et al. (2020) conducted a valuation of Baraiyadhala National Park and arrived at a market value of BDT 561.36 million. They assessed ten components across four ecosystem services, with an average value per component of BDT 5.61 million. In contrast, the market value of ecosystem services determined in this study was BDT 6.89 billion. This valuation included a larger number of components, specifically 22, across the same four ecosystem services. The average market value per component was found to be BDT 313.18 million. The comparison reveals noteworthy variations in the assessed market values and the number of components considered. While Lawachara National Park holds the highest market value, Sitakunda Botanical Garden and Eco-park exhibit a higher market value than Baraiyadhala National Park. The variation in the number of components evaluated suggests a more extensive analysis for Sitakunda Botanical Garden and Eco-park, highlighting its potentially greater ecological significance and economic value.

The government assumes managerial responsibility for the eco-park, focusing on conservation efforts through regular patrolling and occasional tree planting. The financial expenses incurred by the government for sustainable management and conservation are relatively minimal compared to the extensive benefits provided by the park to the local community and the associated environment. Forest managers play a crucial role in ensuring the diverse benefits provided by parks are recognized and prioritized over specific services. It is important to disseminate the ideas about ecosystem services among community members, visitors, and local stakeholders. Understanding the value of these services becomes essential for decision-makers to establish sustainable yield thresholds in the face of climate change and enhance the overall management of forest ecosystems. By acknowledging the broader range of benefits, forest managers can make informed decisions that promote long-term sustainability and effectively communicate the significance of these ecosystems to various stakeholders.

## **5. Challenges**

The study observed a significant challenge faced by the Sitakunda Botanical Garden and Eco-Park, which is the issue of land encroachment (Figures 53 & 54). Approximately 15% of the park's land (eye estimation) has been taken over by influential and politically powerful individuals for purposes such as horticulture, agriculture, and private gardens. The majority of the land encroachment has occurred in the eastern, northeastern, and southern areas of the park. This not only impacts the park's resources and ecosystem but also the livelihoods of those who rely on the park for their work and income.

Another challenge identified in the study was the issue of theft and robbery. This issue not only affects those who extract resources from the park but also tourists, researchers, and even the park staff. Man-made forest fires also pose a serious threat to the park's ecosystem and its services.

Despite these challenges, the study found that the vegetation composition and wildlife status of the park are in good condition. If proper management and resources are allocated, the economic value of the Sitakunda Botanical Garden and Eco-park could increase significantly. It is crucial that the authorities address these challenges and ensure the proper conservation and management of this valuable natural resource.

## **6. Recommendation**

The study by Brookshire et al., (1983) which was mentioned by Chopra (1993) highlights the importance of proper maintenance in preserving parks for future generations. According to that study, if a park is to be sustained, a minimum of 16% of its total use value should be allocated towards maintenance purposes each year. The total use value of the Sitakunda Botanical Garden and Eco-park was calculated to be BDT 6.89 billion, meaning that BDT 1.10 billion (USD 11.58 million) should be set aside annually to ensure its proper management. The non-use values were not taken into consideration in this study. While this amount may seem disproportionate to our country's economic condition, we suggest initiating funding at 10% of the recommended value and progressively increasing it each year, aiming to reach the target within the next ten years. It is noted that if the recommended budget is not allocated, the park's services may gradually decrease over time. This can result in a decline in the park's condition and its ability to provide the same level of services to society each year. Thus, the author suggests that the authority should take the necessary steps to allocate the budget for maintenance and ensure that it is utilized properly.

This will help to maintain the park's condition and preserve its value for future generations to enjoy. Some activities are suggested here briefly that can be considered to allocate the budget for the maintenance of the Sitakunda Botanical Garden and Eco-park and ensure its proper utilization:

- a) **Regular infrastructure maintenance:** Allocate funds to repair and enhance trails, walkways, visitor centers, restrooms, and picnic areas, for ensuring safe and comfortable access to visitors.
- b) **Ecosystem restoration and conservation:** Invest in eradicating invasive species, restoring habitats, and nurturing native flora and fauna to preserve biodiversity and ecological balance.
- c) **Wildlife protection and management:** Establish programs for wildlife monitoring, anti-poaching patrols, and technology-driven safeguards against illegal hunting and wildlife trade.
- d) **Visitor engagement and education:** Develop educational programs, guided tours, workshops, and interpretive signage to enhance visitor understanding of the park's ecological value.
- e) **Research and monitoring:** Allocate resources for scientific research and data collection to inform effective management strategies.
- f) **Fire prevention and management:** Regularly maintain firechecking, equipped firefighting resources and strong monitoring to prevent manmade fires.
- g) **Community engagement and livelihood support:** Generate local jobs through maintenance, tours, and conservation projects while fostering partnerships for sustainable livelihoods aligned with conservation goals.
- h) **Training and capacity building:** Provide ongoing training for park staff and local communities in ecological management, visitor services, emergency response, and sustainable resource use.
- i) **Emergency preparedness:** Set aside a portion of the budget for unforeseen events like natural disasters or ecological crises.
- j) **Public awareness campaigns:** Fund campaigns to raise public awareness about the park's importance, preservation needs, and ongoing maintenance efforts.

It's also important to establish a transparent and accountable system for budget allocation and utilization, involving stakeholders, experts, and community representatives. Regular audits and evaluations should also be conducted to ensure that the allocated funds are being effectively utilized for the park's maintenance and conservation.

## **7. Conclusion**

The study focused on gaining a comprehensive understanding on the economic value of ecosystem services and their various components and subcomponents. The research aimed to determine the extent to which these services are utilized by local communities and industries, and to evaluate the benefits they provide. The results of the study revealed that a significant portion of the population in the selected villages is dependent on forests for their daily needs, and some industries also rely on forest products and streams. Furthermore, tribal communities such as the Tripura are completely dependent on the forest for their livelihood and way of life. The degradation of the forest could have a profound impact on these communities and their future existence.

Additionally, the study also found out the Total Economic Value (TEV) of the Sitakunda Botanical Garden and Eco-Park. It was also recommended that a portion of the TEV should be allocated annually for the proper maintenance and management of the park. Without this budget allocation, the quality and quantity of the services provided by the park are likely to decrease over time.

Moreover, the findings of this study provide valuable insights that can be used to develop and implement future research and development programs. For example, research can be conducted to further explore the interdependence between nature, communities, and their reliance on natural resources and services. Such research will help to shed light on the complex relationships between these different elements and provide valuable information that can be used to conserve and protect ecosystems and their services for future generations.



**Figure 56: People are getting continuous benefit from ecosystem services in SBGEP**

In conclusion, the study provides a comprehensive analysis of the economic value of ecosystem services and their impact on local communities and industries. The findings of this study underscore the importance of allocating sufficient resources for the conservation and management of natural resources and ecosystems. By doing so, we can ensure the continued provision of these valuable services for both future generations and the planet.

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## 9. Annexure

### Annex 1: List of Plants Recorded From Sitakunda Botanical Garden and Eco-park

#### Tree plants recorded from SBGEP

S.N.	Scientific name	Family	Local name	Use Pattern
1.	<i>Acacia auriculiformis</i> A. Cunn. ex Benth.	Mimosaceae	Akashmoni	RL
2.	<i>Acacia catechu</i> (L. f.) Willd.	Mimosaceae	Khair	M
3.	<i>Acacia mangium</i> Willd.	Mimosaceae	Mangium	RL
4.	<i>Adenanthera pavonina</i> L.	Mimosaceae	Roktochandan	M
5.	<i>Adina cordifolia</i> Benth. & Hook.	Rubiaceae	Holdu, Kaika	RL
6.	<i>Aegle marmelos</i> (L.) Corr.	Rutaceae	Bel	EF+M
7.	<i>Albizia chinensis</i> (Osbeck) Merr.	Mimosaceae	Cakua Koroi	RL
8.	<i>Albizia procera</i> (Roxb.) Benth.	Mimosaceae	Sil koroi	RL
9.	<i>Albizia richardiana</i> King & Prain	Mimosaceae	Raj Koroi	AP
10.	<i>Alstonia macrophylla</i> Wall. ex G. Don	Apocynaceae	Sri-Lankan Chatian	M

11.	<i>Alstonia scholaris</i> (L.) R. Br.	Apocynaceae	Chatim, Chatian	M
12.	<i>Anacardium occidentale</i> L.	Anacardiaceae	Kaju Badam	EF
13.	<i>Anisoptera scaphula</i> (Roxb.) Pierre	Dipterocarpaceae	Boilam	RL
14.	<i>Aphanamixis polystachya</i> (Wall.) R.N.Parker	Meliaceae	Pitraj, Roina	FW
15.	<i>Aquilaria agallocha</i> Roxb.	Thymelaeaceae	Agar	E
16.	<i>Araucaria columnaris</i> (Frost. F.) Hook.	Araucariaceae	X-mass tree	AP
17.	<i>Areca catechu</i> L.	Arecaceae	Superi	E+FW
18.	<i>Artabotrys hexapetalus</i> (L.f.) Bhandari	Annonaceae	Kathali champa	AP
19.	<i>Artocarpus chama</i> Buch.-Ham. ex Wall.	Moraceae	Chapalish, Cambo	RL
20.	<i>Artocarpus heterophyllus</i> Lamk.	Moraceae	Kanthal, Jack fruit	EF
21.	<i>Artocarpus lacucha</i> Buch.-Ham.	Moraceae	Dewa, Borta	EF
22.	<i>Azadirachta indica</i> A. Juss.	Meliaceae	Neem	M
23.	<i>Baccaurea ramiflora</i> Lour.	Euphorbiaceae	Lotkon, Horpata	EF
24.	<i>Bambusa balcooa</i> Roxb.	Poaceae	Borak	B
25.	<i>Bambusa bambos</i> (L.) Voss	Poaceae	Bish kata, Kanta	B
26.	<i>Bambusa burmanica</i> Gamble	Poaceae	Mitinga	B
27.	<i>Bambusa tulda</i> Roxb.	Poaceae	Mitinga bans	B
28.	<i>Bambusa tuldoidea</i> Munro	Poaceae	Ghoti bans	B
29.	<i>Bambusa vulgaris</i> Schard	Poaceae	Baijja, Bairga	B
30.	<i>Bambusa vulgaris</i> var. <i>Striata</i>	Poaceae	Sharna, Sonali	B
31.	<i>Barringtonia acutangula</i> (L.) Gaertn.	Lecythidaceae	Hijol	AP
32.	<i>Bauhinia malabarica</i> Roxb.	Caesalpiniaceae	Kanchan	AP
33.	<i>Bischofia javanica</i> Blume	Euphorbiaceae	Kainjal, Lowvadi	FW
34.	<i>Bombax ceiba</i> L.	Bombacaceae	Simul	E
35.	<i>Borassus flabellifer</i> L.	Arecaceae	Tal, Fan palm	EF
36.	<i>Butea monosperma</i> (Lamk.) Taub.	Fabaceae	Palash	AP
37.	<i>Callicarpa macrophylla</i> Vahl.	Verbenaceae	Bormala	FW
38.	<i>Calophyllum inophyllum</i> L.	Clusiaceae	Punnyal	RL
39.	<i>Carica papaya</i> L.	Caricaceae	Papye, Papaya	V
40.	<i>Cassia fistula</i> L.	Caesalpiniaceae	Bandarlathi, Sonalu	AP
41.	<i>Cassia nodosa</i> L.	Caesalpiniaceae	Bon sonalu	FW
42.	<i>Cassia siamea</i> Lamk.	Caesalpiniaceae	Minjiri	RL
43.	<i>Ceiba pentandra</i> (L.) Gaertn.	Bombacaceae	Pahari tula	FW
44.	<i>Chukrasia tabularis</i> A. Juss.	Meliaceae	Chikrassi	RL
45.	<i>Cinnamomum camphora</i> (L.) J. Pers.	Lauraceae	Korpur	E
46.	<i>Cinnamomum glaucescens</i> (Nees) Meiss.	Lauraceae	Tej bohol, Gonori	RL
47.	<i>Citrus maxima</i> (Burm.) Merr.	Rutaceae	Jambura	EF
48.	<i>Cocos nucifera</i> L.	Arecaceae	Narikel, Coconut	E
49.	<i>Dalbergia sissoo</i> Roxb.	Fabaceae	Sissoo, Shisum	AP
50.	<i>Dehaasia kurzii</i> King ex Hook. f.	Lauraceae	Menda	M
51.	<i>Delonix regia</i> Rafin.	Caesalpiniaceae	Krishna chura	AP
52.	<i>Dendrocalamus brandisii</i> (Munro) Kurz	Poaceae	Brandis bans	B

53.	<i>Dendrocalamus giganteus</i> Munro	Poaceae	Budum bans	B
54.	<i>Dendrocalamus hamiltonii</i> Nees. & Arn. ex Munro	Poaceae	Pencha bans	B
55.	<i>Dendrocalamus longispatus</i> (Kurz) Kurz	Poaceae	Ora, Khang, Rupai	B
56.	<i>Dillenia indica</i> L.	Dilleniaceae	Chalta	EF
57.	<i>Dillenia scabrella</i> Roxb. ex Wall.	Dilleniaceae	Hargaja, Ajuli	RL
58.	<i>Diospyros blancoi</i> A. DC.	Ebenaceae	Bilati gab	EF
59.	<i>Diospyros malabarica</i> (Desr.) Kostel.	Ebenaceae	Gab, Deshi gub	EF
60.	<i>Diospyros montana</i> Roxb.	Ebenaceae	Bongab, Tomal	RL+M
61.	<i>Dipterocarpus turbinatus</i> Gaertn.	Dipterocarpaceae	Teligarjan	RL
62.	<i>Duabanga grandiflora</i> (Roxb. ex DC.) Walp.	Sonneratiaceae	Bandorhola	RL
63.	<i>Elaeocarpus floribundus</i> Blume	Elaeocarpaceae	Jolpai, Belpoi	EF
64.	<i>Elaeocarpus serratus</i> L.	Elaeocarpaceae	Jolpai	EF+M
65.	<i>Erythrina variegata</i> L.	Fabaceae	Mandar, Palita madar	FW
66.	<i>Eucalyptus camaldulensis</i> Dehn.	Myrtaceae	Eucalyptus	RL
67.	<i>Eucalyptus citriodora</i> Hook.	Myrtaceae	Scented Eucalyptus	RL
68.	<i>Feronia limonia</i> (L.) Swingle	Rutaceae	Kodbel	M
69.	<i>Ficus benghalensis</i> L.	Moraceae	Bot	FW
70.	<i>Ficus glomerata</i> Roxb.	Moraceae	Jagya dumur	FW
71.	<i>Ficus racemosa</i> L.	Moraceae	Boro dumur	M
72.	<i>Ficus religiosa</i> L.	Moraceae	Ashwath, Pan bot	FW
73.	<i>Firmiana colorata</i> (Roxb.) R. Br.	Sterculiaceae	Udal, Faissa Udal	RL
74.	<i>Flacourtia jangomas</i> (Lour.) Raeusch.	Flacourtiaceae	Bonkhoi, Boicy	EF
75.	<i>Garcinia cowa</i> Roxb. ex DC.	Clusiaceae	Kao, Kow-gula	EF
76.	<i>Gigantochloa andamanica</i> (Kurz) Kurz	Poaceae	Kalibans	B
77.	<i>Gliricidia sepium</i> (Jacq.) Kunth ex Walp.	Fabaceae	Gliricidia	EF
78.	<i>Gmelina arborea</i> Roxb.	Verbenaceae	Gamar, Jugini cakkar	RL
79.	<i>Grewia serrulata</i> DC.	Tiliaceae	Panisara	FW
80.	<i>Hevea brasiliensis</i> Muell.-Arg.	Euphorbiaceae	Rubber	E
81.	<i>Holarrhena antidysenterica</i> (L.) Wall. ex Decne.	Apocynaceae	Kurchi, Kuruch	M
82.	<i>Hopea odorata</i> Roxb.	Dipterocarpaceae	Telsur	RL
83.	<i>Hydnocarpus kurzii</i> (King.) Warb.	Flacourtiaceae	Calmugra	
84.	<i>Lagerstroemia speciosa</i> (L.) Pers.	Lythraceae	Jarul	RL
85.	<i>Lannea coromandelica</i> (Houtt.) Merr.	Anacardiaceae	Jiol vadi, Jhiga	FW
86.	<i>Lawsonia inermis</i> L.	Lythraceae	Mehedi	E
87.	<i>Leucaena leucocephala</i> (Lamk.) de Wit.	Mimosaceae	Ipil-ipil	EF
88.	<i>Litchi chinensis</i> (Gaertn.) Sonn.	Sapindaceae	Litchu, Litchi	EF
89.	<i>Litsea monopetala</i> (Roxb.) Pers.	Lauraceae	Menda	FW
90.	<i>Lophopetalum fimbriatum</i> Wight	Celastraceae	Rokton	RL
91.	<i>Macaranga denticulata</i> (Blume) Muell.-Arg.	Euphorbiaceae	Bura	FW
92.	<i>Madhuca indica</i> Gmel.	Sapotaceae	Mahua	M
93.	<i>Mangifera indica</i> L.	Anacardiaceae	Am	E
94.	<i>Mangifera sylvatica</i> Roxb.	Anacardiaceae	Uri Aam	EF

95.	<i>Manilkara zapota</i> L.	Sapotaceae	Sofeda	EF
96.	<i>Melaleuca leucadendron</i> L.	Myrtaceae	Chasuputi	M
97.	<i>Melia azedarach</i> L.	Meliaceae	Ghora neem	FW
98.	<i>Melocanna baccifera</i> (Roxb.) Kurz	Poaceae	Muli , Paiyya	B
99.	<i>Mesua ferrea</i> L.	Clusiaceae	Nageshwar	AP
100.	<i>Michelia champaca</i> L.	Magnoliaceae	Champa, Campaful	AP
101.	<i>Mimosops elengi</i> L.	Sapotaceae	Bakul	EF
102.	<i>Mitragyna parvifolia</i> (Roxb.) Korth. var. <i>microphylla</i> (Kurz) Ridsdale	Rubiaceae	Dakrum, Putikadam	FW
103.	<i>Moringa oleifera</i> Lamk.	Moringaceae	Sajna	M
104.	<i>Neolamarckia cadamba</i> (Roxb.) Bosser	Rubiaceae	Kadam	FW
105.	<i>Neonauclea sessilifolia</i> (Roxb.) Merr.	Rubiaceae	Kom	RL
106.	<i>Ochna squarrosa</i> L.	Ochnaceae	Loamori, Shiuri	RL
107.	<i>Oroxylum indicum</i> (L.) Kurz	Bigoniaceae	Khona, Kanaidinga	M
108.	<i>Peltophorum pterocarpum</i> (DC.) ex Heyne	Caesalpiniaceae	Halud Krisnochura	AP
109.	<i>Phyllanthus emblica</i> L.	Euphorbiaceae	Amloki	EF+M
110.	<i>Pinus caribaea</i> Morelet var. <i>hondurensis</i> Barr. & Golf.	Pinaceae	Pine, pitch pine	AP
111.	<i>Pinus oocarpa</i> Schiede ex Schltdl.	Pinaceae	Pine	AP
112.	<i>Piper longum</i> L.	Piperaceae	Pipul	E
113.	<i>Plumeria obtusa</i> L.	Apocynaceae	Goru chapa	AP
114.	<i>Plumeria rubra</i> L.	Apocynaceae	Kat-golap	AP
115.	<i>Podocarpus neriifolius</i> D. Don.	Podocarpaceae	Banspata	
116.	<i>Polyalthia longifolia</i> (Sonn.) Thw.	Annonaceae	Debdaru	AP
117.	<i>Pongamia pinnata</i> (L.) Pierre	Fabaceae	Korolja, Kerung	FW
118.	<i>Protium serratum</i> (Wall. ex Coelbr.) Engl.	Burseraceae	Gutgutia, Niur	RL
119.	<i>Psidium guajava</i> L.	Myrtaceae	Peyara, guava	EF
120.	<i>Pterocarpus indicus</i> Willd.	Fabaceae	Paduk	RL
121.	<i>Pterospermum acerifolium</i> (L.) Willd.	Sterculiaceae	Moos, Musogdhana	RL
122.	<i>Pterygota alata</i> (Roxb.) R. Br.	Sterculiaceae	Buddho narikel	RL
123.	<i>Ravenala madagascariensis</i> J. F. Gmel.	Sterculiaceae	Panthopadob	AP
124.	<i>Samania saman</i> (Jacq.) F. Muell.	Mimosaceae	Ful koroi, Rain tree	FW
125.	<i>Santalum album</i> L.	Santalaceae	Shet chandan	M
126.	<i>Sapindus mukorossi</i> Gaertn.	Sapindaceae	Ritha, Soap nut	M
127.	<i>Sapium baccatum</i> Roxb.	Euphorbiaceae	Camfata	FW
128.	<i>Saraca asoca</i> (Roxb.) de Willd.	Caesalpiniaceae	Ashoke	M
129.	<i>Schizostachyum dullooa</i> (Gamble) R.B. Majumder	Poaceae	Dolu bans	B
130.	<i>Sesbania grandiflora</i> (L.) Pers.	Fabaceae	Bokphul	F
131.	<i>Shorea robusta</i> (Roxb.) ex Gaertn. f.	Dipterocarpaceae	Shal, Gojari	RL
132.	<i>Spondias dulcis</i> Parkinson	Anacardiaceae	Bilati amra	EF
133.	<i>Spondias pinnata</i> (L. f.) Kurz	Anacardiaceae	Amra	EF

134.	<i>Sterculia villosa</i> (Roxb). ex Smith.	Sterculiaceae	Udal	M
135.	<i>Stereospermum colais</i> Mabberley	Bignoniaceae	Dharmara	RL
136.	<i>Streblus asper</i> Lour.	Moraceae	Sheora , Harba	FW
137.	<i>Swietenia macrophylla</i> King	Meliaceae	Bara mehogoni	RL
138.	<i>Swietenia mahagoni</i> (L.) Jacq.	Meliaceae	Mahagoni	RL
139.	<i>Swintonia floribunda</i> Griff.	Anacardiaceae	Am chundol, Civit	RL
140.	<i>Syzygium cumini</i> (L.) Skeels	Myrtaceae	Jam, Kalo-jam	EF
141.	<i>Syzygium firmum</i> Thw.	Myrtaceae	Dhaki-jam	RL
142.	<i>Syzygium fruticosum</i> (Wall.) Masamune	Myrtaceae	Putijam, Noli-jam	EF
143.	<i>Syzygium jambos</i> (L.) Alston	Myrtaceae	Golap-Jam	EF
144.	<i>Syzygium samarengense</i> (Blume) Merr. & Perry	Myrtaceae	Jamrul	EF
145.	<i>Tamarindus indica</i> L.	Caesalpiniaceae	Tentul	EF+E
146.	<i>Tectona grandis</i> L. f.	Verbenaceae	Shegun, Teak	RL
147.	<i>Terminalia arjuna</i> (Roxb. ex DC.) Wight & Arn.	Combretaceae	Arjun	M
148.	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	Combretaceae	Bohera	M
149.	<i>Terminalia catappa</i> L.	Combretaceae	Kat badam	AP
150.	<i>Terminalia chebula</i> (Gaertn.) Retz.	Combretaceae	Haritaki	M
151.	<i>Toona ciliata</i> M. Roem.	Meliaceae	Toon, Surujdeb	FW
152.	<i>Trewia nudiflora</i> L.	Euphorbiaceae	Pitali, Pitagula	FW
153.	<i>Vitex glabrata</i> R. Br.	Verbenaceae	Horina, Goda	RL
154.	<i>Vitex peduncularis</i> Wall. ex Schauer	Verbenaceae	Arshol	RL
155.	<i>Xylia xylocarpa</i> (Roxb.) Taub.	Mimosaceae	Lohakath	RL
156.	<i>Zanthoxylum rhetsa</i> (Roxb.) DC.	Rutaceae	Bajna	M
157.	<i>Ziziphus mauritiana</i> Lamk.	Rhamnaceae	Boroi	EF+F

### Shrub plants recorded from SBGEP

S.N.	Scientific name	Family	Local name	Use Pattern
1	<i>Abelmoschus esculentus</i> (L.) Moench	Malvaceae	Bondherosh	M
2	<i>Abroma augusta</i> L.	Sterculiaceae	Ulotkombol	M
3	<i>Acalypha hispida</i> Burm. f.	Euphorbiaceae	Boro hatipur	M
4	<i>Alocasia indica</i> (Roxb.) Schott.	Araceae	Man kochu	V
5	<i>Andrographis paniculata</i> (Burm. f.) Wall. ex Nees	Acanthaceae	Kalomegh	M
6	<i>Annona squamosa</i> L.	Annonaceae	Sarifa	EF
7	<i>Bougainvillea spectabilis</i> Willd.	Nyctaginaceae	Bagan bilash	
8	<i>Bryophyllum calycinum</i> Salisb.	Crassulaceae	Patharkuchi	M
9	<i>Caesalpinia pulcherrima</i> (L.) Sw.	Caesalpiniaceae	Radha chura	AP
10	<i>Calotropis gigantea</i> R. Br.	Asclepiadaceae	Akanda	M
11	<i>Carissa grandiflora</i> A. DC.	Apocynaceae	Karamcha	EF
12	<i>Cassia alata</i> L.	Caesalpiniaceae	Dad mardon	M
13	<i>Cassia occidentalis</i> L.	Caesalpiniaceae	Kasundi	FW
14	<i>Catharanthus roseus</i> (L.) G. Don	Apocynaceae	Nayan tara	AP
15	<i>Cestrum nocturnum</i> L.	Solanaceae	Hasnahena	AP

16	<i>Citrus aurantifolia</i> (Christm) Swingle	Rutaceae	Lebu	E
17	<i>Citrus medica</i> L.	Rutaceae	Lebupata	E
18	<i>Clerodendrum viscosum</i> Vent.	Verbenaceae	Bhant	M
19	<i>Cnesmone javanica</i> Blume	Euphorbiaceae	Jongli bichuti	FW
20	<i>Codiaeum variegatum</i> (L.) A. Juss.	Euphorbiaceae	Pata bahar	M
21	<i>Datura metal</i> L.	Solanaceae	Kala Datura	M
22	<i>Datura stramonium</i> L.	Solanaceae	Sada Datura	M
23	<i>Duranta repens</i> L.	Verbenaceae	Kata mehedi	AP
24	<i>Gardenia angusta</i> (L.) Merr.	Rubiaceae	Gandha Raj	AP
25	<i>Gloriosa superba</i> L.	Liliaceae	Ulot chandal	V
26	<i>Gnetum latifolium</i> Blume	Gnetaceae	Netum	E
27	<i>Gossypium herbaceum</i> L.	Malvaceae	Tula	
28	<i>Helicia erratica</i> Hook. f.	Proteaceae	Khara pakan	FW
29	<i>Hibiscus rosa-sinensis</i> L.	Malvaceae	Jaba, China rose	AP
30	<i>Hibiscus schizopetalus</i> (Mast.) Hook. f.	Malvaceae	Jobagach	AP
31	<i>Hydrocotyle sibthorpioides</i> Lamk.	Apiaceae	Gimashak	V
32	<i>Ixora chinensis</i> Lamk.	Rubiaceae	Rongon	AP
33	<i>Jasminum sambac</i> (L.) Aiton	Oleaceae	Bon mollika	AP
34	<i>Jatropha gossypifolia</i> L.	Euphorbiaceae	Lal Bherendha	
35	<i>Justicia adhatoda</i> L.	Acanthaceae	Basok	M
36	<i>Justicia gendarussa</i> Burm. f.	Acanthaceae	Titagach, Kala basok	FW
37	<i>Lantana camara</i> L.	Verbenaceae	Lantana, Nagphul	AP
38	<i>Manihot esculenta</i> Crantz	Euphorbiaceae	Seme alu	V
39	<i>Melastoma malabathricum</i> L.	Melastomataceae	Bontezpata	EF
40	<i>Murraya koenigii</i> (L.) Spreng.	Rutaceae	Kammniful	AP
41	<i>Mussaenda erythrophylla</i> Schumach. & Thonn.	Rubiaceae	Muchanda	AP
42	<i>Nyctanthes arbor-tristis</i> L.	Verbenaceae	Sheuli	AP
43	<i>Ocimum sanctum</i> L.	Lamiaceae	Tulsi	M
44	<i>Pavetta indica</i> L.	Rubiaceae	Kath-chapa	FW
45	<i>Punica granatum</i> L.	Punicaceae	Dalim	EF
46	<i>Ricinus communis</i> L.	Euphorbiaceae	Bherenda	M
47	<i>Sesbania bispinosa</i> (Jacq.) Wight.	Fabaceae	Dhoucha	AP
48	<i>Solanum indicum</i> L.	Solanaceae	Bon Begun	FW
49	<i>Solanum melongena</i> L.	Solanaceae	Begun	V
50	<i>Solanum nigrum</i> L.	Solanaceae	Titbegun	V
51	<i>Solanum torvum</i> Sw.	Solanaceae	Gota begun	V
52	<i>Tabernaemontana recurva</i> Roxb.	Apocynaceae	Tagor	AP
53	<i>Tephrosia candida</i> (Roxb.) DC.	Fabaceae	Bogamedula	AP
54	<i>Thuja orientalis</i> L.	Cupressaceae	Thuja	AP
55	<i>Thunbergia erecta</i> Benth.	Acanthaceae	Nilkantha	F
56	<i>Vitex negundo</i> L.	Verbenaceae	Nishinda	M
57	<i>Vitex trifolia</i> L. f.	Verbenaceae	Nil nishinda	M
58	<i>Woodfordia fruticosa</i> Salisb.	Lythraceae	Daiphul	AP
59	<i>Ziziphus oenoplia</i> (L.) Mill.	Rhamnaceae	Bon-boroi	EF

### Herb plants recorded from SBGEP

S.N.	Scientific name	Family	Local name	Use Pattern
1.	<i>Acalypha indica</i> L.	Euphorbiaceae	Mukta jhuri	F
2.	<i>Achyranthes aspera</i> L.	Amaranthaceae	Apang	M
3.	<i>Aloe vera</i> (L.) Burm. f.	Aloaceae	Greeta kumari	M
4.	<i>Alpinia nigra</i> (Gaertn.) B. L. Burt	Zingiberaceae	Jongli ada	M
5.	<i>Alternanthera philoxeroides</i> (Mart.) Griseb.	Amaranthaceae	Helencha	V
6.	<i>Amaranthus spinosus</i> L.	Amaranthaceae	Kantashak	V
7.	<i>Amorphophallus campanulatus</i> (Roxb.) Bl.	Araceae	Ol kochu	V
8.	<i>Ananas comosus</i> (L.) Merr.	Bromeliaceae	Anarosh	EF
9.	<i>Andropogon citratus</i> DC.	Poaceae	Lemon grass	M
10.	<i>Antigonon leptopus</i> Hook. & Arn.	Polygonaceae	Ananta lata	
11.	<i>Asclepias curassavica</i> L.	Asclepiadaceae	Moriccha	
12.	<i>Asparagus racemosus</i> Willd.	Liliaceae	Satamuli	M
13.	<i>Boerhavia repens</i> L.	Nyctaginaceae	Punornova	M
14.	<i>Bryophyllum pinnatum</i> (Lamk.) Oken	Crassulaceae	Pathor kuchi	M
15.	<i>Calendula officinalis</i> L.	Asteraceae	Calendula	
16.	<i>Capsicum frutescens</i> L.	Solanaceae	Morich	E
17.	<i>Centella asiatica</i> (L.) Urban	Apiaceae	Thankuni	V
18.	<i>Chenopodium album</i> L.	Chenopodiaceae	Batua shak	V
19.	<i>Chromolaena odorata</i> (L.) King & H.E. Robinson	Asteraceae	Assam gach	M
20.	<i>Chrysopogon aciculatus</i> (Retz.) Trin.	Poaceae	Premkanta	
21.	<i>Clitoria ternatea</i> L.	Fabaceae	Aparajita	AP
22.	<i>Colocassia esculenta</i> (L.) Schott	Araceae	Kochu	V
23.	<i>Coriandrum sativum</i> L.	Apiaceae	Dhoney	
24.	<i>Crotalaria juncea</i> L.	Fabaceae	Jhun-jhuni	FW
25.	<i>Croton bonplandianus</i> Baill.	Euphorbiaceae	Bankhira	FW
26.	<i>Cynodon dactylon</i> (L.) Pers.	Poaceae	Durba grass	M
27.	<i>Desmodium heterophyllum</i> (Willd.) DC.	Fabaceae	Bon motorshuti	FW
28.	<i>Desmostachya bipinnata</i> (L.) Stapf.	Poaceae	Kusha	
29.	<i>Eclipta alba</i> (L.) Hassk.	Asteraceae	Kalokeshy	FW
30.	<i>Eichhornia crassipes</i> (Mart.) Solms	Pontederiaceae	Kochuripana	
31.	<i>Emilia sonchifolia</i> (L.) DC.	Asteraceae	Bon-tulshi	FW
32.	<i>Enhydra fluctuans</i> Lour.	Asteraceae	Bon helencha	V
33.	<i>Euphorbia hirta</i> L.	Euphorbiaceae	Dudhiya	FW
34.	<i>Glinus oppositifolius</i> (L.) A. DC.	Molluginaceae	Gimashakh	V
35.	<i>Glycyrrhiza glabra</i> L.	Fabaceae	Jashti madhu	M
36.	<i>Helianthus annuus</i> L.	Asteraceae	Surjamukhi	AP
37.	<i>Heliotropium indicum</i> L.	Boraginaceae	Hati sur, Bhurundi	M
38.	<i>Hibiscus sabdariffa</i> L.	Malvaceae	Tok patha, Rosella	
39.	<i>Imperata cylindrica</i> (L.) Roesch.	Poaceae	Chhon	S

40.	<i>Ipomoea fistulosa</i> Mart. ex Choisy	Convolvulaceae	Dholkolmi	FW
41.	<i>Lasia spinosa</i> (L.) Thw.	Araceae	Bishkochu, Kantakochu	
42.	<i>Limnocharis flava</i> (L.) Buchenau	Limnocharitaceae	Khude pana	FW
43.	<i>Malachra capitata</i> (L.) L.	Malvaceae	Bon vindi	
44.	<i>Melochia corchorifolia</i> L.	Tiliaceae	Tiik okhra	M
45.	<i>Mimosa diplotricha</i> Sauv.	Mimosaceae	Bara lajjabati	FW
46.	<i>Mimosa pudica</i> L.	Mimosaceae	Lajjabati	M
47.	<i>Musa paradisiaca</i> L.	Musaceae	Aitta kola	V
48.	<i>Nymphaea capensis</i> Thunb.	Nymphaeaceae	Nil Shapla	V
49.	<i>Opuntia dillenii</i> Haw.	Cactaceae	Phonimonsha	Ap
50.	<i>Opuntia monacantha</i> Haw.	Cactaceae	Phonimonsha	AP
51.	<i>Paederia foetida</i> L.	Rubiaceae	Gondha Bhadali	V
52.	<i>Persicaria hydropiper</i> (L.) Spach	Polygonaceae	Bishkanthali	F
53.	<i>Phragmites karke</i> (Retz.) Trin.	Poaceae	Nal, Nalkhagra	
54.	<i>Pilea microphylla</i> (L.) Liebm.	Urticaceae	Mariccha lata	F
55.	<i>Rauvolfia serpentina</i> (L.) Benth. ex Kurz	Apocynaceae	Sharpagandha	M
56.	<i>Ruellia tuberosa</i> L.	Acanthaceae	Chatpotey	
57.	<i>Rumex vesicarius</i> L.	Polygonaceae	Tokpalong	
58.	<i>Saccharum officinarum</i> L.	Poaceae	Akh, Kussyal	EF
59.	<i>Saccharum spontaneum</i> L.	Poaceae	Kash	BT
60.	<i>Schumannianthus dichotomus</i> (Roxb.) Gagnep.	Marantaceae	Patipata, Murta	E
61.	<i>Scoparia dulcis</i> L.	Scrophulariaceae	Bondhoney	M
62.	<i>Senna tora</i> (L.) Roxb.	Caesalpiniaceae	Cakundo	FW
63.	<i>Solanum tuberosum</i> L.	Solanaceae	Golalu	V
64.	<i>Spilanthes clava</i> DC.	Asteraceae	Kannaghias	M
65.	<i>Tagetes erecta</i> L.	Asteraceae	Ganda, Gendaphul	FW
66.	<i>Thysanolaena maxima</i> (Roxb.) Kuntze	Poaceae	Jharuphul	F
67.	<i>Urena lobata</i> L.	Malvaceae	Bon-okhra	FW
68.	<i>Vanda roxburghii</i> L.	Orchidaceae	Rasna	AP
69.	<i>Xanthium indicum</i> Koen. ex Roxb.	Asteraceae	Ghagra	FW
70.	<i>Zingiber officinale</i> Rosc.	Zingiberaceae	Ada	M
71.	<i>Zingiber zerumbet</i> (L.) Sm.	Zingiberaceae	Bon Ada	M
72.	<i>Zinnia elegans</i> Jacq.	Asteraceae	Jinnia	AP

### Climber plants recorded from SBGEP

S.N.	Scientific name	Family	Local name	Use Pattern
1.	<i>Abrus precatorius</i> L.	Fabaceae	Kuch	M
2.	<i>Aristolochia saccata</i> Wall.	Aristolochiaceae	Ishwarimul	M
3.	<i>Benincasa hispida</i> (Thunb.) Cogn.	Cucurbitaceae	Calkumra	
4.	<i>Bougainvillea glabra</i> Choisy	Nyctaginaceae	Baganbilash	AP
5.	<i>Calamus erectus</i> Roxb.	Arecaceae	Kadam, Sitar supari	E
6.	<i>Calamus latifolius</i> Roxb.	Arecaceae	Korak, Budum	EF
7.	<i>Calamus tenuis</i> Roxb.	Arecaceae	Jal, Jayot, Sachi bet	EF
8.	<i>Calamus viminalis</i> Willd.	Arecaceae	Kerak	EF
9.	<i>Chromolaena odorata</i> (L.) King & Robinson	Asteraceae	Asamlota	M
10.	<i>Coccinia grandis</i> (L.) Voigt	Cucurbitaceae	Telakucha	V
11.	<i>Cucurbita maxima</i> Duch. ex Lamk.	Cucurbitaceae	Mistikumra	V
12.	<i>Daemonorops jenkinsianus</i> (Griff.) Martius	Arecaceae	Golla, golak, goara	RL
13.	<i>Entada rheedii</i> Spreng.	Mimosaceae	Gilalata	AP
14.	<i>Gnetum montanum</i> Mgf.	Gnetaceae	Netumlota	
15.	<i>Jasminum scandens</i> Vahl.	Oleaceae	Jongli Jui	AP
16.	<i>Lablab purpureus</i> (L.) Sweet	Fabaceae	Shim	V
17.	<i>Lagenaria siceraria</i> (Molina) Standl.	Cucurbitaceae	Lau	V
18.	<i>Luffa acutangula</i> (L.) Roxb.	Cucurbitaceae	Jhinga	V
19.	<i>Mikania cordata</i> (Burm. f.) Robinson	Asteraceae	Lifijilota, Tuphanilota	M
20.	<i>Paederia foetida</i> L.	Rubiaceae	Gondhobhaduli	V
21.	<i>Piper betle</i> L.	Piperaceae	Pan	M
22.	<i>Smilax ocreata</i> A. DC.	Smilacaceae	Kumarilota	M
23.	<i>Vitis quadrangularis</i> Wall.	Vitaceae	Harzora	M

### Fern and Epiphyte plants recorded SBGEP

S.N.	Scientific name	Family	Local name	Use Pattern
1.	<i>Adiantum incisum</i> Forssk.	Adiantaceae	Patashak	M
2.	<i>Cheilanthes belangeri</i> (Bory) C. Chr.	Sinopteridaceae	Sada Dheky	M
3.	<i>Diplazium esculentum</i> (Retz.) Sw.	Athyriaceae	Dhekia	V
4.	<i>Drynaria quercifolia</i> (L.) J. Sm.	Polypodiaceae	Choto Dheky	FW
5.	<i>Lindsaea ensifolia</i> Sw.	Lindsaeaceae	Bon dheky	
6.	<i>Pronephrum nudatum</i> Roxb.	Thelypteridaceae	Dhekia	
7.	<i>Pteris pellucida</i> Presl.	Pteridaceae	Dhekia	FW
8.	<i>Pteris vittata</i> L.	Pteridaceae	Dhekia	FW
<b>Epiphyte</b>				
1.	<i>Pothos scandens</i> L.	Araceae	Jumbolota	M
2.	<i>Rhynchosstylis retusa</i> (L.) Blume	Orchidaceae	Orchid	AP

## Annex 2: Wildlife Diversity of Sitakunda Botanical Garden and Eco-park

### Amphibians in sitakunda botanical garden and eco-park

SN	Order	Family	Scientific Name	Common English Name	Local Name
1.	Anura	Bufonidae	<i>Dattaphrynus melanostictus</i>	Common Toad	Kuno Bang
2.			Dicroglossidae	<i>Euphlyctis cyanophlyctis</i>	Skipper Frog
3.		<i>Fejervarya asmatai</i>		Asmat's Cricket Frog	Asmater Jhi-jhiBang
4.		<i>Fejervarya cancrivora</i>		Crab-eating Frog	Kakra bhuk Bang
5.		<i>Fejervarya pierrei</i>		Pierre's Cricket Frog	Jhi-jhi Bang
6.		<i>Fejervarya nepalensis</i>		Nepal Cricket Frog	Jhi-jhi Bang
7.		<i>Fejervarya syhadrensis</i>		Syhadra Crickert Frog	Jhi-jhi Bang
8.		Microhylidae	<i>Microhyla ornata</i>	Ornate Microhylid	Cheena Bang
9.		Megophryidae	<i>Hoplobatrachus tigerinus</i>	Bull Frog	Bhawa Bang
10.			<i>Hoplobatrachus litoralis</i>	Coastal Bull Frog	Upokulio Sona Bang
11.		Rhacophoridae	<i>Polypedates leucomystax</i>	Six-lined Tree Frog	Dorakata Gechho Bang
12.			<i>Polypedates maculatus</i>	Maculated Tree Frog	Gechho Bang

### Reptiles in sitakunda botanical garden and eco-park

SN	Order	Family	Scientific Name	Common English Name	Local Name
1.	Squama	Gekkonidae	<i>Gekko gekko</i>	Tokkhak	Shanda
2.			<i>Hemidactylus frenatus</i>	Common House Gecko	Tiktiki
3.			<i>Hemidactylus brookii</i>	Spotted House Lizard	Tiktiki
4.		Agamidae	<i>Calotes versicolor</i>	Garden Lizard	Rokto Chusha
5.		Lacertidae	<i>Takydromus khasiensis</i>	Long-tailed Lizard	Tiktiki
6.		Scincidae	<i>Eutropis carinata</i>	Keeled Grass Shink	Anjon
7.			<i>Eutropis macularia</i>	Bronze Grass Shink	Ghash Anjon
8.	Testudines	Testudinidae	<i>Indotestudo elongata</i>	Elongated Tortoise	HoludPah
9.	Serpentes	Varanidae	<i>Varanus bengalensis</i>	Bengal Monitor	Kala Gui
10.			<i>Varanus flavescens</i>	Yellow Monitor	Sona Gui
11.		Boidae	<i>Python molurus</i>	Rock Python	Ajogor
12.		Elaphidae	<i>Najakaou kauthia</i>	Monocellate Cobra	Gokhra Shap
13.			<i>Naja naja</i>	Spectacled Cobra	Khoya Gokhra
14.			<i>Bungarus niger</i>	Black Krait	Kal Keutey Shap
15.			<i>Enhydris enhydris</i>	Smooth Water Snake	Paina Shap
16.			<i>Bungarus fasciatus</i>	Banded krait	Shonkhini Shap
17.			Colubridae	<i>Ptyas mucosa</i>	Indian Rat Snake
18.		<i>Ahaetulla nasuta</i>		Common Vine Snake	Laudoga Shap
19.		<i>Xenochropis piscator</i>		Checkered Keel Dora	Dora Shap
20.		<i>Lycodon aulicus</i>		Common Wolf Snake	Gharginni Shap

### Aves of sitakunda botanical garden and eco-park

SN	Order	Family	Scientific Name	Common English Name	Local Name	
1.	Galliformes	Phasinidae	<i>Gallus gallus</i>	Red Junglefowl	Bon Morog	
2.			<i>Lophura leucomelanos</i>	Kalij Pheasant	Mothura	
3.			<i>Polyplectron bicalcaratum</i>	Grey Peacock Pheasant	Kath moyur	
4.	Charadriformes	Turnicidae	<i>Turnix suscitator</i>	Barred Battonquail	--	
5.	Piciformes	Picidae	<i>Dendrocopos macei</i>	Fulvous-breasted Woodpecker	Jarad Kaththokra	
6.			<i>Dinopium javanense</i>	Common Flame Back	Kaththokra	
7.			<i>Picus xanthopygaeus</i>	Streak throated woodpecker	Sabujey Kaththokra	
8.			<i>Dinopium benghalense</i>	Black rumped Flame back	Sonali Kaththokra	
9.			<i>Dendrocopos canicapillus</i>	Gray Capped Pygmy woodpecker	Choto Kaththokra	
10.			<i>Picumnus innominatus</i>	Speckled Piculet	Khudey Kaththokra	
11.			<i>Chrysocolaptes gutta cristatus</i>	Common Golden back Woodpecker	Boro Kaththokra	
12.		Megalaimidae	<i>Megalaima asiatica</i>	Blue-throated Barbet	Bosontho bauri	
13.			<i>Megalaima lineata</i>	Lineated Barbet	Bosontho bauri	
14.			<i>Megalaima haemacephala</i>	Coppersmith Barbet	Bosontho bauri	
15.			<i>Megalaima australis</i>	Blue-eared Barbet	Neelkan Boshonto	
16.		Bucerotiformes	Bucerotidae	<i>Anthracoseros albirostris</i>	Pied Hornbill	Kao Dhanesh
17.		Upupiformes	Upupidae	<i>Upapa epops</i>	Common Hoope	Hudhud
18.		Coraciformes	Alcedinidae	<i>Halcyon smyrnensis</i>	White-throated Kingfisher	Manchranga
19.				<i>Halcyon atthis</i>	Common Kingfisher	Manchranga
20.	<i>Halcyon capensis</i>			Stork-Billed Kingfisher	Megh-Hou	
21.	Meropidae		<i>Merops orientalis</i>	Green Bee-eater	Suichura	
22.			<i>Merops leschenaulti</i>	Chestnut-headed Bee-eater	Suichura	
23.	Cuculiformes	Centropodidae	<i>Centropus sinensis</i>	Greater Coucal	Kanakuka	
24.			<i>Centropus bengalensis</i>	Lesser Coucal	Kukka	
25.			<i>Cuculus micropterus</i>	Indian Cuckoo	Bau kotha kou	
26.			<i>Eudynamis scolopacea</i>	Asian Cuckoo	Kokil	
27.			<i>Phaenicophaeus tristis</i>	Green Billed Malkoha	Sobuj Kokil	
28.			<i>Hierococcyx varius</i>	Common hawk Cuckoo	Chokgelo Pakhi	
29.			<i>Cacomantis merulinuss</i>	Plaintive Cuckoo	Chatak	
30.	Psittaciformes	Psittacidae	<i>Pittacula krameri</i>	Rose Ringed Parakeet	Tia	
31.			<i>Pittacula alexanderi</i>	Red-breasted Parakeet	Tota	
32.	Apodiformes	Apopidae	<i>Apus affinis</i>	House Swift	Ababil	
33.			<i>Cypsiurus balasiensis</i>	Asian Palm Swift	Nakkati	
34.		Caprimulgidae	<i>Caprimulgus macrurus</i>	Long-tailed Indian Nightjar	Rat Chara Phakhi	

35.	Strigiformes	Strigidae	<i>Athene brama</i>	Spotted Owl	Khuruly Pencha
36.			<i>Glauclidium cuculoides</i>	Asian Barred Owlet	Pencha
37.	Culumbiformes	Culumbidae	<i>Columba livia</i>	Rock Pigeon	Jalali Kobutar
38.			<i>Streptopelia chinensis</i>	Spotted Dove	Tila Ghughu
39.			<i>Treron phoenicoptera</i>	Yellow footed Green Pigeon	Holudpa Horial
40.	Ciconiiformes	Ralidae	<i>Amaurornis phoenicurus</i>	White Breasted Waterhen	Dahuk
41.		Jacanidae	<i>Metopodius indicus</i>	Bronze-winged Jacana	Jolpipi
42.		Charadriidae	<i>Vanellus indicus</i>	Red Wattle Lawping Bird	Hot Ti-Ti
43.		Accipitridae	<i>Spilornis cheela</i>	Crested Serpent Eagle	Tila Eagle
44.			<i>Milvus migrans</i>	Black Kite	Bhuban Chil
45.		Falacrocoracidae	<i>Falacrocorax niger</i>	Little Cormorant	Pankouri
46.		Ardeidae	<i>Bubulcus ibis</i>	Cattle Egret	Go-Bok
47.			<i>Egretta garzetta</i>	Little Egret	Sada Bok
48.			<i>Ardeola grayii</i>	Pond Heron	Kani Bok
49.			<i>Amastomus Oscitans</i>	Asian Openbill	Shamuk-Khol
50.			Cisticolidae	<i>Prinia inornata</i>	Plain Prinia
51.		<i>Cisticola juncidis</i>		Zitting Cisticola	Bhomra Soton
52.		Irenidae	<i>Chloropsis aurifrons</i>	Golden-fronted Leaf Bird	Shonakopali Horbola
53.	Sturnidae	<i>Acridotheres tristis</i>	Common Myna	Bhat Shalik	
54.		<i>A fuscus</i>	Jungle Myna	Jhuti Shalik	
55.		<i>Sturnus contra</i>	Pied Myna	Gobrey Shalik	
56.		<i>Sturnus malabaricus</i>	Grey Hooded Myna	Kat Shalik	
57.	Corvidae	<i>Corvus splendens</i>	House Crow	Pati Kak	
58.		<i>Corvus macrorhynchos</i>	Jungle Crow	Dar Kak	
59.		<i>Dendrocitta vagabunda</i>	Tree Pie	Kutum Pakhi	
60.		<i>Cissa chinensis</i>	Common Green Magpie	Sobuj Harichacha	
61.	Dicruridae	<i>Dicrurus macrocercus</i>	Black Drongo	Fingey	
62.		<i>Dicrurus hottentottus</i>	Spangled Drongo	Fingey	
63.		<i>Dicrurus paradiseus</i>	Racket Tail Drongo	Fingey	
64.	Corvidae	<i>Dicrurus aeneus</i>	Bronzed Drongo	Fingey	
65.		Oriolidae	<i>Oriolus xanthornus</i>	Black-headed Oriole	Holdy Pakhi
66.			<i>Oriolus oriolus</i>	Eurasian Golden Oriole	Sona Bau
66.		Aegithinidae	<i>Aegithina tiphia</i>	Common Iora	Fatikjol
67.		Artamidae	<i>Artamus fuscus</i>	Ashy Woods wallow	Latora
68.		Rhipiduridae	<i>Rhipidura albicollis</i>	White-throated Fantail	Lejnachani
69.		Campephagidae	<i>Tephrodornis pondicerianus</i>	Common Wood Shrike	Shudhuka/ Dukka
70.			<i>Pycnonotus jocosus</i>	Red Whiskered Bulbul	Sipahi Bulbul
71.					

72.	Passeriformes	Pycnonotidae	<i>Pycnonotus cafer</i>	Red-vented Bulbul	Kalo Bulbul
73.			<i>Pycnonotus atriceps</i>	Black Headed Bulbul	Kalo Bulbul
74.			<i>Alophoixus flaveolus</i>	White-throated Bulbul	Kalo Bulbul
75.		Muscicapidae	<i>Copsychus malabaricus</i>	White rumped Shama	Shama
76.			<i>Copsycus saularis</i>	Magpie-Robin	Doyel
77.			<i>Monticola solitarius</i>	Blue Rock Thrush	Shiladama
78.			<i>Myophonus caeruleus</i>	Blue whistling Thrush	Nil-shiladama
79.			<i>Culicicapa ceylonensis</i>	Grey-headed Canary Flycatcher	Metematha Choto- Chotok
80.			<i>Musicapa dauurica</i>	Asian Brown Flycatcher	Ashio Khoiri Chotok
81.			<i>Zoothra citrina</i>	Orange Headed Thrush	Komla Dama
82.			Sylviidae	<i>Orthotomus sutorius</i>	Tailor Bird
83.		<i>Orthotomus cuculatus</i>		Mountain Tailor bird	Pahari Tuntuni
84.		Timaliidae	<i>Turdoides striata</i>	Jungle Babbler	Satvaila
85.			<i>Garrulax pectoralis</i>	Greater- Necklaced Laughingthrush	Panga
86.			<i>Garrulax ruficollis</i>	Rufous - Necklaced Laughingthrush	Lalcheyghar -wala Panga
87.			<i>Garrulax galbanus</i>	Yellow-throated Laughingthrush	Holdegola-Penga
88.		Nectarinidae	<i>Nectarinia sperata</i>	Purple throated Sunbird	Begunibook Moutus
89.			<i>Nectarinia asiatica</i>	Purple Sunbird	Niltuni
90.			<i>Aethopyga siparaja</i>	Crimson Sunbird	Shindury Moutushi
91.		Dicaeidae	<i>Dicaeum cruentatum</i>	Scarlet Backed Flowerpecker	Lal Fuljhuri
92.			<i>Dicaeum erythrorhynchos</i>	Pale-billed Flowerpecker	Metethot Fuljhuri
93.			<i>Dicaeum chrysorrheum</i>	Yellow-vented Flowerpecker	Holde tola Fuljhuri
94.			<i>Dicaeum agile</i>	Thick-billed Flowerpecker	Thotmota Fuljhuri
95.		Paridae	<i>Parus major</i>	GreatTit	Tit Phakhi
96.	Passeridae	<i>Passer domesticus</i>	Houses parrow	Charui Pakhi	
97.	Ploceidae	<i>Ploceus manyar</i>	BayaWeaver	Babui	
98.	Motacillidae	<i>Anthus rufulus</i>	Paddy Field Pipit	Mat Chorai	
99.		<i>Lonchura punctulata</i>	Scaly-breasted Munia	Tila Munia	
100.		<i>Motacilla alba</i>	White Wagtail	Sada Khonjon	
101.		<i>Motacilla cinerea</i>	Gray Wagtail	Dhushar Khonjon	
102.		<i>Motaciila flava</i>	Yellow Wagtail	Holdey Khonjon	

### Mammals of sitakunda botanical garden and eco-park

SN	Order	Family	Scientific Name	Common English Name	Local Name
1.	Primates	Cercopithecidae	<i>Macaca assamensis</i>	Assamese Macaque	Assamese Bandor

2.			<i>Trachypithecus pileatus</i>	Capped Langur	Lal Hanuman	
3.	Carnivora	Canidae	<i>Canis aureus</i>	Golden Jackal	Pati Sheal	
4.		Viverridae	<i>Vivvera zibetha</i>	Large Indian Civet	Bagdash	
5.			<i>Vivericula indica</i>	Small Indian Civet	Khatash	
6.			Herpestidae	<i>Herpestes edwardsi</i>	Common Indian Mongoose	Benji
7.		<i>Herpestes auropunctatus</i>		Small Indian Mongoose	Chhoto Beji, Nakul	
8.		Felidae	<i>Prionailurus viverrina</i>	Fishing cat	Mechho Biral	
9.			<i>Felis chaus</i>	Jungle cat	Bono Biral	
10.			<i>Prionailurus bengalensis</i>	Leopard Cat	Leopard Cat	
11.		Rodentia	Sciuridae	<i>Callosciurus pygerythrus</i>	Irrawaddy Squirrel	Badami Kat Birali
12.			Hystricidae	<i>Hystrix indica</i>	Indian Crested Porcupine	Shojaru
13.	Muridae		<i>Bandicota indica</i>	Bandicoot Rat	Boro Indur	
14.			<i>Mus musculus</i>	House Mouse	Nengti Indur	
15.			<i>Mus booduga</i>	Indian Field Mouse	Metto Indur	
16.			<i>Rattus norvegicus</i>	Brown Rat	Indur	
17.			<i>Rattus rattus</i>	Common Indian Rat	Indur	
18.	Suidae		<i>Sus scrofa</i>	Wild Boar	Shukor	
19.	Artiodactyla		Cervidae	<i>Muntiacus muntjac</i>	Barking Deer	Maya Horin
20.				<i>Arctonyx collaris</i>	Hog-Badger	Gor khodok
21.	Logomorpha	Leporidae	<i>Caprologus hispidus</i>	Assam Rabbit	Khargosh	
22.	Insectivora	Soricidae	<i>Suncus murinus</i>	Grey musk Shrew	Chika	
23.	Chiroptera	Pteropodidae	<i>Pteropus giganteus</i>	Flying fox	Badur	
24.			<i>Cynopterus spinx</i>	Fruit Bat	Badur	
25.		Megadermatidae	<i>Megaderma lyra</i>	False Vampire Bat	Badur	
26.		Pteropodidae	<i>Rousettus leschenaulti</i>	Fulvous Fruit Bat	Kolabatur	
27.		Vespertilionidae	<i>Pipistrellus coromandra</i>	Indian Pipistrelle	Cham Chika	

### Annex 3: Descriptive Statistics of Independent and Dependent Variables

Variable	Mean	Standard Error	95% Confidence Interval	
			Lower	Upper
<i>incrop</i>	7952.54	661.79	6870.08	9198.24
<i>sppdensity</i>	5.78	0.34	5.11	6.52
<i>ecoextent</i>	0.63	0.06	0.54	0.75
<i>villtype</i>	0.30	0.04	0.20	0.41
<i>age</i>	43.32	1.23	40.76	46.14
<i>female</i>	0.12	0.03	0.06	0.19
<i>higher</i>	0.08	0.02	0.04	0.13
<i>inonagri</i>	14167.95	1678.19	11704.61	18048.95
<i>agriland</i>	0.59	0.08	0.48	0.87
<i>irrigateland</i>	36.71	2.10	31.86	40.91
<i>vlilter</i>	61.81	3.23	55.26	67.32
<i>tripura</i>	0.13	0.03	0.07	0.21

### Annex 4. Effects of Crop Diversity and Forest Area on Crop Income of the Farm Households

Model	coefficient	Standard Error	t	P >  t	95% Conf. Interval	
					Lower Bound	Upper Bound
(Constant)	-2134.55	2968.253	-0.72	0.474	-8024.951	3755.851
<i>sppdensity</i>	715.5112	173.0308	4.14	0.000	372.1372	1058.885
<i>ecoextent</i>	3120.273	1282.532	2.43	0.017	575.1298	5665.417
<i>villtype</i>	-3996.795	1733.837	-2.31	0.023	-7437.539	-556.051
<i>age</i>	1.6337	46.63726	0.04	0.972	-90.91642	94.18382
<i>female</i>	801.1885	1990.213	0.40	0.688	-3148.325	4750.702
<i>higher</i>	564.2223	2277.352	0.25	0.805	-3955.108	5083.553
<i>innonagri</i>	-.0792943	.0431814	-1.84	0.069	-.1649865	.0063979
<i>agriland</i>	158.2263	870.3063	0.18	0.856	-1568.868	1885.321
<i>irrigateland</i>	33.80688	28.09363	1.20	0.232	-21.94402	89.55778
<i>vlilter</i>	65.34175	19.9642	3.27	0.001	25.72343	104.9601
<i>tripura</i>	5473.07	1834.31	2.98	0.004	1832.94	9113.199

Note: Number of observations (households) = 110; Population size = 4404; prob > F = 0.000; R<sup>2</sup> = 0.336; P < 0.05).

### Annex 5: Test of Multicollinearity

Variables	VIF	1/VIF	Variables	VIF	1/VIF
<i>sppdensity</i>	1.21	0.825055	<i>innonagri</i>	1.77	0.565230
<i>ecoextent</i>	2.00	0.500058	<i>agriland</i>	1.91	0.524365
<i>villtype</i>	1.95	0.512500	<i>irrigateland</i>	1.17	0.851472
<i>age</i>	1.12	0.895615	<i>vlilter</i>	1.40	0.712545
<i>female</i>	1.28	0.783793	<i>tripura</i>	1.22	0.816498
<i>higher</i>	1.20	0.830408	Average	1.48	-

### Annex 6: Data Normality of Dependent Variable INCROP

