Comparison of Regeneration and Tree Species Diversity of Disturbed and Less Disturbed Zones of Sitakund Botanical Garden and Eco-Park, Chittagong, Bangladesh

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Dedicated to my parents
for their continuous support and encouragement

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ABSTRACT

This study presents the natural regeneration status and tree species diversity of the Sitakund Botanical Garden and Eco-park, Chittagong, Bangladesh. The study area was classified as disturbed and less disturbed zones based on the current anthropogenic disturbances. Stratified and systematic random sampling was used to select the sample plots, 30 in less disturbed zone and 20 in disturbed zone. A total number of 109 plant species from 43 families were recorded in the study, of which 93 were naturally originated species and rest were planted. Among the naturally originated species 66 were tree species, 9 were shrub species and 18 were climbers. The average densities (N/ha) of height range (0 - 0.5) m, (0.5 - 2) m, (> 2 m < 6 cm dbh) and trees (> 6 cm dbh) were 72333, 11291, 2770 and 790 in the less disturbed zone and 122500, 12687, 1640 and 150 in the disturbed zone respectively. The average basal areas (m^2 / ha) in the disturbed and less disturbed zone were 3.29 and 6.80 respectively. *Holarrhena antidysenterica, Stereospermum chelonioides, Dehasia kuruzi*, *Garuga pinnata*, *Albizzia procera*, Kurulla were dominant tree species in the disturbed zone and *Holarrhena antidysenterica, Stereospermum chelonioides*, *Dehasia kuruzi*, *Garuga pinnata*, *Syzygium fruticosum*, *Ficus hispida* were dominant tree species in the less disturbed zone.32 trees and 9 climbers were common in both zones. Herb coverage in the disturbed and less disturbed zone was 67% and 40% respectively. Most of the shrub species were common in both zones. Species richness, density (N / ha) for regeneration from (0 - 0.5) m range and trees (> 6 cm dbh) and disturbance index showed significant differences between zones. Species richness and basal area (m^2/ha) showed a negative relationship with disturbance index. Number of total individuals decreased as the diameter and height of trees increased. It is evident from the results that plant species richness and tree species diversity were influenced by the level of anthropogenic disturbances. Therefore, native forest eco-system could be restored if the anthropogenic disturbances can be minimized.

Keywords: Human influence, Species diversity, Vegetation structure, Regeneration, Disturbance index

KURZFASSUNG

In dieser Arbeit wird die Naturverjüngung und Baumartenvielfalt in durch den menschlichen Einfluss unterschiedlich geprägten Gebieten des Sitakund Botanical Garden und Eco-park in Chittagong in Bangladesh untersucht.

Das Untersuchungsgebiet mit einer Größe von 1570 ha wurde auf Basis der aktuellen menschlichen Aktivitäten klassifiziert, wobei in der weniger beeinflussten Zone 30 Stichprobenpunkte und in der beeinflussten Zone 20 Stichprobenpunkte aufgenommen wurden. Die stratifizierte Auswahl der Stichprobenpunkte erfolgte nach einem systematischen Raster zufällig. Insgesamt konnten 109 Pflanzenarten aus 43 Familien identifiziert werden, wobei 93 einen natürlichen Ursprung aufweisen, der Rest war künstlich eingebracht. Von den ursprünglichen Arten konnten 66 Baumarten, 9 Straucharten und 18 Kletterpflanzen unterschieden werden. Die Baumartenvielfalt und Pflanzendichten waren zwischen den beiden Zonen entsprechend den Höhenklassen (0 - 0.5) m , (0.5 - 2) m, (> 2 m < 6 cm BHD) und (> 6 cm BHD) signifikant unterschiedlich. Die durchschnittliche Grundfläche war mit 3.29 m^2/ha in der beeinflussten Zone geringer als in der weniger beeinflussten Zone mit 6.80 m^2/ha. *Holarrhena antidysenterica*, *Stereospermum chelonioides*, *Dehasia kuruzi*, *Garuga pinnata*, *Albizzia procera* und Kurulla waren die dominanten Baumarten in der beeinflussten Zone. *Holarrhena antidysenterica*, *Stereospermum chelonioides*, *Dehasia kuruzi*, *Garuga pinnata*, *Syzygium fruticosum* und *Ficus hispida* waren die dominanten Baumarten in der wenig beeinflussten Zone. Neben den dominaten Baumarten *Holarrhena antidysenterica*, *Stereospermum chelonioides*, *Dehasia kuruzi* und *Garuga pinnata* kamen auch noch zusätzlich 32 Baumarten, 9 Kletterpflanzen und die meisten Straucharten in beiden Zonen gemeinsam vor. Die Bedeckung mit krautiger Vegetation war mit 67% in der beeinflussten Zone höher als in der weniger beeinflussten Zone mit 40%. Die Baumartenvielfalt und die Grundfläche waren mit dem Grad des menschlichen Einflusses signifikant negativ korreliert. Die Anzahl der Arten nahm mit steigendem Durchmesser und Baumhöhe ab. Es konnte in der Arbeit die Bedeutung von menschlichen Aktivitäten auf die Diversität der Waldökosysteme dargestellt werden. Hinweise für die Erhaltung einer möglichst naturnahen Artenkombination werden gemacht.

Keywords: Menschliche beeinflussung, Artenvielfalt, Vegetationsstruktur, Verjüngung, Störungsindex

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ABBREVIATIONS

FD = Forest Department

FMP = Forestry Master Plan

BFRI = Bangladesh Forest Research Institute

MOEF = Ministry of Environment and Forest

FAO = Food and Agriculture Organization

FRA = Forest Resources Assessment

IUCN = International Union for Conservation of Nature

WWF = World Wildlife Fund

UNFP = United Nations Environment Programme

CBD = Convention on Biological Diversity

CNPPA = Commission on National Parks and Protected Areas

NFSC = National Forest Seed Centre

RIMS = Resource Information Management System

NTFP = Non Timber Forest Product

ANOVA = Analysis of Variance

SPSS = Statistical Package for the Social Sciences

SD = Standard Deviation

Chapter 1 INTRODUCTION

1. 1 Background, Problem Statement and Justification

Bangladesh is a small country of about 144,000 sq km land area with a large population of 153,546,901 (2008 est.).It is one of the most densely populated countries in the world. Bangladesh was well endowed with a very diverse compliment of terrestrial and aquatic biological resources. The combined effect of habitat destructions and over exploitation of biological resources, increased settlements, land use systems have been severely depleted the biodiversity. Many species are now extinct in the country and many more species are listed as threatened and endangered (Ahmed,1995) .The biological diversity of tropical forests constitutes a unique national and international asset maintaining global ecological systems and achieving sustainability of biological resources and now being widely recognized goals of world's nations (Trivedi, 2000).

An arbitrary felling of trees mainly from the hill forests have resulted in a stern running down of tropical forest tree species causing a serious degradation of native ecosystems. Most of the hill forests areas have been lying denuded of forest cover for decades. Even though Bangladesh Forest Department has undertaken reforestation programmes in some of these degraded hill forests through the World Bank and Asian Development Bank aided projects (Misbahuzzaman, 2004) ,no satisfactory results have so far been achieved either in respect of a successful establishment of plantation or in terms of the area brought under tree cover. The plantation programmes are not successful due to the poor biophysical condition of the degraded hill soils and seasonal moisture stress. Steep slopes and deep gorges may further affix to the difficulties of carrying out activities for establishment of plantation. Nevertheless, the Government of Bangladesh has recognized the importance of its native forest ecosystems mainly, because of its concerns for biodiversity conservation and climate change issues. Concentrated efforts have recently been made in an attempt to restore the unique condition of native forest ecosystems in some critical forest areas of the country. One of such initiatives was to establish eco-parks for ecological restoration of native hill forest ecosystems and development of eco-tourism on nature conservation in different parts of the country (Misbahuzzaman & Alam, 2006).

An Eco-park is a natural recreational centre where people can enjoy the beauties of the nature in its natural habitated, see the natural landscapes and biodiversity closely. Likewise, a botanical garden plays a vital role for recreation. The National Botanical Garden was the only botanical garden in the country which is situated in Mirpur, Dhaka. This garden is at present mostly used for recreation purposes. A project was supposed to be implemented considering the needs of recreation facilities of the people in Chittagong city and adjoining areas, ex-situ conservation of biodiversity and genetic resources and display areas for plants, the practical demonstration plots for developing a Botanical Garden in Chittagong Metropolitan area during 1994-95. It was supposed to be implemented by five years, but could not run properly due to land administration problems. Last of all Ministry of Environment and Forests, Government of Bangladesh decided in August 1998 to establish a Botanical Garden at Chandranath Hill, Sitakund. In a meeting in September 1999, the planning Commission, Government of Bangladesh decided to merge 'Barabkunda Hot Spring and Baroiardhala Waterfall Project' another proposed project of Forest Department with the Botanical Garden project, as both the projects are located in the same area. Finally a project titled 'Establishment of Botanical Garden and Eco-park at Sitakund 'was approved for five years from 1999 - 2000 to 2003 - 2004 (FD & MOEF, 2000) .This was the first implementation phase of the project. Currently the second phase has been implemented at the same place and this will run up to 2009 - 2010 fiscal years on ward.

The forests that once covered the hills in Chittagong have been largely destroyed. Though there are no accurate data on how much forest has been lost from Chandranath reserve forest, Chittagong, records of the Forest Department (FD) show that around 21,000 ha of forest has been lost, due to encroachment, illegal felling and the ravages of the 1941-1945 and 1971 liberation war periods (FMP, 1992) .The depletion of the forests has decreased soil fertility by accelerating soil erosion, reducing water yield because of increased runoff and compaction of the topsoil (Alam, 2001). Now-a-days, because of the establishment of Sitakund Botanical Garden and Eco-park, regeneration is improving. But local people have been evicted from their rights to use park resources. As there is a lack of other alternative means to sustain livelihoods, they have been involved in many illegal activities such as illegal logging, poaching and hunting of wild animals which have weakened the conservation efforts undertaken by the authority. Local people sometimes take the risk of grazing their cattle inside the reserve boundaries as they have no other alternative. Therefore, it can be seen that the main goal of the park to restore the biodiversity of the region is under threat because of the conflict rising between the Park Authority and local people. Adjoining hills near to the border of the area especially on the east and south under Forest Department are mostly degraded (Nath & Alauddin, 2005). For this reason, it was of great importance and interesting to observe how anthropogenic disturbances are influencing the regeneration of plant species and tree species diversity in different areas of Sitakund Botanical

Garden and Eco-park. However, there was no research on regeneration status and tree species diversity based on the anthropogenic disturbances in that area. Therefore, the study was carried out to observe the regeneration status and tree species diversity in some disturbed and less disturbed zones of the Sitakund Botanical Garden & Eco-park, Chittagong, Bangladesh.

1. 2 Research Objectives

The general objective of the study was to compare the regeneration status and tree species diversity in different zones of the Sitakund Botanical Garden and Eco-park, Chittagong, Bangladesh. To that general objective the following research questions are related:

- What are the differences between the study areas according to
    - species richness (mature trees, regeneration, shrub, climber)?
    - density (N/ha) of tree, regeneration, shrub?
    - herb coverage percentage?
    - the height and dbh (Diameter at Breast Height) distribution?
    - basal area (m^2 /ha)?
    - anthropogenic disturbances?
- What is the proportion of planted species in relation to naturally regenerated species in disturbed zones?
- What are the dominant naturally regenerating tree species in the different study sites and how do their importance value indexes (IVI) differ? What is the composition of dominating tree species at their regeneration stage?
- What is the impact of anthropogenic disturbances on the biological diversity (in terms of species richness, basal area (m^2/ha) and density (N/ha)) in the study area?

Chapter 2 LITERATURE REVIEW

2. 1 The Concept of Bio-diversity

"Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. (Convention of Biological diversity-Article 2) (CBD, 1992).Biological diversity has recently become one of the most popular topics of discussion both in scientific and political forum at local, national, regional and global level.

The term biodiversity includes three different but closely related aspects,

I) **Genetic diversity**: It refers to the variation of genes within species. This constitutes distinct population of the same species or genetic variation within population or varieties within a species.

II) **Species diversity**: It refers to the variety of species within a region. Such diversity could be measured on the basis of number of species in a region.

III) **Ecosystem diversity**: In an ecosystem, there may exist different landforms, each of which supports different and specific vegetation. Ecosystem diversity in contrast to genetic and species diversity is difficult to measure since the boundaries of the communities which constitute the various sub-ecosystems are elusive. Ecosystem diversity could best be understood if one studies the communities in various ecological niches within the given ecosystem; each community is associated with definite species complexes. These complexes are related to composition and structure of the biodiversity.

2. 2 Status of Bio-diversity in Bangladesh

Bangladesh is the world largest deltaic region, lies in the northeastern part of South Asia (Hossain, 2001). The majority of country's land is formed by alluvium from the Ganges and the Brahmaputra Rivers and their tributaries and consists mostly of flood plains (80%), with some hilly areas (12%) (Islam, 2003). Bangladesh has a sub-tropical monsoon climate; its natural forests are classified into three major vegetation types occurring in three distinctly different land types: hill forest (evergreen to semi-evergreen), plain land Sal (*Shorea robusta*) forests and mangrove forests. There is contradictory information on the actual forest extent of Bangladesh. According to the Bangladesh Forest Department and some other sources (Khan *et al*. 2007, Hossain *et al*. 1996 & Hossain, 2005), forest cover is about 2.53 million ha, representing approximately 17.5% of the country's total surface area (Table 1), but according to FAO's FRA-2005, forest extent is only about 0.87 million ha (FAO, 2006) Officially the FD manages 1.53 million hectares of forest land of the country (Roy, 2005).

Table 1 Forest types referring to ecosystem diversity in Bangladesh

Forest Type	Location	Area (million ha)	Remarks
Hill forests Managed reserve forest (evergreen to semi-evergreen)	Eastern part of the country (Chittagong, Chittagong Hill Tracts and Sylhet)	0.67	Highly degraded forests.Mainly managed by the Forest Department
Unclassed State Forest(USF)	Chittagong Hill Tracts	0.73	Under the control of district administration and denuded mainly due to faulty management and shifting cultivation. Mainly scrub forest.
Plain land forest Tropical moist deciduous forest	Central and north-western region (Dhaka, Mymensingh, Tangail etc.	0.12	Mainly Sal forest but now converting to exotic short rotation plantations. Managed by the Forest Department.
Mangrove			
Sundarbans	Southwest (Khulna, Satkhira)	0.57	World's largest continuous mangrove forest and including 0.17 million ha of water.
Coastal forest	Along the shoreline of twelve districts	0.10	Mangrove plantations along the shoreline of 12 districts. Managed by Forest Department.
Village forest	Homestead forest all over the country	0.27	Diversified productive system. Fulfill majority of country's domestic timber,fuelwood and bamboo requirements
Plantation in tea and rubber gardens	Chittagong Hill Tracts and Sylhet	0.07	Plantations of various short rotation species (mainly exotics)
Total forest		2.53	17.49 % of country's total land mass

Source: Khan *et al*. 2007, Hossain *et al*.1996 & Hossain, 2005

Bangladesh is part of the Indo-Burma region, which is one of the ten global hot-spot areas for biodiversity, with 7000 endemic plant species (Mittermeier *et al*. 1998). Due to its unique geo-physical location and characteristics, Bangladesh is characterized by an exceptionally rich biological diversity (Hossain, 2001, Nishat *et al*. 2002 & Barua *et al*. 2001). Its flora includes as estimated 5,700 species of angiosperms alone, including 68 woody legume species, 130 species of fibre yielding plants, 500 medicinal plant species, 29 orchid species, three species of gymnosperms and 1,700 pteridophytes (Firoz *et al*. 2004 & Khan, 1977). Some 2,260 plant species have been reported from the hilly region of Chittagong alone, which falls between two major floristic regions of Asia (Annonymous, 1993). The homestead forests are usually composed of multipurpose fast growing trees, fruits trees, bamboo, rattan, medicinal and some aquatic plants. There are about 8000 varieties of rice and nearly 3000 varieties of other miscellaneous crops in Bangladesh (Hassan, 1995).

Lately much attention has been given to the direct causes of biodiversity loss. However, there are usually underlying factors, including policies and laws, which provide the conditions for biodiversity loss (Ruskin, 1992). Population growth combined with intensive use of natural resources, poverty and unequal share of resource use at all levels, land tenure problems, micro-economic policies and trade practices are important causes.

2. 3 Conservation of Species Diversity of Natural Forest

The major goal of the world conservation strategy launched in 1980 by IUCN (International Union for Conservation of Nature), WWF (World Wildlife Fund) and UNEP (United Nations Environment Programme) is the integration of conservation and development to ensure the survival and well being of the people. In achieving these goals every country should concentrate on the priority requirements and on the main obstacles for which a strategy can be formulated. The natural forest of Bangladesh possesses a well variety of plant and animal resources. But many of the wild animals have become extinct and many others are not considered vulnerable due to habitat loss. Removal of vegetation cover produces an open space which is unattractive to wildlife. A large area of forest is being converted to agricultural land and habitation (Kumar & Asija, 2000).

Subsidies for agricultural development, livestock rearing and other intensive production system have often resulted in unsustainable development program large scale but avoidable losses of biodiversity worldwide. Low commitment to biodiversity management gives rise to a number of problems. Centralized planning prevents local stakeholders from participating in decision-making concerning land use and research.

Unless adequate conservation measures are taken the loss of tree species diversity will be irreplaceable. Ex-situ and In-situ conservation programs had been started in Bangladesh as the obligations of CBD in order to protect plants.

2.3. 1 In Situ Conservation

IUCN (1978) categorized the *in situ* conservation areas as strict nature reserves, national parks, natural movements, nature conservation reserves or wild life sanctuaries, resource reserves, world heritage sites. IUCN has recognized through its commission on national parks and protected areas (CNPPA), 10 categories of conservation areas representing different levels of protection from strict nature reserves to multiple use areas and varying degrees of local, regional and global importance. Each category is designed to meet different objectives. However, it is considered that a country may not need to develop all, as it has to reflect to its own objectives and constraints (IUCN, 1984). Though there are some wilderness areas in Chittagong Hill Tracts, but there are no records of conservation of these areas (Haque *et al*. 1997). However, there are 15 notified protected areas in Bangladesh, size vary from 27 ha to 71, 502 ha. The total area of the notified protected areas is 240,606 ha (Ghani, 1998). This is accomplished through maintenance of plants and animals within their natural ecosystem. The noble way of doing is to declare a network of protected areas that include the maximum number of threatened species and representative areas of ecosystem types.

Three types of protected areas are defined in the Bangladesh Wildlife Preservation Act, 1974. These are National park; Wildlife sanctuary and Game reserve (Table 2).

National park**:** A comparatively large area of outstanding scenic and natural beauty, in which the protection of wildlife and preservation of the scenery, flora and fauna in their natural state is the primary objective and to which the public may be allowed access for recreation, education and research. Hunting, killing or capturing any wild animal within a national park or one mile (1.6 km) of its boundaries, causing any disturbance (including firing of any gun) to any wild animal or its breeding place, felling, tapping, burning or in any other way damaging any plant or tree, cultivation, mining or breaking up any land, and polluting water flowing through a national park are not allowed. Such prohibitions may be relaxed for scientific purposes, aesthetic enjoyment of the scenery or any other exceptional reason. Construction of access roads, rest houses, hotels and public amenities should be planned so as not to impair the primary objective of the establishment of a national park.

Table 2 List of protected areas in Bangladesh

Sl.	Protected Areas	Forest types	Location	Area (ha)	Established (Extended)
A. NATIONAL PARKS (IUCN category V)					
01.	Modhupur NP	Sal forest	Tangail	8,436	1962 (1982)
02.	Bhawal NP	Sal forest	Gazipur	5,022	1974 (1982)
03.	Himchari NP	Hill forest	Cox's Bazar	1,729	1980
04.	Lawachara NP	Hill forest	Maulvibazar	1,250	1996
05.	Kaptai NP	Hill forest	Rangamati	5,464	1999
06.	Ramsagar NP	Sal forest	Dinajpur	27.75	2001
07.	Nijhum Dweep NP	Coastal mangrove	Noakhali	16,352.23	2001
08.	Medha Kachapia NP	Hill forest	Cox's Bazar	395.92	2004
09.	Satchari NP	Hill forest	Habiganj	242.82	2005
10.	Khadimnagar NP	Hill forest	Sylhet	679	2006
B. WILD LIFE SANCTUARIES (IUCN category IV)					
11.	Sundarban (East) WS	Natural mangrove	Bagerhat	31,226.94	1960 (1996)
12.	Pablakhali WS	Hill forest	Rangamati	42,087	1962 (1983)
13.	Char Kukri Mukri WS	Coastal mangrove	Bhola	40	1981
14.	Chunati WS	Hill forest	Chittagong	7,761	1986
15.	Rema-Kalenga WS	Hill forest	Habiganj	1,795.54	1996
16.	Sundarban (South) WS	Natural mangrove	Khulna	36,970.45	1996
17.	Sundarban (West) WS	Natural mangrove	Satkhira	71,502.13	1996
C. GAME RESERVE					
18.	Teknaf GR	Hill forest	Cox's Bazar	11,615	1983

Wildlife sanctuary**:** An area closed to hunting and maintained as an undisturbed breeding ground, primarily for the protection of wildlife including all natural resources such as vegetation, soil and water. Entry or residence, cultivation, damage to vegetation, killing or capturing wild animals within one mile (1.6 km) of its boundary, introduction of exotic or domestic species of animals, lighting of fires, and pollution of water are not allowed, but any of these prohibitions may be relaxed for scientific reasons, or for the improvement or aesthetic enjoyment of the scenery.

Game reserves**:** An area in which the wildlife is protected to enable populations of important species to increase. Capture of wild animals is prohibited. Hunting and shooting may be allowed on a permit basis.

Presently, there are 18 notified protected areas (i.e., ten national parks, seven wildlife sanctuaries and one game reserve) in Bangladesh (NSP, 2006). Compared to other regions of the world, this figure is still very poor. The protected areas of Bangladesh cover nearly 1.7% of the total landmass of the country. There are two Eco-parks in Bangladesh, one is Sitakund Botanical Garden and Eco-park (1996 acres) and another one is Bangabandhu Eco-park (1500 acres).The two eco-parks are belonged to the hill forests of the eastern part of the country.

2.3. 2 Ex-situ Conservation

There could be two approaches to this aspect; (I) Perpetuating sample species outside the natural habitat i.e. in the botanical gardens, herbarium etc. (2) Genetic storage in germplasm bank. In Bangladesh the responsibility of preservation of the germplasm belonging to the numerous crops rest with the Agricultural and Forestry research organization (e.g. Bangladesh Forest Research Institute, Bangladesh Tea Research Institute etc). Ex-situ conservation methods include any of those practices that conserve genetic material outside the natural distribution of the parent population and they may use reproductive material of individuals or stands located beyond the site of the parent population. Ex-situ conservation is necessary because in-situ conservation may sometimes fail due to intense pressure on land, weak legislation and implementation of conservation regulation and a public opinion unaware of conservation needs. Various methods of Ex-situ conservation (Rahman and Hossain, 2002) include the following:

- ***Preservation plot*****:** BFRI established one preservation plot of endangered tree species at Hyankoo, Chittagong, which consist of seven species (Raktan, Bakul, Civit, Dakroom, Kainjal, Pitraj and Boilam). Another conservation plot of ten endangered species (Pitraj, Urium, Deshi gab, Baitta garjan, Agar, Guttguttya, Batna, Mahua, Dharmara and Narikeli) was established at Chittagong Cantonment. One preservation plot of nine medicinal plant species has been established at Chittagong.

- ***Botanical gardens*****:** In Mirpur Botanical garden, there are about 255 tree species, 310 shrubs, 385 herbs and in Baldah garden, there are about 18000 plants of tree, shrubs and herbs which play a great role in conserving the biodiversity in Bangladesh. There are also some other botanical gardens spreaded all over the country. Sitakund Botanical Garden and Eco-park is one of them. There are about 156 tree species, 110 shrubs, 119 herbs and 27 climbers in this botanical garden and eco-park area.

- ***Arboretum*****:** One bamboo arboretum has been established at BFRI Campus, which contains collection of 27 bamboo species, including six exotic ones and another arboretum of medicinal plants has been established which contains collection of 40 species including six exotic ones. One cane arboretum of seven species has also been established at BFRI.

- ***Seed storage:*** It refers to storage of intact seeds in a controlled environment. Under controlled temperature and moist conditions, stored seeds of some species remain viable for decades. There is a National Forest Seed Centre (NFSC) at BFRI. But this centre does not have any facilities for long time storage of seeds. Non-calcitrant seeds can be stored here for few years.

- ***Pollen storage/gene banks*****:** With modern freeze-drying technique, pollen of some species can be stored at a very low moisture condition. For regeneration purposes, this technique requires complementary female structures to enable use of the pollen in seed production. There is no facility in Bangladesh for storage of pollen grains of forest species.

- ***Tissue culture*****:** The technique involves micro propagation (meristems, embryo or other). It requires large investment, but if cryogenic storage is developed, it provides a secure conservation method. BFRI has so far developed tissue culture techniques for six tree species (Kanthal, Zakrandra, Teak, Hybrid acacia, Neem, Eucalyptus) and six bamboo species (*Bambusa bambos, B. arundinacea, Dendrocalamus brandisii, Melocanna baccifera, B. vulgaris, B. nutans*).

- ***Cryogenic storage*****:** It is the preservation of biological material suspended above or in liquid nitrogen at temperature from - 150^0C to – 196^0C. It has become used for many years as a means of keeping animal semen for breeding purposes. This technology is relatively new to seed storage. There is no cryogenic storage facility in Bangladesh for forest tree species.

2. 4 Participation and Involvement of Bangladesh in the International Political Process

Bangladesh is signatory to a number of international political processes. These are

- Convention on wetlands of international importance, especial water flow habit, 1971 (Ramsar Convention).
- Convention concerning the protection of world cultural and natural heritage, 1972.
- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).
- Convention on Biological Diversity (CBD), 1992.
- Montreal Protocol for Protection of Ozone Layer.

2. 5 Government's Policies, Legislations and Major Initiatives for Bio-diversity Conservation

There are several legislative polices and initiatives that provide provisions for regulating the use and protection of plants and animals in the country. These are:

- Bangladesh Wildlife (Preservation) (Amendment) Act, 1974.
- Bangladesh Forest Act, 1878 and subsequent amendments.
- Forest Policy and Forestry Sector Master Plan.
- Protection and conservation of fish-Fish Act, 1950 and Fish Rules, 1985.
- Environment Policy, 1992.
- Bangladesh Environmental Conservation Act 1995 and Environment Conservation Rules, 1997.
- Declaration of Ecologically Critical Areas (ECA).
- National Conservation Strategy (NCS).
- National Environment Management Action Plan (NEMAP).
- Sustainable Environment Management Programme (SEMP).
- Coastal and Wetland Biodiversity Management Project in Cox's Bazar and Hakaluki haor in Greater Sylhet.

In addition to the above, the Government has taken up the following projects concerning biodiversity management. These are:

- Madhupur National Park Development Project.
- Botanical Garden and Eco-park at Sitakund, Chittagong
- Coastal Greenbelt Project.
- Establishment of Madhutila Eco-park and
- Development of Bhawal National Park, Baldha Garden and Botanical Garden.

Chapter 3 MATERIALS AND METHODS

3. 1 Research Methodology

This chapter describes the research approach, data collection procedure, sampling method and data analysis.

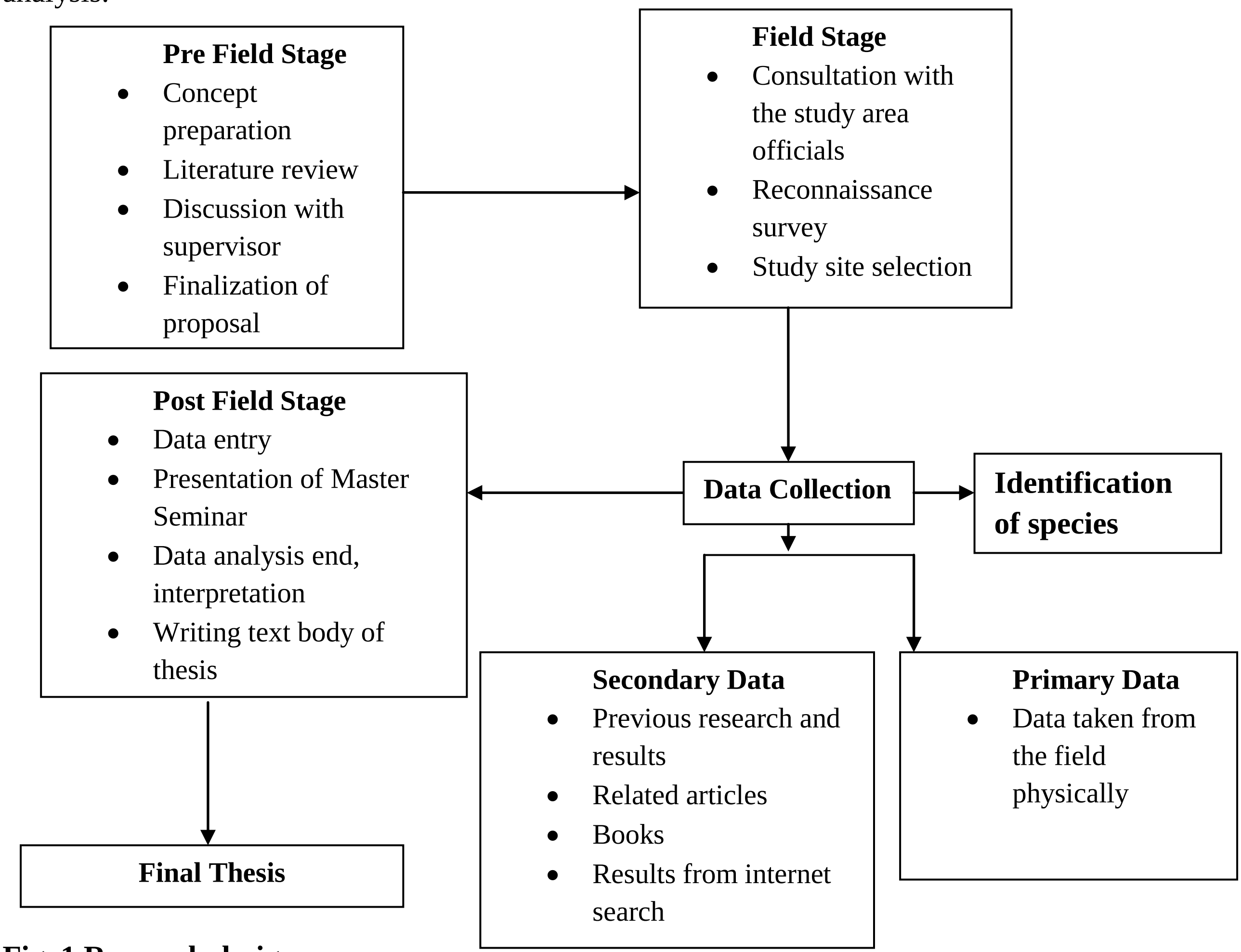


Fig. 1 Research design

3. 2 Data Collection

The study was carried out in Sitakund Botanical Garden and Eco-park, Chittagong, Bangladesh. The study area is situated on the southeast part of Bangladesh which is at the northwestern part of Chittagong district, between $22^{0}36^{/}$ and $22^{0}39^{/}$ N latitude and $91^{0}40^{/}$ and $91^{0}42^{/}$ E longitudes. The study area is composed of a number of low and high hills having peak slopes and streams covered with thorny bush and climbers. Coppice and root suckers occur in a scattered manner that apparently has no spatial uniformity. The study was based on field data collection through physical measurement in the field and review of relevant literature. A reconnaissance survey was conducted to become familiar with the study sites and the relevant information was collected from the Sitakund Botanical Garden & Eco-park, Nondonkanon, Chittagong; Range office, Sitakund Botanical

Garden & Eco-park; Bariordala Range office, Sitakund and Sitakund Beat Office. To have an idea of species composition of the whole study area, a number of through field visit was conducted at the onset of the field work (Fig. 1). The objective of the field visit was to get familiar with the vegetation community and to get an idea about the various species in the study area.

3. 3 Identification of Species

The species were identified directly in the field. Local people working in the field and forest officials also helped in identifying some species. Some species could not be referred to a given scientific name and also family name that is why they had been identified by their local name.

3. 4 Instrument and Other Materials Used in the Study

To conduct the study, the following instruments were used for the collection of the necessary data.

- ✓ Spiegel Relascope was used for height measurement with the help of forestry student of the University of Chittagong.
- ✓ Bamboo stick was used for height measurement in most of the cases.
- ✓ Diameter tape was used for measurement of DBH.
- ✓ Meter tape was used for distance measurement.
- ✓ Wooden pegs were used for pointing out the plot area.

3. 5 Field Data Collection Procedures

In this study, the Sitakund Botanical Garden and Eco-park was classified in two zones on the basis of human disturbances. (1) Disturbed zones (which are very close to the road), consisting with exotic tree species and agricultural cultivation, mainly in the south eastern part of the area and (2) Less disturbed zones (vally type which has inaccessibility and unavailability of tourist path) consisting of naturally originated species, mainly in the north portion of the area. But there were some plots taken from the areas very near to the stream considered as less disturbed zone. Tourists visit this stream each year.

For the study, 20 circular plots of 314 m^2 area have been established in the disturbed zone and 30 circular plots of same area in the less disturbed zone. All plots were taken along a transect, whereas the start of the transect was chosen randomly. On each circular plot (10 m radius of each), square plots (1 m *1 m , 2 m * 2 m and 4 m * 4 m) at 4 m distance from the center of the plot in both sides were demarcated (Fig. 2). The distance between the centers of two circular plots was 100 m. Within each plot, regeneration data was taken in the smaller plot (these small plots were fixed in the field on the basis of abundance). In the small plot size 1 m * 1 m, regeneration of trees and shrubs from height range (0 – 0.5) m was sampled. For plot size 2 m * 2 m, regeneration data was sampled from height range (0.5 m - 2 m) and for plot size 4 m * 4 m, regeneration within height range (> 2 m < 6 cm dbh) was recorded. Data for herb coverage percentage was taken from 4 m * 4 m in both sides of the plots. So total area for herb coverage percentage was 640 m^2 and 960 m^2 in the disturbed and less disturbed zone respectively. On the whole plot (314 m^2), trees (> 6 cm dbh) were recorded including height and diameter measurement.

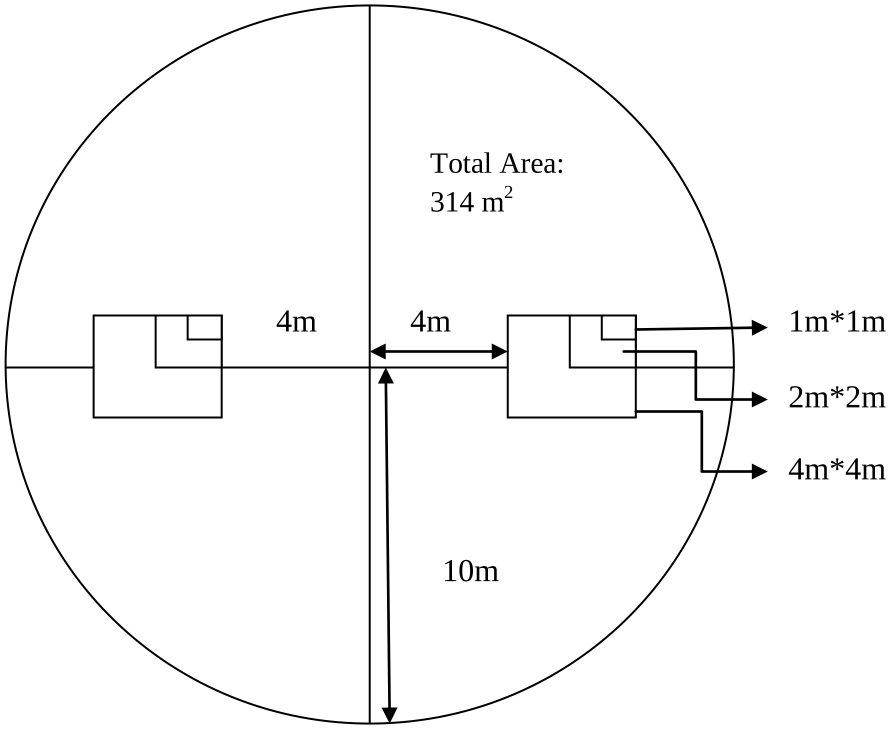


Fig. 2 Plot design for data collection of regeneration and tree species diversity

The intensity of disturbances was assessed according to the present impact. In the study area, human disturbances were identified in different categories. There are different ways recorded for developing disturbance indices are reported. Pandey and Shukla (2003) developed a disturbance index on the ratio of the number of trees that have been cut and the total number of individuals within a plot. Kumar and Ram (2005) considered mean canopy cover to estimate the human disturbance level. In this study a disturbance index was calculated on the basis of the qualitative assessment of the intensity of different disturbance elements observed in the field by following the formula modified according to Rahman *et al*. (2009). Disturbances like logging, cutting of regeneration, cutting of non wood products, bark peeling, litter collection, agro forestation, firing, and tourism were assessed as present disturbances (Table 3).

Different qualitative classes of elements like very high, high, medium, low, very low, absent, present were used to assess the current condition of disturbance elements (Table 4). For agro forestation, data were taken as present or absent. Weight was given by preference of each disturbance element.

Current Disturbance Index (CDI) =

$1/8 \sum_{i=1}^{8} (W_i S_c) \quad \sum_{i=1}^{8}(Wi)$ Where, Wi is the weight of ith (i=1, 2, 3…8) element, S_c is the scores for elements

Table 3 Framework for the assessment of disturbance elements

Elements	**Qualitative Assessment of Elements**						**Weights of elements (W_i)**
Logging	Very High	High	Medium	Low	Very Low	Absent	12
Cutting of regeneration	Very High	High	Medium	Low	Very Low	Absent	10
Cutting of non wood products	Very High	High	Medium	Low	Very Low	Absent	8
Bark peeling	Very High	High	Medium	Low	Very Low	Absent	6
Litter collection	Very High	High	Medium	Low	Very Low	Absent	5
Agro forestation	Present/Absent						4
Firing	Very High	High	Medium	Low	Very Low	Absent	3
Tourism	Very High	High	Medium	Low	Very Low	Absent	2

Table 4 Scores for the qualitative classes of disturbance elements

Classes of qualitative assessment (QC)	Scores (S_c)
Absent	0
Present	10
Very low	20
Low	40
Medium	60
High	80
Very High	100

QC: Classes of qualitative assessment, S_c: Scores for elements

The relative values of frequency, density (N/ha) and basal area (m^2/ha) for each single tree species were used to calculate the Importance Value Index (IVI) according to Phillips (1959) and Curtis (1959):

IVI= Relative Frequency + Relative Density + Relative Basal Area

The Shanon-Winner index for diversity (Michael, 1990):

$$H = - \sum pi \ln pi$$

Where,

H = Index of species diversity

Pi = No. of individual of one species / Total no. of individuals of all species (ni/N)

Evenness was calculated by Pielou's index from the formula given by (Magurran, 1988):

$$E = H / \text{In}\ S$$

Where,

E = Species evenness index

H = Shanon-Winner index of diversity

S = Total no.of species

Simpson's index (Simpson, 1949) measured the concentration of dominance (CD):

$$CD = \sum_{i=1}^{s} (p_i)^2$$

Where, CD = Index of dominance, p_i = It is the same as for Shannon-Wiener Information function .Value of CD ranges from 0 - 5. With this index, 0 represents high diversity and 1, low diversity. That is, the bigger the value of CD, the lower the diversity.

Species area curve was drawn from the total number of plant species found at different plots. Data were compiled and processed with the help of MS Excel Programme and then analyzed by one way ANOVA to find out significant differences in case of species richness, density (N/ha) and Disturbance Index (DI) between two zones. Spearman's and Pearson's correlation were used to find out the relation between disturbance index with density (N/ha) and basal area (m^2/ha) and species richness. In case of basal area (m^2/ha), Spearman's correlation was performed as the data were not normally distributed and in case of normally distributed data, Pearson's correlation was used. Data were summarized using tabled charts and graphs. All statistical analysis was done by using the SPSS package (version 16.0, 2007).

3. 6 Study Area

3.6. 1 Location, Area and Boundary

Fig.3 represents Sitakund Botanical Garden and Eco-park location. It is under Sitakund Upazila of Chittagong District. It comprises Chandranath Reserve Forest under the jurisdiction of Chittagong Forest Division. It lies between $22^0 36^/$ and $22^0 39^/$ N latitude and $91^0 40^/$ and $91^0 42^/$ E longitude. It is about 35 km north to Chittagong city, 3 km far away from Sitakund Upazila head quarter and about one kilometer east to the Dhaka-Chittagong high way. Numbers of hills cover the area and the hills are elevated gradually from the south to the north and from west to the east. Three waterfalls at different elevations, almost perennial have enhanced beauties and touring values of the areas. The Botanical Garden and Eco-park comprises an area of about 800 ha (1996 acres).

The Garden covers an area of 1000 acres (405 ha) and rest of the area (996 acres or 403.38 ha) is under the Eco-park. As shown in the attached map (Fig. 4), the Botanical Garden and Eco-park is generally surrounded by the different forest blocks like Barabkunda, Baroyadhala, Shovonchari and Udalia forest blocks.

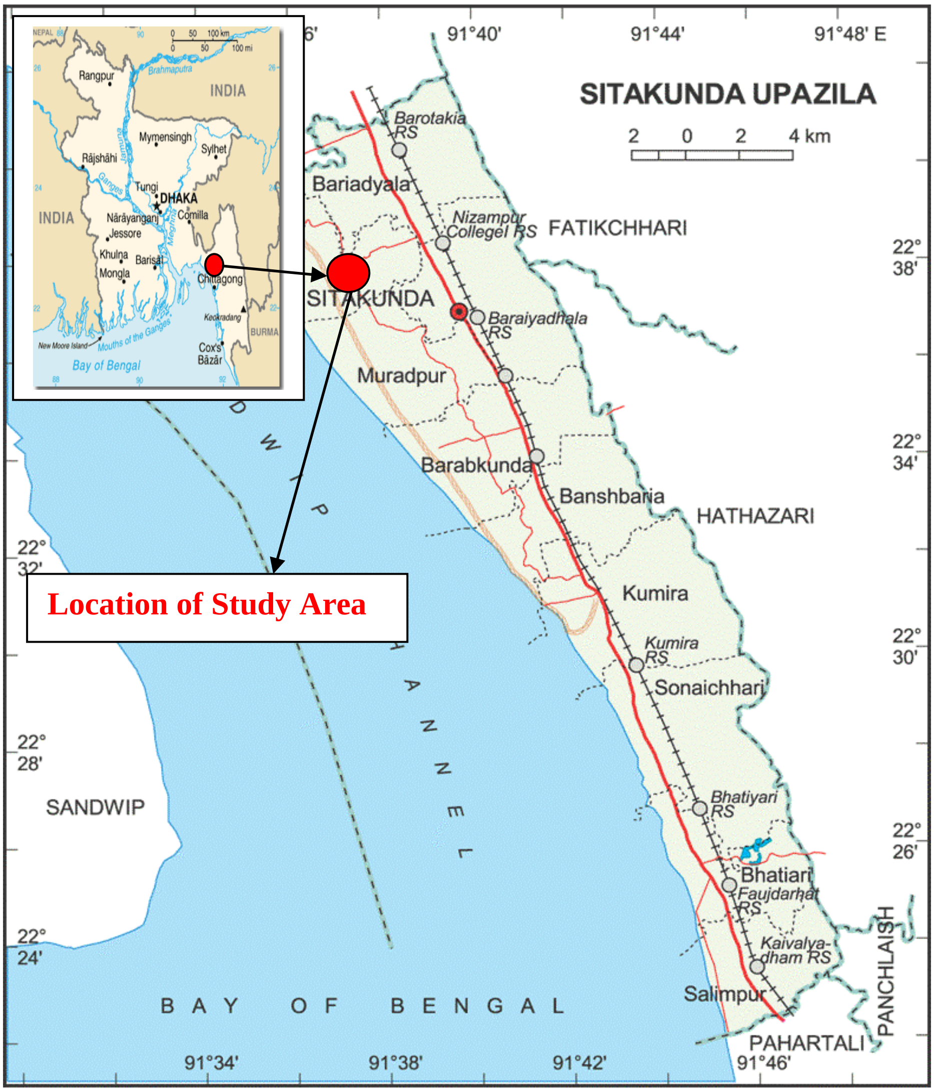


Fig. 3 Map of Bangladesh and Location of study area

Source: http://images.google.com/imgres & http://mychittagong.net (2nd June, 2009)

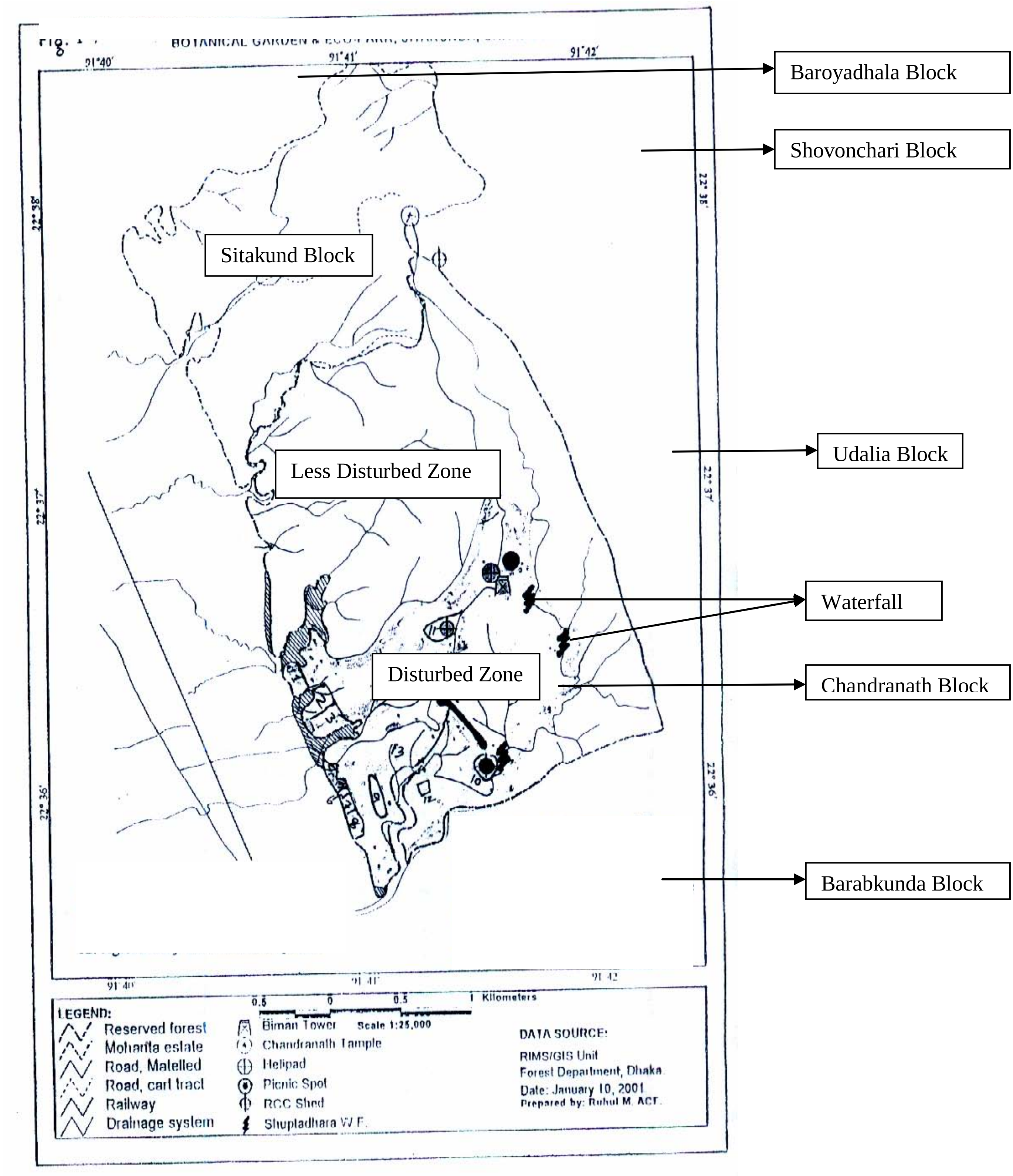


Fig. 4 Map of Sitakund Botanical Garden and Eco-park, Chittagong, Bangladesh

Source: RIMS/GIS Unit, Forest Department, Dhaka (10th January, 2001)

3.6. 2 Climate and Site Information

The area lies under the tropical climate zone. It is located in the east of the Bay of Bengal, 6-7 km from the coast that helps to get heavy rain as the winds of the southwest monsoon blow in this direction. The mean annual temperature in the area is 26.6^0 C. Average temperature in the area is 27.45^0 C. Maximum high temperature is during the month of May. Normal rainfall occurs during the month of May to September for five months. Maximum rainfall is in the month of July and the amount is 689.2 mm (average).

The soils of Sitakund hill are developed on Tertiary hill sediments of Tipam-Surma Series. These are well structured, brown, acidic, loamy soils resting on hard rocks within 100 cm depth. Soils in the high hills are loamy to clayey particularly towards the south and the west. Apparently these soils do not show any mineral deficiency or toxicity that may limit tree growth. Soils of the high hills are extremely drained. Because of the steepness of the slopes, they show some degrees of erodibility.

The main limiting factor for tree growth of soils developed on consolidated Tertiary hill sediments is surprisingly the soil moisture. Despite the favorable monsoon climate, moisture stress over a period of 100 days or more in this steep denuded hill soils is evident.

The forests that once occurred on the hills have been largely destroyed. The depletion of forests has decreased soil fertility by accelerated soil erosion, reducing water yield by increased run-off, compaction of the top soil and presence of drought pan nearer the surface.

Peak elevation about 407 m is reached east to Sitakund Bazar near the temple. The hills are elevated from the south and west towards the east and north. The landscape has a broken topography comprising of very steep hills and V-shaped valleys. The degrees of slopes range from 40-90 degrees. The valleys serve as drainage channels. There are some broad valleys dissecting the low hills.

Therefore land use planning in the high hills has to take into account (1) steep slope of the terrain (> 30% slope), (2) shallow depths of soil, (3) serve seasonal doughtiness (January - May), (4) large access of seasonal rainfall (July - October) and (5) difficult and poor accessibility of the landscape.

3.6. 3 Vegetation

Flora

Sitakund was one of the richest areas of biodiversity in Chittagong in the past. Semi evergreen forests comprising many evergreen and deciduous species covered once Sitakund hills. The hilly forest of Sitakund is part of the flora of Chittagong which is floristically and geographically more related to Indo-China than any other part of Indian sub continent (Khan, 1991a). More than two century back Francis Buchanan (later on Buchanan-Hamilton) noted the abundance of timber trees like Jarul (*Lagerstroemia speciosa*),Telsur (*Hopea odorata*), Surusbed (*Cedrela toona*),Arsol (Vitex spp.),Kalibole (Cordia spp.),Chickrassy (*Chickrassia tabularis*) (Van Schendel,1992). Hooker and Tomson had made a number of botanical collections from Sitakund during their visit to Chittagong in 1851 and recorded many species in the Flora of British India (1872-1892) (Khan, 1991b).

In 2004 the plant species and also the ornamental species including rose garden at Botanical garden & Eco-park, Sitakund, Chittagong were recorded. This survey was done by only one Botanist named Md.Shamsul Haque in that particular period. He did extremely laborious job for collecting the existing plant species including ornamental species at eco-park. According to the survey 96 plant families were found, with a total of 291 genus and species 412 in total .Total tree were found 156 including 110 shrubs, 119 herbs and 27 climbers. Addition to that he found and collected a total list of roses in the garden which comprises 42 numbers in total (Haque, 2004).

Fauna

Once the evergreen forests of Sitakund comprised the typical representative fauna of Chittagong. There is no documented report on the fauna of the Garden and Park area. Faizuddin (1981) reported capped languor (*Presbytis pileatus*), barking deer (*Munticus muntijak*), Rhesus monkey (*Macaca mullata*), Wild boar (*Sus scrofa*) from Karerhat which is a continuation of Sitakund hill range. Once there occurred Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Asiatic elephant (*Elephus maximus*), Sambar (*Cervus unicolor*), Gaur (*Bos gaurus*), Slow Loris (*Nycticebus coucang*), Rhesus monkey (*Macaca mullata*), Capped monkey (*Presbytis pileatus*), Gibbon (*Hylobetes hooloock*), Malayan Sun Bear (*Helarectos malayana*) and species of bird, Reptiles and Amphibians. There has been a great depletion of population density and species composition of wildlife mammals, birds, reptiles and amphibians. Some of the animals occurring currently in the garden and park area are jungle cat, large civet, rhesus monkey, common mongoose, fox, jackal and black rabbit, barking deer, common otter, lizard (*Aranus bengalensis*) wild boar and a number of birds (FD, 2001a) . Same observation was done by Haque (2004) on animals and birds and he reported animals in total 13 comprising Ban-biral, Baghdasha, Honuman, Banor and Beji. Additionally he found very popular birds in the eco-park area like Tia, Chil, Bhutum Pay-cha and Monyna.

3.6. 4 Land Use Characteristics at Botanical Garden and Eco-park

At present the study area is under the management of the Botanical Garden and Eco-park. Previously it was under Sitakund Beat of Bariadhala Range under Chittagong Forest Division. Still 1999 there were plantations of short rotation species, mainly Eucalyptus spp., and *Acacia auriculiformis*. In early 1990s, Bangladesh Forest Research Institute had implemented experimental plantations of Eucalyptus and *Acacia auriculiformis*. Now there exist few patches of *Acacia auriculiformis* and coppices of Eucalyptus. Most of the plantations either failed because of difficult site conditions or human interferences. Now scrub forests comprising of shrubs, grasses, degenerating muli bamboo culms and herbs cover the area. Due to recent protection measures, saplings of different indigenous species are coming from root suckers.

People living in the vicinity of Sitakund hill and surrounding areas exploit woody plants for fuel wood, support sticks (gils) for country beans and betel leaves and other domestic purposes. Shrubs are hardly 2 m tall that indicate heavy exploitation. There are patches of sun grass though out the area. People collect sun grass during the months of November – March and burn the area after harvest to enhance new growth. This practice however degrades the soil. This is the tradition of the local people surrounding the eco-park. They have been practicing since long. As a result, only the fire tolerant species are surviving without any kind of disturbances in these areas. Except fire tolerant species, other species are declining day by day. These kind of practices of the local people are the most important threats for biodiversity conservation in the eco-park.

Local people have also cultivated fruit trees like jackfruit, mango, guava, lemon, other fruit tree orchards in moderately hill slopes. They grow different green vegetables particularly the cucurbits along with fruits also. When there is scarcity of fodder in the plain fields, people collect fodder from the hills. Local people collect other NTFPs from the hills also. The stream coming down from the hills feed the plain agricultural fields at the down.

A paved road from Dhaka-Chittagong highway enters the area from the south-west. It passes to the north across the area and leads to the temple. It roughly divides the area into two halves.

Another road enters the area at the southeast border and leads to further east along the south border.

A helicopter pad and a radio transmission tower of Bangladesh Air Force are situated at about middle of the area by the side of the road to the temple. A deep tube well with residences of staff under Barabkunda Chemical Complex lies in the southern border of the area. At southwest corner and hundred meters north from the main gate along the western border there are two shrines of two saints namely Yasin Shah and Gafur Shah respectively. There are two sheds inside the area. One green house also is being constructed inside the garden area.

Seepage water drains in the form of streams come towards the western side of the garden. Drainage of seepage water at different levels from the north towards the south has made the immense beauties of three waterfalls. At least two of them are almost perennial throughout the year.

The old Hindu temple at the highest peak of Sitakund hills attracts large number of pilgrims once a year of about three days in April; a few pilgrims visit the temple at other times of the year also. Generally during the visit in April, the pilgrims climb the hill along the foot trails just adjacent to the temple. Many of them get down along the paved road across the park and garden areas. Few visitors visit the shrines of Yasin Shah and Gafur Shah throughout the year. These shrines have connecting roads with the main highway. The paved road from the Dhaka-Chittagong Highway is also used to attract a number of visitors for visiting the temple and for sightseeing. Recently with the inauguration of the Botanical Garden and Eco-park, numbers of visitors per year have increased. Every day people of different age groups are coming to the park for visits.

Chapter 4 RESULTS

4. 1 Current Situation of Disturbances

In the study area, different types of disturbances were observed which were logging, cutting of regeneration, cutting of non wood products, bark peeling, litter collection, agro forestation, firing, and tourism which were assessed as present disturbances.

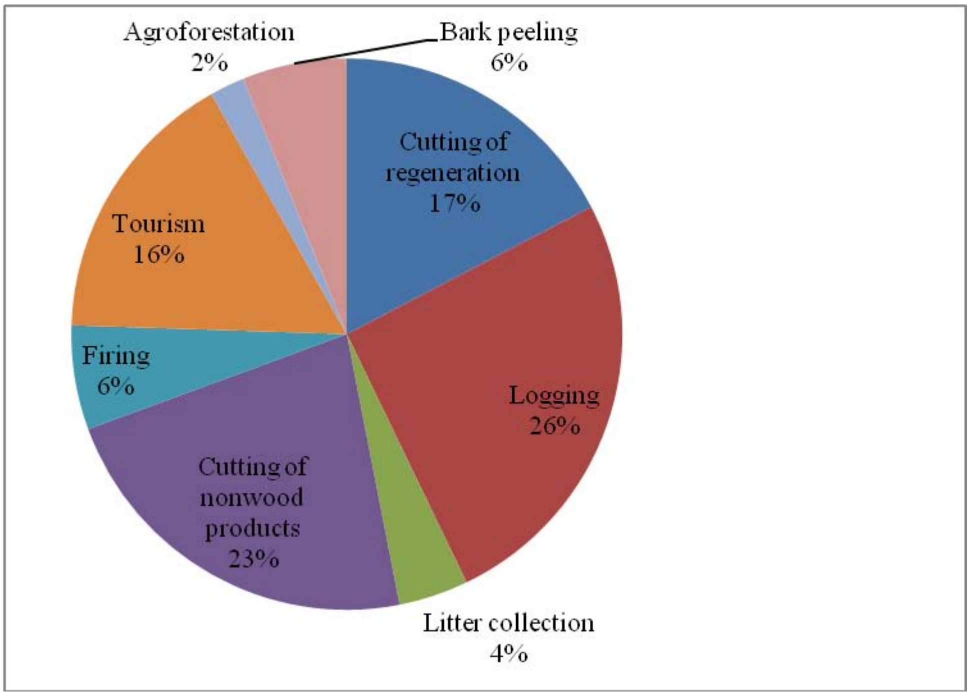


Fig. 5 Share (%) of each disturbance category on the sample plots of the disturbed zone

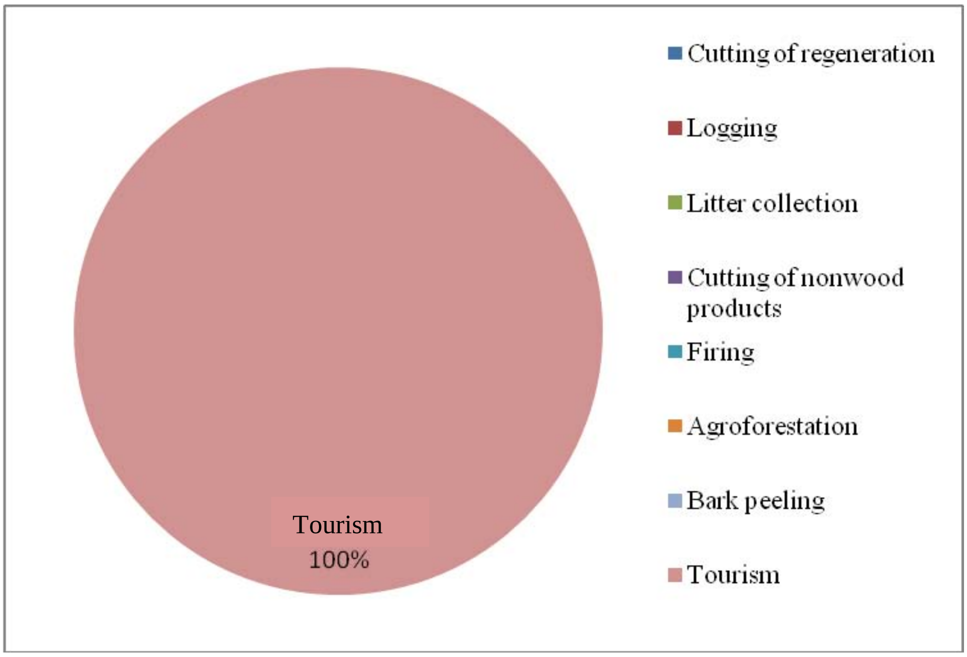


Fig. 6 Share (%) of each disturbance category on the sample plots of the less disturbed zone

Local people collect fuel wood through entering the eco-park area illegally and they are engaged in logging also (Photograph 3). Some trees were found damaged by bark peeling (Photograph 2). Local people peel the bark of tree species like *Dehasia kuruzii* and *Holarrhena antidysenterica* for making medicine against mosquito. They were engaged in agro forestation in the disturbed zones and planted betel leaf, cucurbits along with fruits, chilly etc. Some trees were affected with fire as visitors in the study area make the burning unintentionally by throwing cigarettes (Photograph 1). Fewer trees were found in that area. But tall grasses were found more at the fire affected area. Local people collect those tall grasses as fuel wood purpose (Photograph 3). It was observed that during the fuel wood collection, they cut saplings also and collect it to sell in the market. Streams coming down from the hills are a source of beauty for the visitors. Each year tourists come and few of them visit the streams even there is no well constructed road there. From (Fig. 5) it can be observed that in the disturbed zone logging had the highest share (26%) whereas cutting of non wood products had the second highest share (23%) among other disturbances. Tourism (16%) and cutting of regeneration (17%) have also remarkable share among other disturbances. In the less disturbed zone, only tourism was observed as disturbance and it occupied 100 % share (Fig. 6).

Some problems were observed personally which are listed below:

- Fire protection is the major threat for Eco-park. For controlling fire, there exists no logistic support in the eco-park. Inadequate water supply and less supporting staffs are the basic causes for fire extreme.
- There are very less facilities for enjoying the natural view of eco-park inside the area.
- Local people are responsible for most disturbances inside the park. As they don’t have other alternatives so they are engaged in collecting products from the eco-park everyday which lead to the slow destruction of the area.

There are problems in administration as well which were realized by talking with staffs from the eco-park

- Inadequate number of supporting staffs in the Sitakund Botanical Garden and Eco-park is the main problem for the park performance.
- This park is used as a public recreational place, so every day different types of visitors come for recreation. So availability of toilet, water supply, refreshment purposes are very essential. But due to fund crisis, facilities for these are very less which influence the proper maintenance of the park.

Photograph 1 Effect of fire in disturbed zone

Photograph 2 Bark peeling for making medicine against mosquito

Photograph 3 Local people are collecting tall grasses and saplings from the disturbed zone

Photograph 4 Present condition of the less disturbed zone

Photograph 5 Water stream passing through the less disturbed zone

4. 2 Composition and Species Richness

A total number of 109 plant species belonging to 43 families were recorded as from which 93 are of natural origin, from that 66 were identified as tree species, 9 as shrub species and 18 as climbers and the rest as planted tree species (Table 5, Table 6 & Table 7). From the total area of 1.570 ha about 0.628 ha were sampled from the disturbed zone and 0.942 ha from the less disturbed zone. Table 8 represents the lists of tall grasses found in the disturbed zone.

Table 5 List of tree species composition and family recorded in the eco-park

Species Code	Family	Local Name	Scientific Name	Origin
1	Leguminosae	Akashmoni	*Acacia auriculiformis*	Planted
2	Euphorbiaceae	Amloki	*Emblica officinalis*	Planted
3	Caesalpinieae	Ashok	*Saraca indica*	Planted
4	Tiliaceae	Asar	*Grewia microcos*	Natural
5	Bombacaceae	Bonshimul	*Salmalia insignis*	Natural
6	Rhamnaceae	Bonboroi	*Zizyphus oenoplea*	Natural
7	Moraceae	Borta	*Artocarpus lacucha*	Natural
8	Fagaceae	Batna	*Quercus spicata*	Natural
9	Caesalpinieae	Bohera	*Terminalia belerica*	Planted
10	Bignoniaceae	Boropata	*Haplophragma adenophyllum*	Natural
11	Lythraceae	Bandorhola	*Duabanga grandiflora*	Natural
12	Malvaceae	Boxbadam	*Sterculia foetida*	Natural
13	Lythraceae	Bonjarul	*Lagerstroemia indica*	Natural
14	Papilionaceae	Bogamedula	*Taphrosia candida*	Natural
15	Apocynaceae	Chatian	*Alstonia scholaris*	Natural
16	Mimosaceae	Chakkua koroi	*Albizzia chinensis*	Planted
17	Bignoniaceae	Dharmara	*Stereospermum chelonioides*	Natural
18	Moraceae	Dumur	*Ficus hispida*	Natural
19	Verbenaceae	Gamer	*Gmelina arborea*	Planted
20	Burseraceae	Gutgutya	*Bursera serrata*	Natural
21	Burseraceae	Giolvadi	*Garuga pinnata*	Natural
22	Mrytraceae	Guava	*Psidium guajava*	natural
23	Vaticeae	Godahorina	*Vitis glabrata*	Natural
24	Vitaceae	Harjora	*Cissus quadrangularis*	Natural
25	Dilleniaceae	Hargoja	*Dillinia pentagyna*	Natural
26	Rubiaceae	Haldu	*Adina cordifolia*	Natural
27	Sapindaceae	Horina gota	*Aphania danura*	Natural
28	Mimosaceae	Ipil-ipil	*Leucaena leucocephala*	Planted
29	Papilionaceae	Junguriya	*Derris robusta*	Natural
30	Ulmaceae	Jibon	*Trema orientalis*	Natural
31	Lythraceae	Jarul	*Lagerstroemia speciosa*	Natural
32	Anacardiaceae	Jongli Amra	*Spondias pinnata*	Natural
33	Theaceae	Konok	*Schima walliichii*	Planted
34	Myrtraceae	Kalojam	*Syzygium cumini*	Natural
35	Apocynaceae	Kuruch	*Holarrhena antidysenterica*	Natural
36	Palmaceae	Khejur	*Phoenix sylvestris*	Natural
37	Leguminosae	Khair	*Acacia catechu*	Planted
38	Apocynaceae	Katmaloti	*Tabernaemontana dichotoma*	Natural

Species Code	Family	Local Name	Scientific Name	Origin
39	Bignoniaceae	Kanaidinga	*Oroxylum indicum*	Natural
40	Euphorbiaceae	Lalbura	*Macaranga dinticulata*	Natural
41	Meliaceae	Mehogony	*Swietenia macrophylla*	Planted
42	Caesalpinieae	Minjiri	*Cassia siamea*	Planted
43	Lauraceae	Manda	*Dehasia kuruzii*	Natural
44	Meliaceae	Neem	*Azadirachta indica*	Planted
45	Myrtaceae	Putijam	*Syzygium fruticosum*	Natural
46	Lauraceae	Pichla-menda	*Litsea sebifera*	Natural
47	Piperaceae	Pipul	*Piper longam*	Natural
48	Meliaceae	Royna	*Aphanamixis polystachya*	Natural
49	Mimosaceae	Raintree	*Samanea saman*	Natural
50	Sapindaceae	Rita	*Sapindus mukorossi*	Natural
51	Verbenaceae	Shegun	*Tectana grandis*	Planted
52	Mimosaceae	Silkoroi	*Albizzia procera*	Natural
53	Dipterocarpaceae	Sal	*Shorea robusta*	Planted
54	Malvaceae	Shimul	*Bombax ceiba*	Natural
55	Caesalpinieae	Sonalu	*Cassia fistula*	Natural
56	Burseraceae	Silvadi	Unknown	Natural
57	Moraceae	Sheora	*Streblus asper*	Natural
58	Leguminosae	Tetua Koroi	*Albizzia odoratissima*	Natural
59	Papilionaceae	Turichandal	*Desmodium motorium*	Natural
60	Meliaceae	Toon	*Cedrela toona*	Natural
61	Sterculiaceae	Udal	*Sterculia villosa*	Natural
62		Longgota	Unknown	Natural
63		Huoirga gach	Unknown	Natural
64		Gungurigota	Unknown	Natural
65		Bolgota	Unknown	Natural
66	Euphorbiaceae	Chitki	*Phyllanthus reticulatus*	Natural
67		Security gach	Unknown	Natural
68		Thougach	Unknown	Natural
69		Tokpata	Unknown	Natural
70		Boxudal	Unknown	Natural
71		Bonpapya	Unknown	Natural
72		Kurulla	Unknown	Natural
73		Kuratanga	Unknown	Natural
74		Korda	Unknown	Natural
75		Kanisfal	Unknown	Natural
76		Kalofal	Unknown	Natural
77		Longkot	Unknown	Natural
78		Neemvadi	Unknown	Natural
79		Velva	Unknown	Natural
80	Cycadaceae	Cycas	*Cycas pectinata*	Natural
81	Podocarpaceae	Banspata	*Podocarpus neriifolia*	Planted
82	Sapotaceae	Mahua	*Madhuca indica*	Planted

Table 6 List of shrub species family, local and scientific name recorded in the eco-park

Family	Local Name	Scientific Name
Solanaceae	Ahorshogonda	*Withania coagulans*
Flacourtiaceae	Boichi	*Flacourtia indica*
Verbenaceae	Bormala	*Callicarpa macrophylla*
Costaceae	Keu	*Costus speciosus*
Rubiaceae	Shetorongon	*Ixora parviflora*
Apocynaceae	Shorpogonda	*Rauwolfia serpentina*
	Batik	Unknown (1)
	Koshgoda	Unknown(2)
Apocynaceae	Kathmaloti	*Tabernaemontana dichotoma*

Table 7 List of climber species family, local and scientific name recorded in the eco-park

Family	Local Name	Scientific Name
Compositae	Asam lata	*Mikania cordata*
Liliaceae	Kumari lata	*Smilax macrophylla*
Asclepiadaceae	Dugdho lata	*Doemia extensa*
Rubiaceae	Gondovadali	*Paedoria foetida*
Combretaceae	Guccholata	*Calycopteris floribunda*
Araceae	Hatirlada	*Pothos scandens*
Liliaceae	Shotomuli lata	*Asparagus racemosus*
Leguminosae	Katapanlata	*Derris trifoliata*
Fabaceae	Nata lata	*Mucuna monosperma*
Acanthaceae	Sadagonto	*Thunbergia grandiflora*
Oleaceae	Pahari Jui	*Jasminum angustifolium*
Cucurbitaceae	Pahari Kakrol	Unknown 1
	Nilgonto	Unknown 2
	Rubber lata	Unknown 3
	Mar lata	Unknown 4
	Huoirgalata	Unknown 5
	Koroilata	Unknown 6
	Koairja lata	Unknown 7

Table 8 Lists of tall grasses found in the disturbed zone

Local Name	Scientific Name	Uses
Balansa	*Narenga fallax*	Fuel wood
Khagra/Kash	*Saccharum spontaneum*	As fodder during scarcity, also as fuelwood in sugarcane industry in local area
Jharu	*Thrysanalaena maxima*	To make broom (a cleaning implement for sweeping)
Sungrass	*Imperata cylindirca*	Fuel wood
Nal	*Erianthes rivenae*	Fuel wood

From the total number of tree and shrub species was 58 were in the height range (0 - 0.5) m, 50 in the height range (0.5 - 2) m, 42 in the range (> 2 m < 6 cm dbh) and 56 for trees (> 6 cm dbh) in the less disturbed zone whereas in case of disturbed zone, it was 39 and 7 for the height range (0 - 0.5) m, 39 and 6 for (0.5 - 2) m, 37 and 6 for (> 2 m < 6 cm dbh) and 47 for trees (> 6 cm dbh) (Table 9). In case of disturbed zone, naturally regenerating plant species were less and there were some planted tree species. Total number of climber species was 13 and 14 for the less disturbed and disturbed zone respectively (Table 9). Within the height range (0 - 0.5 m), 33 tree species and 7 shrub species were common to both zones whereas for the height range (0.5 - 2) m, 29 tree species and 6 shrub species were common. For height range (> 2 m < 6 cm dbh), 18 tree species and 6 shrub species and for trees (> 6 cm dbh), 32 tree species were common to both zones (Table 9). 9 climber species were common to both zones. Average herb coverage percentage was 40% in less disturbed zone and 67% in disturbed zone respectively.

Table 9 Species richness and overlapping of plant species and percentage coverage of herb between two zones

Height Range of Plants	**Species Richness**				**Species Overlapping**	
	Less Disturbed		Disturbed		Less Disturbed-Disturbed	
	Tree	Shrub	Tree	Shrub	Tree	Shrub
(0 - 0.5) m	50	8	39	7	33	7
(0.5 - 2) m	43	7	39 (35+4*)	6	29	6
(> 2 m < 6 cm dbh)	35	7	37 (24+13*)	6	18	6
Trees (> 6 cm dbh)	56		47 (32+15*)		32	
Climbers	13		14		9	
Herbs	40		67			

* including exotic species

Table 10 ANOVA for the comparison of species richness between zones

Tree Parameter	**Height Range**	**ANOVA**	
		F	**P**
Species Richness	(0 - 0.5) m	8.25	0.006
	(0.5 - 2) m	0.011	0.91
	(>2 m < 6 cm dbh)	41.88	0.000
	Trees (> 6 cm dbh)	55.90	0.000

From Table 10, it can be observed that both zones showed significant difference at $p < 0.05$ for species richness at all ranges except (0.5 - 2) m. As the Levine's test of homogeneity criteria (equal variances assumed) for unequal sample sizes were fulfilled, it was possible to compare species richness between zones with one way ANOVA.

Species area curve indicates that in the disturbed zone, the total number of species was increasing very slowly with the increasing number of samples (Fig. 7). After 10 plots, very small number of species was identified. In the less disturbed zone, total number of species was increasing up to 20 plots but after that not so many additional species were identified.

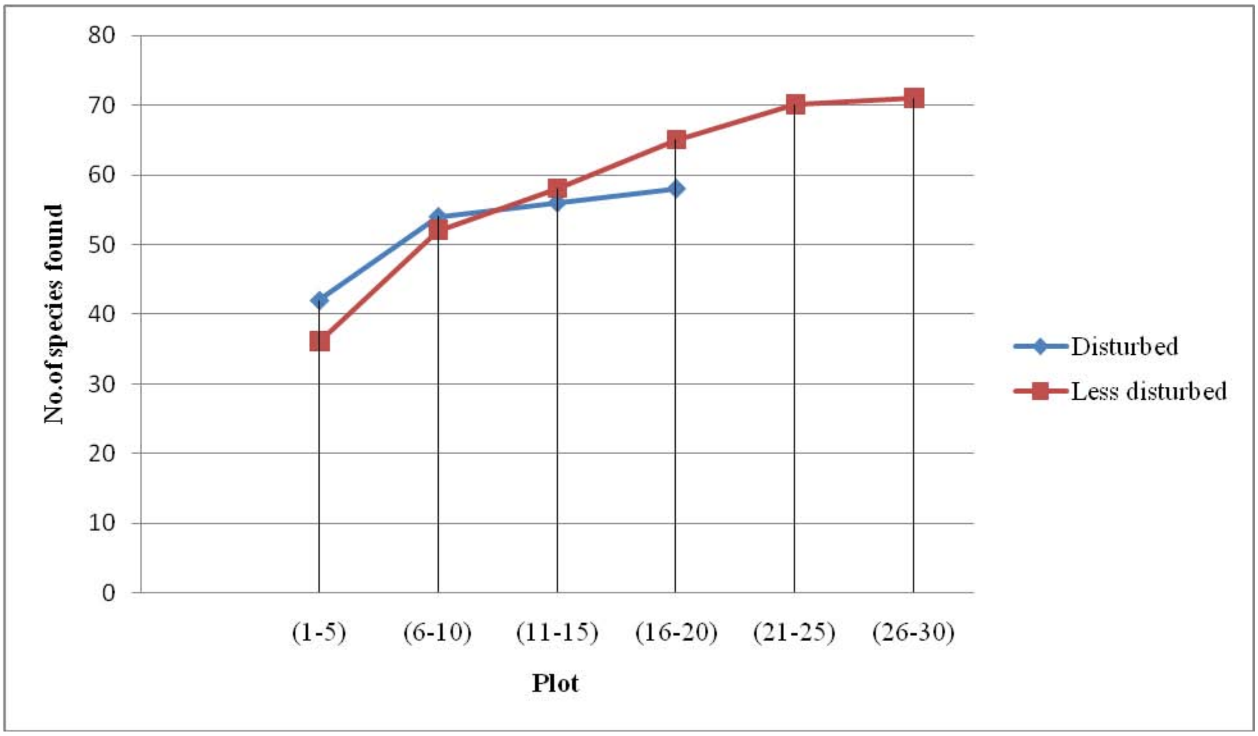


Fig. 7 Species area curve for the disturbed and less disturbed zone

4. 3 Diversity Indices and Disturbances

Diversity index was calculated only for species with natural origin as in disturbed zone there were some planted species as well. The Shannon-Wiener index was highest (3.78) in the less disturbed zone for the height range (0 - 0.5) m whereas the value was 3.72 for the trees (> 6 cm dbh), 3.35 for (0.5 - 2) m height range and 3.70 for the height range (> 2 m < 6 cm dbh) (Table 11). So it can be concluded that the vegetation for the height range (0 – 0.5) m was more diversified than other height ranges of plants. Where as in the disturbed zone, for the (0 - 0.5) m and (0.5 - 2) m range, the vegetation was more diversified during regeneration stage. But for height range (>2 m < 6 cm dbh) and trees (> 6 cm dbh), the diversity index value was less which is an indication for the less diversified vegetation for that range.

In the less disturbed zone, dominance index was lowest in (0 - 0.5) m range compared to other height ranges (Table 11). So it can be concluded that this range had more diversity. In the same time, for the disturbed zone, the value was lowest from (0 - 0.5) m, (0.5 - 2) m and (> 2 m < 6 cm dbh) compared to trees (> 6 cm dbh) range. So it can be explained that plants at their regeneration stage were more diverse.

Eveness index indicates that the total number of individuals was distributed more evenly among all possible species in disturbed zone at all ranges (Table 11). In the less disturbed zone, the species were more evenly distributed in all height ranges except for (0.5 -2) m range which showed less even distribution (Table 11)

Table 11 Shanon -Weiner Index of Tree Diversity, Index of Dominance and Evenness Index in two zones

Index	Height Range	Less Disturbed	Disturbed
Diversity Index	(0 - 0.5) m	3.78	3.7
	(0.5 - 2) m	3.35	3.68
	(> 2 m < 6 cm dbh)	3.7	3.37
	Trees (> 6 cm dbh)	3.72	3.44
Dominance Index	(0 - 0.5) m	0.018	0.027
	(0.5 – 2) m	0.028	0.026
	(> 2 m < 6 cm dbh)	0.025	0.035
	Trees (> 6 cm dbh)	0.021	0.037
Evenness Index	(0 - 0.5) m	0.93	0.96
	(0.5 – 2) m	0.85	0.99
	(> 2 m < 6 cm dbh)	0.99	0.99
	Trees (> 6 cm dbh)	0.92	0.99

Table 12 Relationship between disturbance index with species richness, density (N/ ha) and basal area (m^2 / ha) in two zones

Value of Coefficient	Relationship between	(0 – 0.5) m	(0.5 - 2) m	(> 2 m < 6 cm dbh)	Trees (> 6 cm dbh)
r value	Disturbance Index Species Richness	-0.39^{**}	-0.01^{ns}	-0.48^{**}	-0.62^{**}
r value	Disturbance Index Density	0.64^{**}	0.08^{ns}	-0.43^{**}	-0.72^{**}
r_s value	Disturbance Index Basal Area				-0.69^{**}
** ($p < 0.01$), ns (non significant) n=50 r = Pearson's value , r_s = Spearman's value					

For the correlation between disturbance index with species richness and density (N/ha), the relationship was tested with the Pearson's (*r*) correlation. There was a relatively weak negative relationship between the disturbance index and the density (N/ha) of trees (> 6 cm dbh) and (> 2 m < 6 cm dbh) range and species richness for trees of all ranges except (0.5 - 2) m range which showed no significant relationship (Table 12). For density (N/ha) at regeneration level from (0 - 0.5) m height range a modest positive relationship was found with disturbance index whether height range from (0.5 - 2) m showed no significant relationship. Using Spearman's (r_s) correlation, basal area (m^2/ha) of trees (> 6 cm dbh) was found to be negatively correlated with disturbance index (Table 12).

4. 4 Community Structure

Flacourtia indica had the highest density (N/ha) in the disturbed zone at the height range (0 - 0.5) m whereas in the less disturbed zone, *Ixora parviflora* occupied the highest density (N/ha). For the height range (0.5 -2) m, Batik had the highest density (N/ha) in the disturbed zone but in the less disturbed zone, *Withania coagulans* had the highest density (N/ha). Batik showed maximum density (N/ha) for the height range (>2 m < 6 cm dbh) for both zones (Table 13).

Fig. 8 indicates that from (0 - 0.5) m range, there were no planted species in the disturbed zone. For the range (0.5 - 2) m and trees (> 6 cm dbh), the mean density was less than the range (> 2 m < 6 cm dbh).

Table 13 Density (N/ha) of shrubs (Mean ± SD) in two zones

Botanical Name	Disturbed Zone			Less Disturbed Zone		
	(0 - 0.5) m	(0.5 - 2) m	(> 2 m < 6 cm dbh)	(0 – 0.5) m	(0.5 - 2) m	(> 2 m < 6 cm dbh)
Withania coagulans	6000±8825	437±786	93±201	3000±4679	833±1521	72±180
Flacourtia indica	6250±10243	125±625	78±232	1833±5166	41±260	10±68
Callicarpa macrophylla	1250±3931	62±312	15±83	666±2132	83±360	10±68
Costus speciosus	250±1118	-	-	333±1268	-	20±94
Ixora parviflora	5500±11798	125±426	46±133	7166±7506	500±831	62±201
Rauwolfia serpentina	-	-	-	166±912	-	-
Batik	3250±4940	1000±1207	140±417	2833±4086	458±741	177±254
Koshgoda	4500±8094	357±773	109±203	2833±3639	416±737	145±301
Tabernaemontana dichotoma	-	-	-	-	41±260	-

(-) = Absent

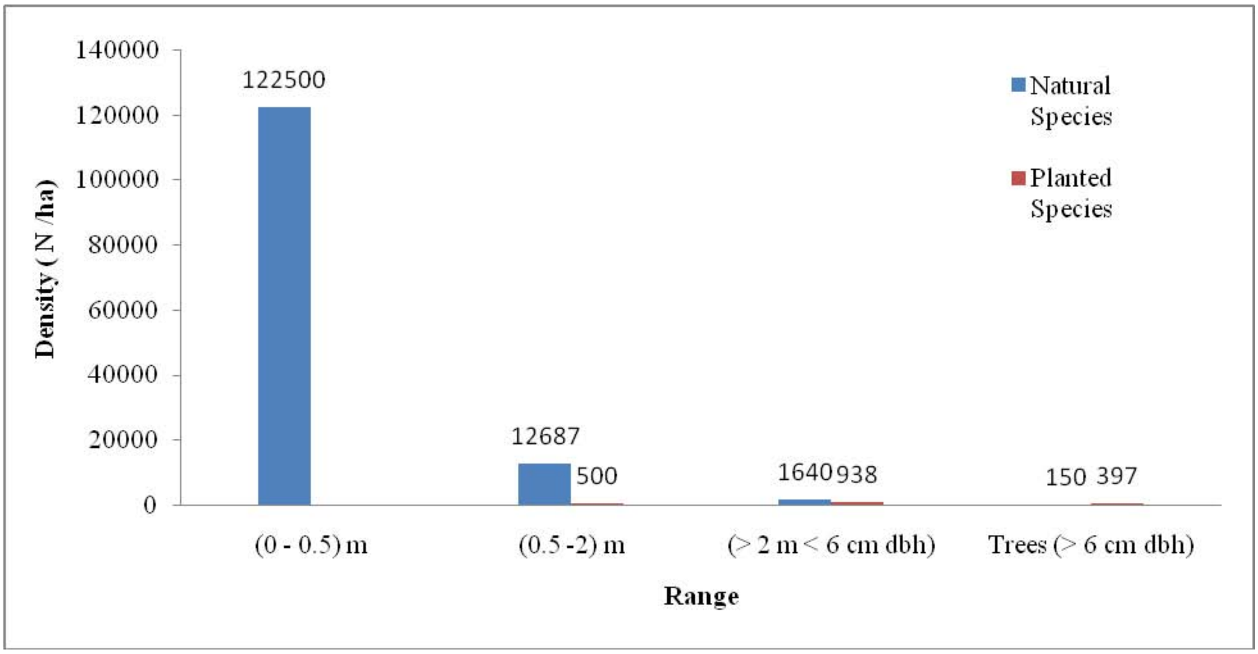


Fig. 8 Density (N/ ha) of tree species from natural origin and plantation in the disturbed zone

Table 14 Mean and standard deviation for density (N/ha), basal area (m^2/ ha) and Important Value Index (IVI) of the enlisted trees (> 6 cm dbh) in the two zones (*indicates planted species)

Botanical Name	Density (N/ha)		Basal Area (m2/ha)		IVI	
	D	LD	D	LD	D	LD
*Acacia auriculiformis**	19.1±31.6		0.06±0.1		8.26	
Artocarpus lacucha	3.1±9.8	22.2±38.8	0.03±0.01	0.25±2.08	2.51	9.30
Alstonia scholaris		2.1±11.6		0.03±0.2		1.08
*Albizzia chinensis**	3.1±14.2		± 0.07		1.55	
Aphania danura		4.2±11.01		0.03±0.10		2.11
Adina cordifolia	17.5±26.3	14.8±24.3	0.09±0.15	0.11±0.21	9.87	6.35
*Acacia catechu**	4.7±11.6		0.01±0		2.82	
*Azadirachta indica**	6.3±13.07		0.01±0.04		3.68	
Aphanamixis polystachya		4.2±10.8		0.02±0.08		1.75
Albizzia procera	17.5±28.2	3.1±9.7	0.18±0.31	0.20±1.15	12.2	3.74
Albizzia odoratissima	7.9±20.3	22.2±42.3	0.15±0.44	0.40±0.94	7.75	10.93
Bombax ceiba	9.5±18.1	14.8±26.9	0.11±0.24	0.15±0.33	7.7	6.8
Bursera serrata	3.1±14.2	11.6±29.06	0.01±0.06	0.08±0.29	1.49	4.42
*Cassia siamea **	15.9±19.33		0.05±0.06		8.88	
Cassia fistula	6.3±16.66	7.4±21.3	0.05±0.15	0.07±0.19	4.36	3.09
Cedrela toona		1.0±5.82		0.1±0.02		0.46
Cissus quadrangularis		6.3±12.9		0.03±0.1		3.0
Duabanga grandiflora		2.1±11.63		0.01±0.07		0.72
Dillinia pentagyna		21.2±46.8		0.18±0.46		7.61
Dehasia kuruzii	20.7±31.4	44.5±53.08	0.11±0.23	0.35±0.43	11.7	16.0
Desmodium motorium		1.0±5.8		0.1±0.01		0.45
*Emblica officinalis**	11.1±21.3		0.03±0.07		5.57	
Ficus hispida	15.9±19.3	46.7±79.3	0.10±2.19	0.36±0.65	10.40	15.03
Grewia microcos	6.3±13.07	32.9±41.6	0.04±0.11	0.20±0.25	4.60	11.8

Botanical Name	Density (N/ha)		Basal Area (m2/ha)		IVI	
	D	LD	D	LD	D	LD
*Gmelina arborea**	35.0±53.5	11.6±29.06	0.01±0.06	0.08±0.29	1.49	4.42
Garuga pinnata	23.8±59.2	33.9±49.5	0.19±0.48	0.32±0.46	13.2	13.4
Haplophragma adenophyllum	1.5±7.1	1.0±5.8	0.01±0.01	0.01±0.02	0.91	0.46
Holarrhena antidysenterica	68.4±104.5	109.3±92.9	0.36±0.61	0.76±0.91	28.5	31.59
Lagerstroemia indica		3.1±17.4		0.01±0.08		0.87
*Leucaena leucocephala**	15.9±24.2		0.06±0.10		8.15	
Lagerstroemia speciosa	1.5±7.1	2.1±7.9	0.02±0.12	0.02±0.09	1.63	1.13
Litsea sebifera	1.5±7.12	4.2±10.8	0.01±0.05	0.04±0.12	1.13	2.22
Macaranga dinticulata	3.1±14.2	19.1±37.3	0.01±0.06	0.29±0.71	1.49	9.20
*Madhuca indica**	3.1±9.8		0.009±0.03		1.83	
Oroxylum indicum	7.9±17.5	15.9±31.5	0.03±0.08	0.11±0.25	4.49	5.83
Piper longam		3.1±9.7		0.01±0.05		1.42
Phyllanthus reticulatus	1.5±7.1	20.1±24.07	0.008±0.03	0.18±0.28	1.01	9.11
Quercus spicata	3.1±14.2	4.2±17.08	0.01±0.05	0.03±0.13	1.44	1.86
*Saraca indica**	4.7±11.6		0.01±0.03		2.76	
Salmalia insignis		1.0±5.7		0.01±0.07		0.58
Sterculia foetida		2.1±11.6		0.04±0.22		1.15
Stereospermum chelonioides	39.8±48.3	48.8±60.8	0.23±0.31	0.33±0.47	20.20	16.62
*Schima wallichii**	1.5±7.1		0.005±0.03		0.94	
Syzygium cumini	1.5±7.1	9.5±26.2	0.02±0.1	0.05±0.16	1.43	3.42
*Swietenia macrophylla**	14.3±31.8		0.06±0.16		7.14	
Syzygium fruticosum	11.1±23.7	60.5±96.95	0.08±0.17	0.47±0.76	6.89	19
Samanea saman		6.3±21.1		0.03±0.13		2.13
Sapindus mukorossi		3.1±9.7		0.01±0.05		1.42
*Shorea robusta**	17.5±28.2		0.06±0.11		8.12	
Streblus asper	3.1±9.8	13.8±26.8	0.01±0.04	0.08±0.16	1.94	5.44
Sterculia villosa	3.1±9.8	8.4±23.1	0.03±0.15	0.06±0.17	2.70	3.05
Taphrosia candida		1.0±5.8		0.01±0.08		0.61
*Terminalia belerica**	23.8±99.8		0.13±0.22		12.7	
Trema orientalis	12.7±19.05	24.4±44.6	0.06±0.1	0.17±0.25	7.64	9.53
*Tectona grandis**	12.7±31.6		0.05±0.14		5.85	
Vitis glabrata	12.7±24.01	19.1±42.5	0.07±0.14	0.14±0.2	6.86	8.59
Silvadi		3.1±9.71		0.03±0.1		1.67
Longgota		1.0±5.82		0.003±0.01		0.45
Huoirga gach		14.8±26		0.16±0.35		6.98
Gungurigota	11.1±18.7	11.6±31.3	0.10±0.23	0.10±0.29	8.10	4.65
Bolgota		1.0±5.8		0.005±0.02		0.48
Tokpata	1.5±7.1	1.0±5.8	0.006±0.03	0.006±0.03	0.97	0.50
Boxudal	1.5±7.1	12.7±52.4	0.02±0.1	0.11±0.49	1.51	4.05
Kurulla	35.0 ±35.6	29.7±45	0.23±0.3	0.18±0.33	19.7	10.26
Kuratanga		3.1±9.7		0.02±0.09		1.57
Korda		2.1±8.08		0.02±0.09		1.14
Kanisfal	1.5±7.1	5.3±4.4	0.01±0.05	0.04±0.16	1.10	2.44
Kalofal		5.3±4.4		0.05±0.22		2.61
Longkot		2.1±8.08		0.01±0.06		1.04
Neemvadi	1.5±7.1	14.8±21.2	0.02±0.09	0.15±0.33	1.41	6.62
Velva		4.2±18.2		0.04±0.2		1.7

The mean basal area (m^2/ ha) was 3.29 and 6.80 respectively in the disturbed and less disturbed zone. *Holarrhena antidysentirica* (IVI=28.5) was the dominant species in the disturbed (D) zone followed by *Stereospermum chelonioides* (IVI=20.25), Kurulla (IVI=19.73), *Garuga pinnata* (IVI=13.24), *Albizzia procera* (IVI=12.21), *Dehasia kuruzii* (IVI=11.75). In the less disturbed (LD) zone *Holarrhena antidysentirica* (IVI=31.59) was highly dominant also followed by *Syzygium fruticosum* (IVI=18.99), *Stereospermum chelonioides* (IVI=16.62), *Dehasia kuruzii* (IVI=16), *Ficus hispida* (IVI=15.03), *Garuga pinnata* (IVI=13.47) (Table 14).

Table 15 Differences between the zones according to the density (N/ha) of naturally originated species and disturbance index

Tree Parameter	Height Range	Less Disturbed Zone	Disturbed Zone	ANOVA	
				F	P
Density (N/Ha)	(0 - 0.5) m	72333±19152	122500±25210	63.827	0.000
	(0.5 – 2) m	11291±3156	12687±3095	2.38	0.129
	(> 2 m < 6 cm dbh)	2770±882.86	1640±581		
	Trees (> 6 cm dbh)	790±151	150±134	97.86	0.000
Disturbance Index		1.66±53.8	95±44.08	134.37	0.000

The less disturbed and disturbed zone were significantly different in case of density (N/ha) for the height range (0 - 0.5) m and trees (> 6 cm dbh) at $p < 0.05$ whereas the height range from (0.5 - 2) m did not show any significant difference. For the height range (> 2 m < 6 cm dbh), data did not fulfill the condition of Levine's test of homogeneity so ANOVA test could not be performed. The mean density of regeneration from (0 - 0.5) m range was significantly higher in the disturbed zone compared to less disturbed zone. For the disturbance index, both zones showed significant difference at $p < 0.05$ (Table 15).

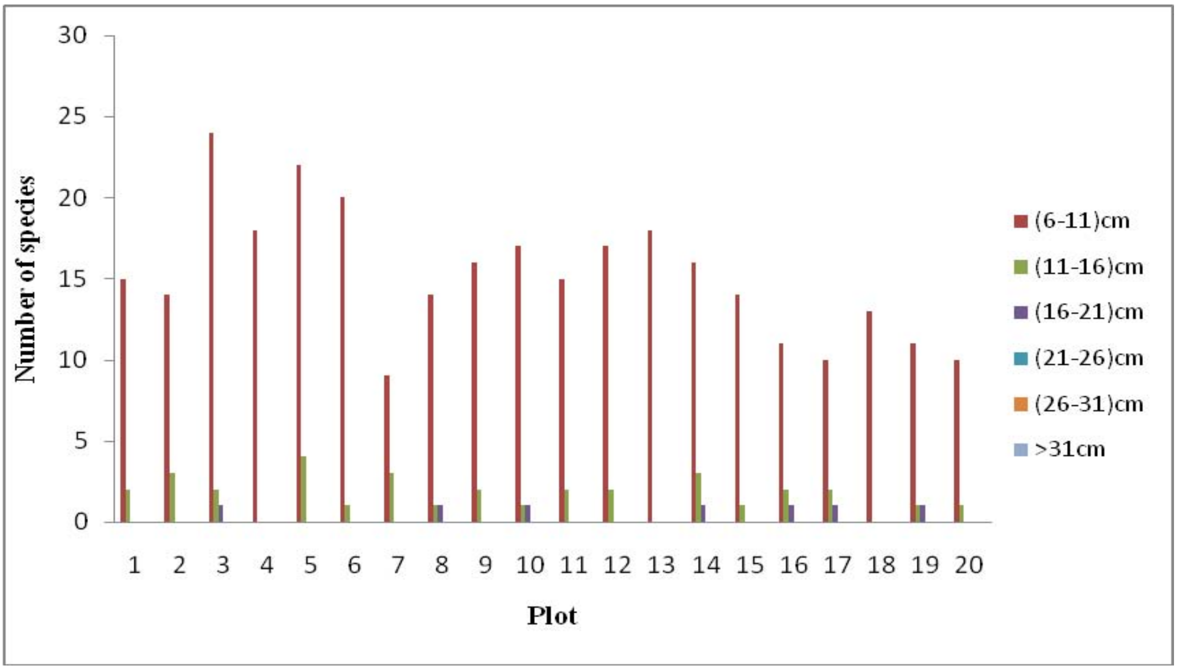


Fig. 9 Number of species with different diameter distribution in different plots for trees (> 6 cm dbh) in the disturbed zone

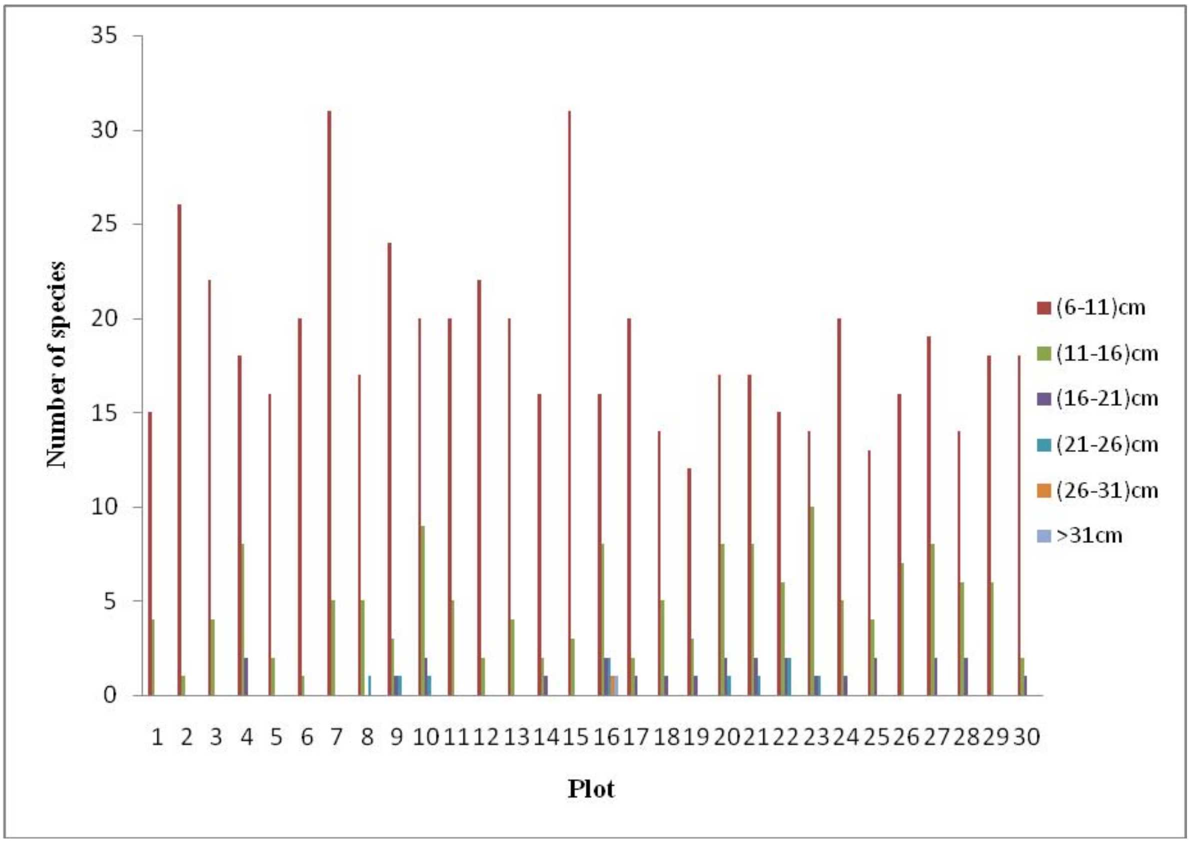


Fig. 10 Number of species with different diameter distribution in different plots for trees (> 6 cm dbh) in the less disturbed zone

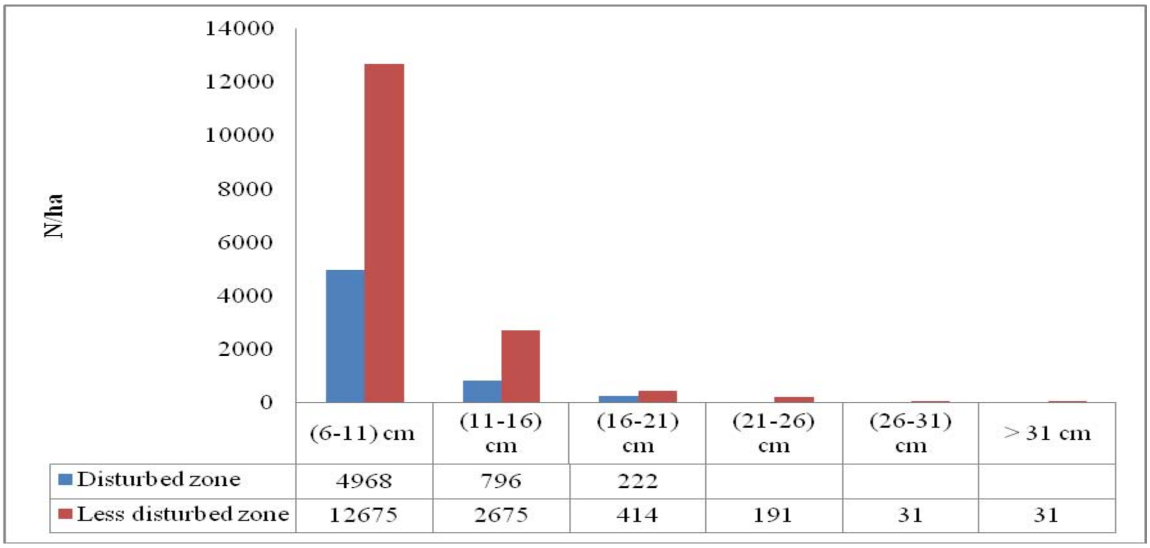


Fig. 11 Density (N/ ha) of trees (> 6 cm dbh) with different diameter (cm) distribution in both zones

Fig. 9 depicts the general diameter distribution considering the number of trees (> 6 cm dbh) of all individual plots taken from the disturbed zone. Number of species were found higher at the range from (6-11) cm on all plots. Very few species were found within the range from (16-21) cm. *Garuga pinnata* showed the highest dbh (19.5 cm) in the disturbed zone.

Fig. 10 illustrates the general diameter distribution considering the number of trees (> 6 cm dbh) of all individual plots taken from the less disturbed zone. Most of the tree species were at the range from (6-11) cm followed by others. There was remarkable number of tree species in the range (11-16) cm dbh. But very few species were found at the range (16-21) cm, (21-26) cm, (26-31) cm and dbh > 31 cm. *Albizzia procera* showed the highest dbh (32.1 cm) in the less disturbed zone.

20 plots were selected randomly from the less disturbed zone to compare the density (N /ha) of trees (> 6 cm dbh) with different diameter (cm) distribution with the disturbed zone. It is observed that with the increase of diameter (cm), density (N /ha) was decreased. In all diameter (cm) classes, density (N /ha) was found higher in the less disturbed zone compared to disturbed zone. Trees with highest diameter class (> 31 cm) were observed in the less disturbed zone (Fig. 11). In both the zones, it can be observed that density (N/ha) decreased with increase of diameter. In case of less disturbed zone, it is observed that with the increase of diameter classes like (21 - 26) cm, (26 -31) cm and (> 31 cm), density decreased.

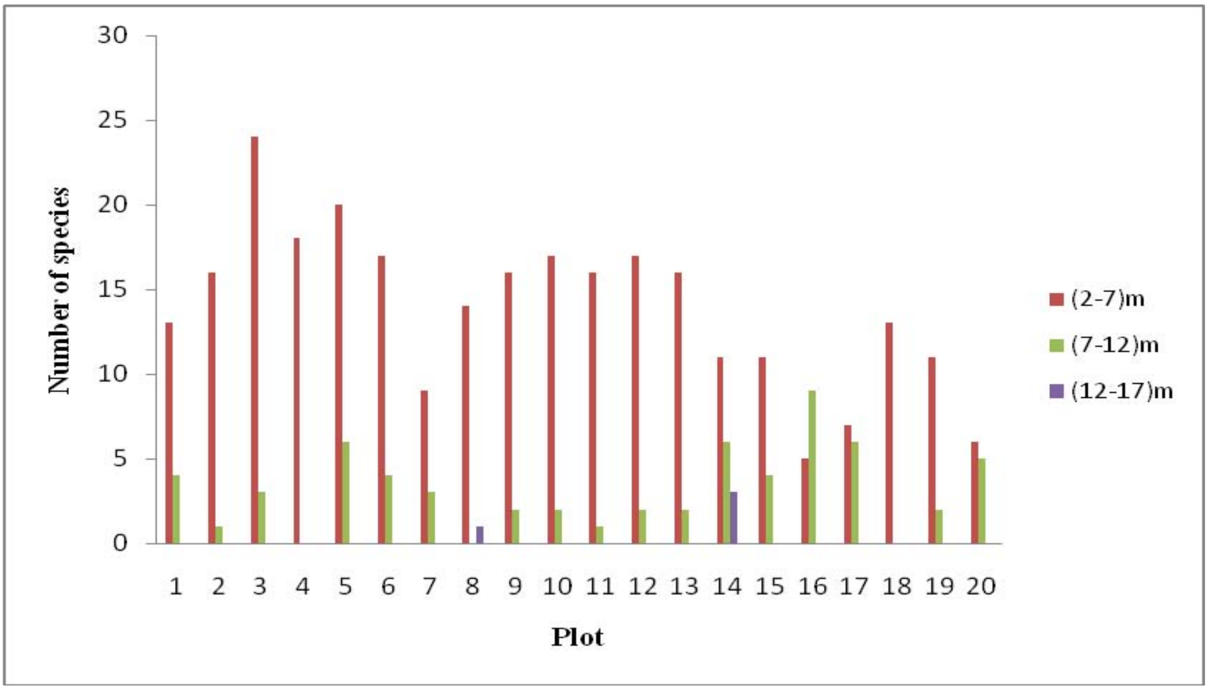


Fig. 12 Number of species with different height distribution in different plots for trees (> 6 cm dbh) in the disturbed zone

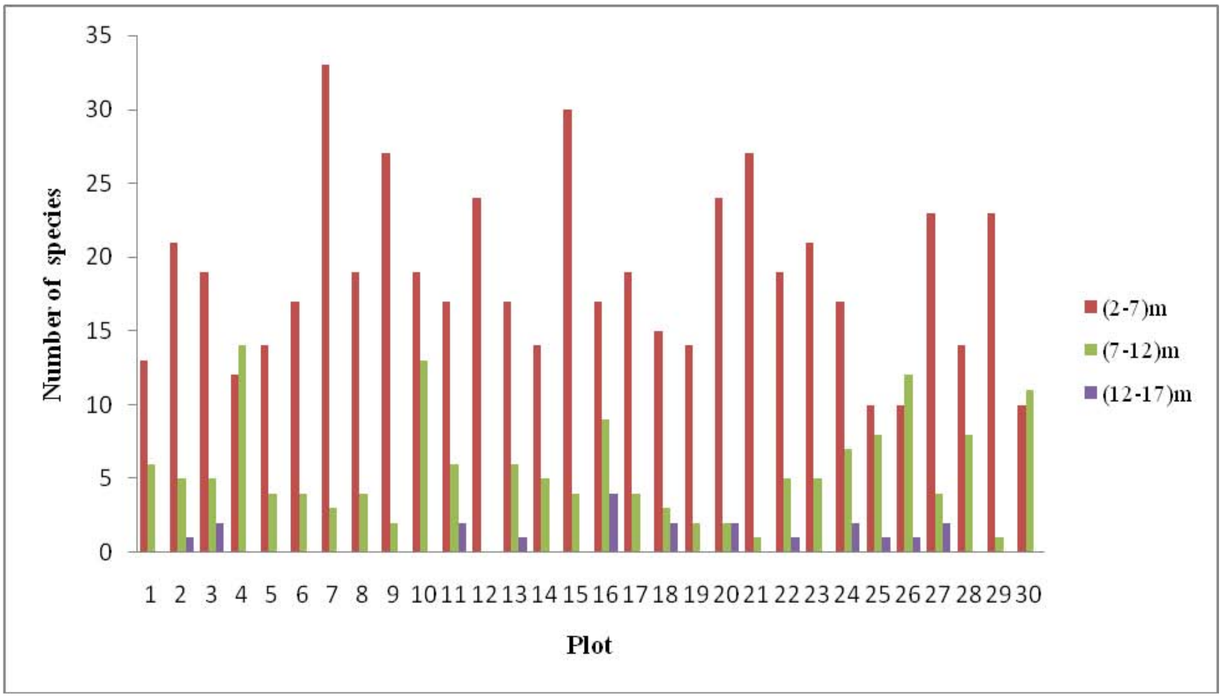
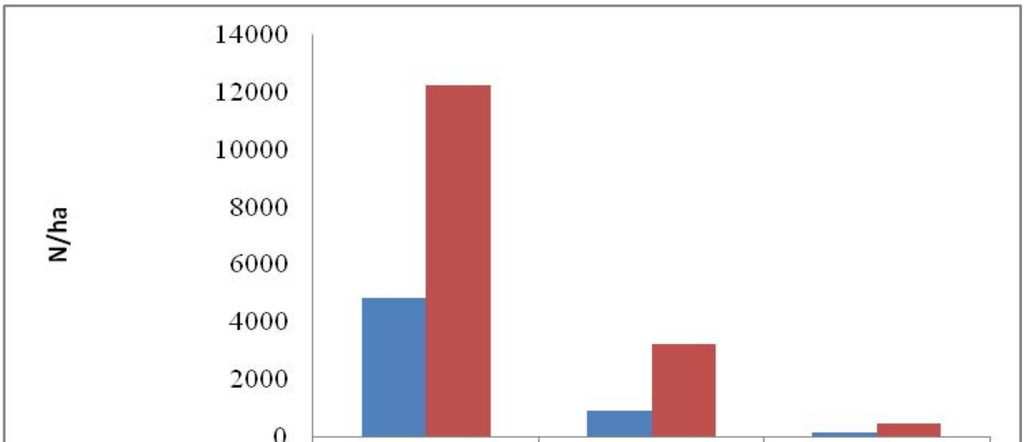


Fig. 13 Number of species with different height distribution in different plots for trees (> 6 cm dbh) in the less disturbed zone



	(2-7) m	(7-12)m	(12 - 16) m
Disturbed zone	4840	891	127
Less disturbed zone	12261	3216	445

Fig. 14 Density (N /ha) of trees (> 6 cm dbh) with different height distribution in both zones

Fig. 12 represents the height distribution considering the trees of all individual plots taken from the disturbed zone. Most of the species were at the range from (2-7) m on all the plots. A remarkable number of trees with height range (7-12) m were also present. Very few species were found within the range from (12-17) m. *Albizzia procera* showed the highest tree height (15 m) in the disturbed zone.

From Fig. 13 it is observed that in the less disturbed zone, at (2-7) m height range the maximum number of individuals of trees of all the plots were found. Tree species within (12-17) m height range were also found in some plots but the number of individuals was very few. *Albizzia procera* showed the highest diameter (32.1 cm) and height (16.2 m) in this zone.

20 plots were selected randomly from the less disturbed zone to compare the density (N /ha) of trees (> 6 cm dbh) according to different height (m) classes with the disturbed zone. It is observed that with the increase of height (m), density (N /ha) decreased. In all height (m) classes, density (N /ha) was found higher than in the less disturbed zone compared to disturbed zone (Fig. 14)

4. 5 Dominant Tree Species

Within the 6 dominating tree species in the disturbed zone, *Holarrhena antidysenterica* occupied 27% of the basal area (m^2/ha) which was the highest share and other dominant tree species were *Stereospermum chelonioides* (18%), Kurulla (17%), *Garuga pinnata* (15%), *Albizzia procera* (14%) and *Dehasia kuruzii* (9%) respectively (Fig. 15).In the less disturbed zone, *Holarrhena* *antidysenterica* comprised 29% of the basal area (m^2/ha) where as others were *Syzygium fruticosum* (18%), *Stereospermum chelonioides* (13%), *Dehasia kuruzii* (13%), *Ficus hispida* (14%), *Garuga pinnata* (13%) (Fig. 16).

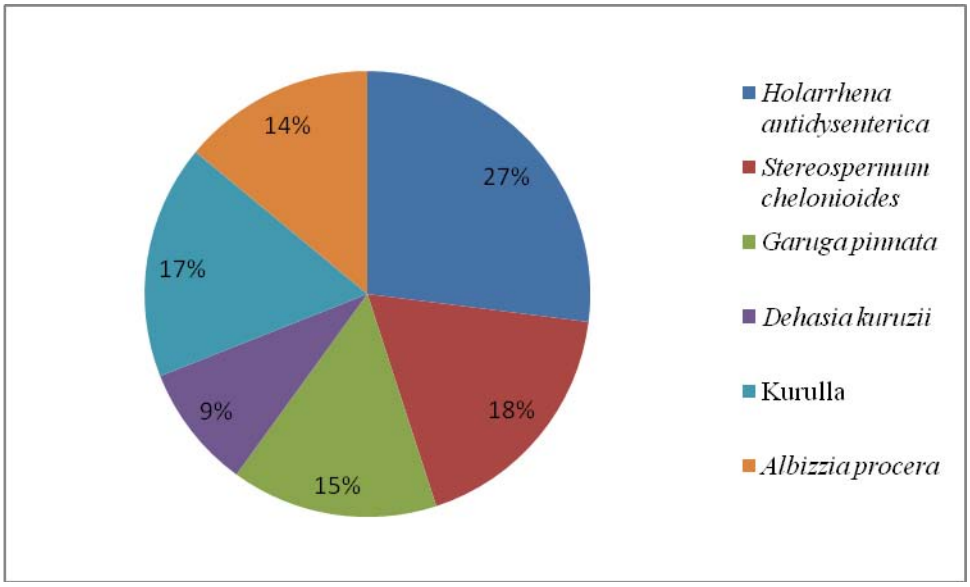


Fig. 15 According to basal area (m2/ ha) percentage of dominating tree species in the disturbed zone

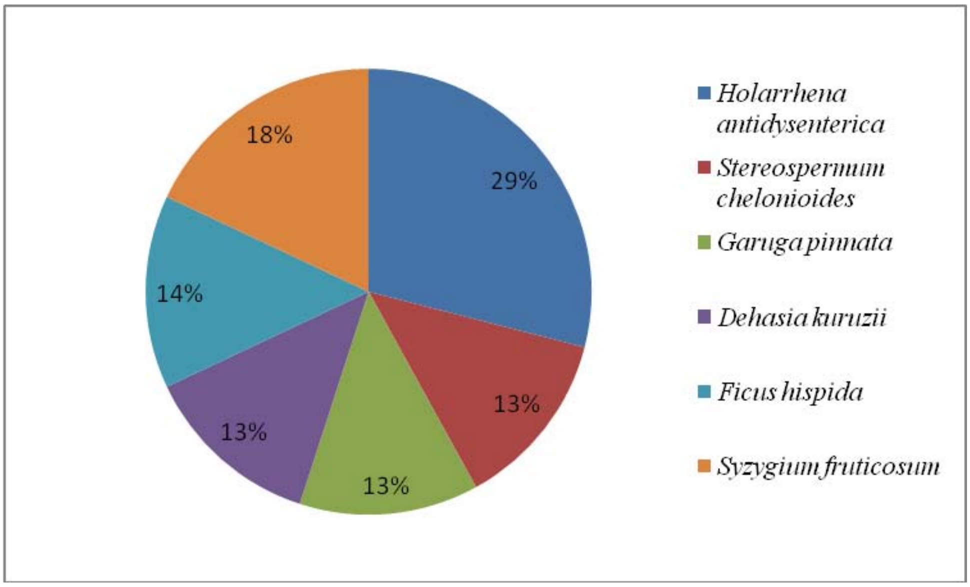


Fig. 16 According to basal area (m2/ ha) percentage of dominating tree species in the less disturbed zone

Table 16 Composition (%) of dominating tree species (natural) at regeneration stage in the disturbed zone

Species	(0 - 0.5) m	(0.5 m - 2 m)	(> 2 m < 6 cm dbh)
Holarrhena antidysenterica	43.3	49.3	31.5
Stereospermum chelonioides	13.2	10.6	0
Kurulla	4.4	9.3	10.5
Garuga pinnata	10.6	4	0
Albizzia procera	8.8	9.3	42.1
Dehasia kuruzi	19.4	17.3	15.7

Table 17 Composition (%) of dominating tree species at their regeneration stage in the less disturbed zone

Species	(0 - 0.5) m	(0.5 m - 2 m)	(> 2 m < 6 cm dbh)
Holarrhena antidysenterica	33.9	32.2	34.7
Syzygium fruticosum	15.5	23.6	19.5
Stereospermum chelonioides	4.8	9.6	11.9
Dehasia kuruzi	24.2	17.2	17.3
Ficus hispida	16.5	13.9	11.9
Garuga pinnata	4.8	3.2	4.3

Table 18 Mean Density (N /ha) of regeneration and composition (%) of tree species within the height range from (0 - 0.5) m in both zones

Species	Density (N/ha)		Percentage of Composition	
	Disturbed Zone	Less Disturbed Zone	Disturbed Zone	Less Disturbed Zone
Grewia microcos	7500	3000	7.85	5.60
Salmalia insignis	2250	-	2.35	
Zizyphus oenoplea	2000	500	2.09	0.93
Artocarpus lacucha	2500	500	2.61	0.93
Quercus spicata	3250	666	3.40	1.24
Haplophragma adenophyllum	1750	-	1.83	
Duabanga grandiflora	-	666		1.24
Lagerstroemia indica	500	-	0.52	
Taphrosia candida	1500	333	1.57	0.62
Stereospermum chelonioides	**3750**	**833**	**3.92**	**1.55**
Ficus hispida	3750	**2833**	3.92	**5.29**
Bursera serrata	250	500	0.26	0.93
Garuga pinnata	**3000**	**833**	**3.14**	**1.55**
Psidium guajava	-	166		0.31
Vitis glabrata	-	1166		2.18

Species	**Density (N/ha)**		**Percentage of Composition**	
	Disturbed Zone	**Less Disturbed Zone**	**Disturbed Zone**	**Less Disturbed Zone**
Cissus quadrangularis	1250	1833	1.30	3.42
Dillinia pentagyna	-	166		0.31
Adina cordifolia	4750	333	4.97	0.62
Aphania danura	2500	3000	2.61	5.60
Derris robusta	2000	333	2.09	0.62
Trema orientalis	750	1166	0.78	2.18
Lagerstroemia speciosa	-	166		0.31
Spondias pinnata	-	833		1.55
Syzygium cumini	1750	333	1.83	0.62
Holarrhena antidysenterica	**12250**	**5833**	**12.82**	**10.90**
Phoenix sylvestris	1000	-	1.04	
Tabernaemontana dichotoma	-	333		0.62
Oroxylum indicum	2250	1500	2.35	2.80
Macaranga dinticulata	1250	166	1.30	0.31
Dehasia kuruzii	**5500**	**4166**	**5.75**	**7.78**
Syzygium fruticosum	500	**2666**	0.52	**4.98**
Litsea sebifera	2000	333	2.09	0.62
Piper longam	250	166	0.2	0.31
Aphanamixis polystachya	-	500		0.93
Sapindus mukorossi	4000	833	4.18	1.55
Albizzia procera	**2500**	-	**2.61**	
Bombax ceiba	-	1166		2.18
Cassia fistula	-	166		0.31
Streblus asper	750	1833	0.78	3.4
Albizzia odoratissima	1750	666	1.83	1.24
Cedrela toona	-	166		0.31
Sterculia villosa	-	833		1.55
Huoirgagach	-	3000		5.60
Gungurigota	250	-	0.26	
Phyllanthus reticulatus	-	2500		4.67
Security gach	250	166	0.26	0.31
Tokpata	2000	1000	2.09	1.86
Boxudal	3000	166	3.14	0.31
Bonpapya	-	166		0.31
Kurulla	**1250**	2000	**1.30**	3.73
Kuratanga	-	833		1.55
Korda	1750	333	1.83	0.62
Kanisfal	3750	1166	3.92	2.18
Kalofal	250	166	0.26	0.31
Longkot	-	333		0.62
Neemvadi	4000	166	4.18	0.31

(-): Absent, Species with bold marked indicates dominant tree species

It is observed from Table 16 that composition varies within dominating tree species at the regeneration stage. *Holarrhena antidysenterica* occupied highest composition (43%) among other five dominating tree species at the range (0 - 0.5) m whereas *Dehasia kuruzi* occupied the second highest (19 %). From this table, it is observed that Kurulla had the lowest composition (4 %) among other dominating tree species at the range of (0 - 0.5) m. At the range (0.5 -2) m, *Holarrhena antidysenterica* and *Dehasia kuruzi* again occupied the highest (49%) and second highest (17%) composition. But at the range (> 2 m < 6 cm dbh) *Albizzia procera* occupied the highest composition (42%) whereas *Holarrhena antidysenterica* had the second highest (31.57%) composition. *Stereospermum chelonioides* and *Garuga pinnata* were absent at this range.

In case of less disturbed zone, the most dominating tree species *Holarrhena antidysenterica* showed approximately 34% composition among other dominating tree species at the range (0 – 0.5) m whereas *Dehasia kuruzi* occupied 24 % composition respectively. *Holarrhena antidysenterica* occupied highest composition e.g. 32 % and 34.74 % at the range (0.5 – 2) m and (> 2 m < 6 cm dbh) respectively. *Garuga pinnata* had lowest composition among other dominating tree species in both ranges (Table 17)

Table 18 represents the density (N/ha) of all tree species among all naturally originated tree species at the range (0 - 0.5) m in both zones. It was observed that the dominating mature tree species were not dominant at the regeneration stage except *Holarrhena antidysenterica*. Some other species have higher composition than the dominant species. *Grewia microcos* had second highest composition in the disturbed zone at the range (0 - 0.5) m. *Holarrhena antidysenterica* and *Dehasia kuruzi* had occupied the highest and second highest composition at this range in case of the less disturbed zone. So it can be concluded that the dominating mature tree species did not comprise the same importance compared with other tree species at the range (0-0.5) m.

Chapter 5 DISCUSSION

The species richness found on the study area of 50 sample plots in both zones of the Sitakund Botanical Garden and Eco-park is 109 among which 66 were identified as tree species, these findings are comparable to other studies accomplished in the same area in December 2003. Misbahuzzaman and Alam (2006) reported 63 naturally regenerating tree species at the same study area. Very few research was done on herb coverage percentage and also shrub species richness in the study area. Species richness was more in the less disturbed zone in the study area whereas in the disturbed zone, it was less. Hossain *et al*. (2004) found 64 regenerating tree species from natural forest and 40 regenerating tree species from enrichment plantation in the Baraitali Forest of Chittagong (South) Forest Division, Kadavul and Parthasarathy (1999) reported 50 tree species on 1 ha area of less disturbed plots which had poor accessibility in the semi-evergreen forest of Shervarayan hills of Eastern Ghats, India whereas in the disturbed plots, it was less than that. Both natural and anthropogenic disturbances reduce observed species richness and diversity (Brown and Gurevitch, 2004). From the study it was observed that species richness decreased with the increasing disturbances. Rahman *et al*. (2009) also found negative relationship between disturbance index and species richness, Parthasarathy (1999), stated more species richness in the undisturbed site compared to selected felled site and frequently disturbed site in the Kalakad National Park, Western Ghats, South India. But Kumar and Ram (2005) observed different relationship in their study. They found anthropogenic disturbances like lopping, grazing, litter removal or fire in the study area. It was found that tree and shrub species diversity was relatively higher in the moderately and highly disturbed forests compared to low disturbed forests. They mentioned disturbances decreased the dominance of single species and increased the plant biodiversity by mixing species of different succession status.

Local people practice agro-forestry, collect litter, cut regeneration and non-woody plants from the disturbed zone which might impact species richness. There is very less variation for the climber and shrub species richness between zones. Most of the time, when local people collect fuel wood, they cut climbers and use it to bind the fuel wood together. That’s why; it was observed that climber density was less. But in the less disturbed zone, because of poor accessibility, absence of management operation, it was observed that climbers were sticked with many trees which hampered the growth of trees.

Both zones showed significant differences for the density (N/ha) of regeneration from (0 – 0.5) m and for trees (> 6 cm). For mean density (N/ha) of trees (> 6 cm dbh) was higher in the less and

and for trees (> 6 cm dbh). The mean density (N/ha) of trees (> 6 cm dbh) was higher in the less disturbed zone compared to disturbed zone which contributed to a significant difference between zones. Due to poor accessibility in the less disturbed zone, resource extraction was minimal. Whereas, the disturbed zones were located near to the main road of the study area where local people can enter easily and engage in illegal logging. This result is comparable with Kadavul and Parthasarathy (1999) where it was reported that due to poor accessibility and location of less disturbed plots away from human habitation, density (N/ha) of woody species was higher than on the disturbed plots. But density (N/ha) of regenerated plants from height range (0 - 0.5) m and (0.5 - 2) m, was higher in the disturbed zone. Maybe due to substantial amount of sunlight on the forest floor that affects the regeneration rate, disturbed zone had a higher density (N/ha) of regeneration. But due to human interference, less number of individuals reach the mature tree stage (tree > 6 cm dbh).

Herb coverage percentage was low in the less disturbed zone which is supported by the results of Kumar and Ram (2005) who stated that herb density (N/ha) was less in the least disturbed forest than compared to highly and moderately disturbed forest. Nath *et al*. (2005) found that herbaceous species were denser in highly disturbed stand compared to moderately disturbed and undisturbed stand also. The low coverage of herbs in the less disturbed zone is due to the less solar radiation on the forest floor caused by the closed canopy cover. The coverage is higher in the disturbed zone due to the sunlight falling through the broken canopy on the forest floor (Bhatnagar, 1966).

From this study, it is observed that *Holarrhena antidysentirica* was the dominant tree species in both zones (Disturbed: 28.5 & Less Disturbed: 31.59).There was one study accomplished during 2003 by a forestry student (Nath,2003) in the same study area and from the result, it was observed that *Holarrhena antidysentirica* had the highest Importance Value Index (IVI) at the Southern (IVI: 24.40) and Western (IVI: 23.77) aspect and also at the top hill (IVI: 20.20) and at the midhill (IVI: 18.23), it had the second highest Importance Value Index (IVI). It was also found from the study that in the natural forest, *Holarrhena antidysentirica* (IVI: 25.60), *Sterlospermum chelonioides* (IVI: 20.40) occupied the second and third highest Importance Value Index (IVI) whereas at the present study, both species had the first and third highest (IVI: 31.59 & 16.62) Importance Value Index (IVI) respectively in the less disturbed zone. In the enrichment plantation area (mixed with natural and planted species), *Sterlospermum chelonioides* (IVI: 19.23) and *Holarrhena antidysentirica* (IVI: 16.10) followed the highest and second highest Importance Value Index (IVI) whereas in the disturbed zone of the present study which had plantation also, *Holarrhena antidysentirica, Sterlospermum chelonioides* showed the maximum Importance Value

Index (IVI).However these differences are mostly linked to the sampling design and the number of plot observed. But the dominating mature tree species of this study showed different status at the regeneration stage. Comparing with the composition of other tree species found in both zones at regeneration stage (0 – 0.5) m, some of these dominant tree species had less share. Among dominant tree species, *Holarrhena antidysentirica* and *Dehasia kuruzi* had a higher share than all other tree species found in the disturbed and less disturbed zone at regeneration stage (0 – 0.5) m. *Grewia microcos* had a higher share at this regeneration stage in both zones. It can be assumed that the disturbed and less disturbed zone of the study area is better suited for regeneration and growth of *Holarrhena antidysentirica* and *Dehasia kuruzi* compared to other dominant tree species.

Holarrhena antidysenterica had the highest share at the range (0 - 0.5) m and (0.5 - 2) m in the disturbed zone but at range (> 2m < 6 cm dbh) *Albizzia procera* had the highest share. So these dominating tree species did not show a similar domination status at their regeneration stage. But in the case of less disturbed zone *Holarrhena antidysentirica* had the highest share among other dominant tree species at the regeneration stage. *Syzygium fruticosum* occupied the second highest share at the regeneration stage (0.5 – 2) m and (> 2 m < 6 cm dbh) whereas *Dehasia kuruzi* at (0 – 0.5) m.

Among all other dominant tree species, *Holarrhena antidysenterica* had the highest share in both zones. This species needs a slight amount of shade but it develops best in full light. It is sensitive to frost, but has good powers of recovery from the base when killed down and may often be found in abundance persisting on grassy areas subject to severe frost. As the area is recruited recently, so there are less trees allowing dense canopy. As the tree develops best in full light, so this may be a reason for its high dominancy. It is not readily browsed, even by goats. It shoots up readily after severe damage by fire. It produces root-suckers in abundance (Troup, 1921).

It can be observed from this study that some of the dominant tree species had a lower proportion than all other tree species found in both zones at their regeneration stage. It can be assumed that due to stand development phase, in the early stage there was high number of individuals of different species. It seems that the dominant tree species adopted better to the environment and made them dominant among all other tree species. Although the hills at the Sitakund Botanical Garden and Eco-park area mostly lack seed bearing trees, many of them have stumps from the previously felled trees and a system of active root suckers is often covered with thorny bush and climbers and other weeds (Misbahuzzaman and Alam, 2006). All the dominant tree species found in the study area regenerate by root suckers and coppice, so this might be an additional reason for the dominance as these tree species depend on less seed dispersal for their regeneration.

The diameter class distribution of trees (> 6 cm dbh) revealed that with an increase of diameter classes, the total number of species decreased. Most of the species were found at the lowest diameter class (6-11) cm on all plots in both zones. *Garuga pinnata* had the highest dbh which was one of the dominant tree species also. In the less disturbed zone, *Albizzia procera* showed the highest dbh but Importance Value Index (IVI) of the species was low because it had low frequency and density (N /ha). It was found that the species recruitment has started recently with an encouraging manner in both zones but due to disturbances, less species are available with high diameter ranges in the disturbed zone. In the less disturbed zone, due to poor accessibility, there are some species with high diameter classes. So adequate protection is necessary to maintain an adequate number of species in each diameter class. Al-Amin *et al*. (2005) reported that most of the species of a deforested area (Bamerchara and Danerchara is reserve forest of Jaldi beat under Jaldi range Chittagong (South) Forest Division) of Bangladesh were in the lowest diameter range. Number of total species was decreasing as diameter class was increasing.

For the height class distribution, the results were similar. The number of species decreased by increasing height classes. In the present study, most of the species are at the height class from (2-7) m in the disturbed zone. But in the less disturbed zone, even the total number of species was more at the class from (2-7) m, but there were more species found at the (7-12) m and (12-17) m classes than compared to the number of species found at that classes in the disturbed zone.

As the number of species decreased with the increase of diameter and height classes it could be hypothesized that the area was degrading continuously in the past. Due to the establishment of Eco-park and Botanical Garden, this process of recruitment with a diverse mixed species was initiated. Rahman *et al*. (2009) found similar results in the Madhupur Sal forest of Bangladesh where it is mentioned that trees with highest height were found in the low disturbed forest type and herb coverage percentage was low in the low disturbed forest type of the Madhupur Sal forest. Giant trees were found only in the low disturbed forest type. The density (N/ha) of regenerated plants from the range of (0 - 0.5) m had a positive relationship with the disturbance index. This result is supported by the research done by Mishra *et al*. (2003) where they found that an increased level of disturbances favored regeneration both by seeds as well as by sprouting. Thus the regeneration behavior of forest trees seems to be closely linked with the level of disturbances.

Chapter 6 CONCLUSION AND RECOMMENDATION

6. 1 Conclusion

Sitakund Eco-park is heterogeneous in terms of species richness and community structure. The study revealed that anthropogenic disturbances influence the regeneration, species richness, density (N/ha) and basal area (m^2/ha). From the study, it is observed that the level of tree species diversity in the less disturbed zone of Sitakund Eco-park is higher compared to the disturbed zone. In the less disturbed zone, climbers were suppressing the growth of other trees even in the disturbed zone. Local people are engaged in cutting of regeneration, cutting of non wood products, logging, bark peeling for making medicine against mosquito, litter collection, agro forestry practices which cause serious impacts on regeneration in the disturbed zone. They are dependent on forest products for their daily livelihood. If in future this trend of extraction remains, it will influence the regeneration on the less disturbed zone, also. Even many vary rare species will be extinct. Gap filling with indigenous species in the disturbed zone could reduce the risk being extinct. Forest management efforts should consider community-based forestry programmes involving local people in forest management activities. Native forest eco-systems of eco-park could be restored to a significant extent if there would be some regular cultural practices such as removal of non woody vegetation like climbers or weeds. However, anthropogenic disturbances should be reduced to facilitate regeneration. Local people participation during afforestation programme can play an important role. For better participation, views of farmers (in species selection, land uses etc.) should be considered in decision-making processes, which would create co-operation between farmers and the Park Authority. Analysis of previous plantation history in this area (FMP, 1992) and (Alam, 2001) indicates that failure of plantations was mostly due to human interference. The local people were not involved in these plantation programmes and still now they don’t have involvement .They should be involved in a participatory way for the sustainability of the plantation programmes in future.

6. 2 Recommendation

Based on the personal observation at the study area, some major recommendations can be given:

As local people in the study area do not have other alternatives, they are engaged in logging, cutting of regeneration, cutting of non wood products, bark peeling, agro forestation, firing and litter collection. Visitors enter the area and cause disturbances. Fire caused by the visitors and local people impacts regeneration. These disturbances are interrupting the ecological restoration of the Sitakund Botanical Garden and Eco-park the reason it was established for. Local people do not engage in conservation activities as they have no ownership for the area. So it can be recommended that participation of local people in decision making, different plantation activities, during selection of species could improve the condition of the status of regeneration and tree species diversity of the study area. Community forestry might be a better idea for upgrading the present condition of the status of regeneration and tree species diversity as well as the economic condition of the local people. Through this approach local people would be more conscious about protection of the area. Awareness raising and better understanding among local people and the eco-park authority could help to minimize the disturbances in the study area.

Based on the information about some other problems in the study area given by the eco-park staff, some recommendation can be given:

For preventing the spreading of forest fires, some logistic support like walky-talky for communication facilities is needed. Water supply and an increased support from staff are other basic recommendations.

Only 12% of the permanent positions are filled up by the local people. There should be some provision to involve more local people at the management level of the Botanical Garden and Eco-park.

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ANNEXES

Annex 1 Species found in the study area with code

Species Code	Scientific Name	Species Code	Scientific Name
1	*Acacia auriculiformis*	44	*Azadirachta indica*
2	*Emblica officinalis*	45	*Syzygium fruticosum*
3	*Saraca indica*	46	*Litsea sebifera*
4	*Grewia microcos*	47	*Piper longam*
5	*Salmalia insignis*	48	*Aphanamixis polystachya*
6	*Zizyphus oenoplea*	49	*Samanea saman*
7	*Artocarpus lacucha*	50	*Sapindus mukorossi*
8	*Quercus spicata*	51	*Tectana grandis*
9	*Terminalia belerica*	52	*Albizzia procera*
10	*Haplophragma adenophyllum*	53	*Shorea robusta*
11	*Duabanga grandiflora*	54	*Bombax ceiba*
12	*Sterculia foetida*	55	*Cassia fistula*
13	*Lagerstroemia indica*	56	Silvadi
14	*Taphrosia candida*	57	*Streblus asper*
15	*Alstonia scholaris*	58	*Albizzia odoratissima*
16	*Albizzia chinensis*	59	*Desmodium motorium*
17	*Stereospermum chelonioides*	60	*Cedrela toona*
18	*Ficus hispida*	61	*Sterculia villosa*
19	*Gmelina arborea*	62	Longgota
20	*Bursera serrata*	63	Huoirgagach
21	*Garuga pinnata*	64	Gungurigota
22	*Psidium guajava*	65	Bolgota
23	*Vitis glabrata*	66	*Phyllanthus reticulatus*
24	*Cissus quadrangularis*	67	Security gach
25	*Dillinia pentagyna*	68	Thougach
26	*Adina cordifolia*	69	Tokpata
27	*Aphania danura*	70	Boxudal
28	*Leucaena leucocephala*	71	Bonpapya
29	*Derris robusta*	72	Kurulla
30	*Trema orientalis*	73	Kuratanga
31	*Lagerstroemia speciosa*	74	Korda
32	*Spondias pinnata*	75	Kanisfal
33	*Schima walliichii*	76	Kalofal
34	*Syzygium cumini*	77	Longkot
35	*Holarrhena antidysenterica*	78	Neemvadi
36	*Phoenix sylvestris*	79	Velva
37	*Acacia catechu*	80	*Cycas pectinata*
38	*Tabernaemontana dichotoma*	81	*Podocarpus neriifolia*
39	*Oroxylum indicum*	82	*Madhuca indica*
40	*Macaranga dinticulata*	1A	*Withania coagulans*
41	*Swietenia macrophylla*	1B	*Flacourtia indica*
42	*Cassia siamea*	1C	*Callicarpa macrophylla*
43	*Dehasia kuruzii*	1D	*Costus speciosus*
		1E	*Ixora parviflora*
		1F	*Rauwolfia serpentina*
		1G	Batik
		1H	Koshgoda
		1M	*Tabernaemontana dichotoma*

Annex 2 Relative Density, Relative Frequency, Relative Abundance and Relative Dominance of tree (> 6cm dbh) in the disturbed zone

Species Code	Relative Density	Relative Frequency	Relative Abundance	Relative Dominance
1	3.488	2.898	2.905	1.882
2	2.034	2.415	2.034	1.124
3	0.872	1.449	1.452	0.442
4	1.162	1.932	1.452	1.513
7	0.581	0.966	1.452	0.964
8	0.581	0.483	2.905	0.383
9	4.360	4.347	2.421	4.015
10	0.290	0.483	1.452	0.141
16	0.581	0.483	2.905	0.493
17	7.267	5.797	3.026	7.189
18	2.906	4.347	1.614	3.180
19	6.395	3.864	3.995	4.130
20	0.581	0.483	2.905	0.428
21	4.360	2.898	3.632	5.988
23	2.325	2.415	2.324	2.125
26	3.197	3.864	1.997	2.812
28	2.906	3.381	2.075	1.864
30	2.325	3.381	1.660	1.935
31	0.290	0.483	1.452	0.864
33	0.290	0.483	1.452	0.175
34	0.290	0.483	1.452	0.660
35	12.5	4.830	6.247	11.19
37	0.872	1.449	1.452	0.506
39	1.453	1.932	1.816	1.110
40	0.581	0.483	2.905	0.433
41	2.616	2.415	2.615	2.116
42	2.906	4.347	1.614	1.627
43	3.779	4.347	2.098	3.627
44	1.162	1.932	1.452	0.592
45	2.034	2.415	2.034	2.440
46	0.290	0.483	1.452	0.364
51	2.325	1.932	2.905	1.593
52	3.197	3.381	2.283	5.635
53	3.197	2.898	2.663	2.025
54	1.744	2.415	1.743	3.572
55	1.162	1.449	1.937	1.752
57	0.581	0.966	1.452	0.394
58	1.453	1.449	2.421	4.848
61	0.581	0.966	1.452	1.162
64	2.034	2.898	1.695	3.168
66	0.290	0.483	1.452	0.242
69	0.290	0.483	1.452	0.202
70	0.290	0.483	1.452	0.743
72	6.395	6.280	2.458	7.062
75	0.290	0.483	1.452	0.335
78	0.290	0.483	1.452	0.640
82	0.581	0.966	1.452	0.291
Total	100	100	100	100

Annex 3 Relative Density, Relative Frequency, Relative Abundance and Relative Dominance of tree (> 6cm dbh) in the less disturbed zone

Species Code	Relative Density	Relative Frequency	Relative Abundance	Relative Dominance
4	4.161	4.644	1.895	3.065
5	0.134	0.273	1.039	0.179
7	2.818	2.732	2.182	3.754
8	0.536	0.819	1.385	0.509
10	0.134	0.273	1.039	0.060
11	0.268	0.273	2.078	0.183
12	0.268	0.273	2.078	0.612
13	0.402	0.273	3.118	0.200
14	0.134	0.273	1.039	0.210
15	0.268	0.273	2.078	0.545
17	6.174	5.464	2.390	4.990
18	5.906	3.825	3.266	5.299
20	1.476	1.639	1.905	1.307
21	4.295	4.371	2.078	4.805
23	2.416	4.098	1.247	2.075
24	0.805	1.639	1.039	0.560
25	2.684	2.185	2.598	2.743
26	1.879	2.732	1.455	1.739
27	0.536	1.092	1.039	0.489
30	3.087	3.825	1.707	2.626
31	0.268	0.546	1.039	0.317
34	1.208	1.366	1.870	0.849
35	13.82	6.557	4.460	11.20
39	2.013	2.185	1.948	1.636
40	2.416	2.459	2.078	4.328
43	5.637	5.191	2.297	5.179
45	7.651	4.371	3.702	6.975
46	0.536	1.092	1.039	0.594
47	0.402	0.819	1.039	0.200
48	0.536	0.819	1.385	0.399
49	0.805	0.819	2.078	0.507
50	0.402	0.819	1.039	0.204
52	0.402	0.273	3.118	3.071
54	1.879	2.732	1.455	2.271
55	0.939	1.092	1.818	1.064
56	0.402	0.819	1.039	0.455
57	1.744	2.459	1.501	1.236
58	2.818	2.185	2.728	5.934
59	0.134	0.273	1.039	0.048
60	0.134	0.273	1.039	0.060
61	1.073	1.092	2.078	0.887
62	0.134	0.273	1.039	0.051
63	1.879	2.732	1.455	2.377
64	1.476	1.639	1.905	1.541
65	0.134	0.273	1.039	0.078
66	2.550	3.825	1.410	2.735
69	0.134	0.273	1.039	0.099
70	1.610	0.819	4.157	1.626
72	3.758	3.825	2.078	2.677
73	0.402	0.819	1.039	0.357
74	0.268	0.546	1.039	0.327
75	0.671	1.092	1.299	0.680
76	0.671	1.092	1.299	0.849

Species Code	Relative Density	Relative Frequency	Relative Abundance	Relative Dominance
77	0.268	0.546	1.039	0.232
78	1.879	2.459	1.616	2.285
79	0.536	0.546	2.078	0.687
Total	100	100	100	100

Annex 4 Relative Density, Relative Frequency and Relative Abundance of plants from (0 - 0.5) m range in the disturbed zone

Species Code	Relative Density	Relative Frequency	Relative Abundance
4	6.122	5.095	2.684
5	1.836	1.910	2.147
6	1.632	1.910	1.908
7	2.040	1.910	2.386
8	2.653	3.184	1.861
10	1.428	1.910	1.670
13	0.408	0.636	1.431
14	1.224	1.273	2.147
17	3.061	2.547	2.684
18	3.061	3.184	2.147
20	0.204	0.636	0.715
21	2.448	1.910	2.863
24	1.020	1.273	1.789
26	3.877	3.184	2.720
27	2.040	1.273	3.579
29	1.632	1.273	2.863
30	0.612	1.273	1.073
34	1.428	1.910	1.670
35	10	7.006	3.188
36	0.816	1.273	1.431
39	1.836	1.910	2.147
40	1.020	0.636	3.579
43	4.489	4.458	2.249
45	0.408	1.273	0.715
46	1.632	0.636	5.726
47	0.204	0.636	0.715
50	3.265	1.910	3.817
52	2.040	2.547	1.789
57	0.612	0.636	2.147
58	1.428	1.910	1.670
64	0.204	0.636	0.715
67	0.204	0.636	0.715
69	1.632	1.273	2.863
70	2.448	1.910	2.863
72	1.020	1.273	1.789
74	1.428	0.636	5.010
75	3.061	3.184	2.147
76	0.204	0.636	0.715
78	3.265	3.184	2.290
1A	4.897	5.732	1.908
1B	5.102	5.095	2.237
1C	1.020	1.273	1.789
1D	0.204	0.636	0.715
1E	4.489	2.547	3.937
1G	2.653	5.095	1.163
1H	3.673	5.095	1.610
Total	100	100	100

Annex 5 Relative Density, Relative Frequency and Relative Abundance of plants from (0 - 0.5) m range in the less disturbed zone

Species Code	Relative Density	Relative Abundance	Relative Frequency
4	4.147	1.890	4.210
6	0.006	1.890	0.701
7	0.006	1.890	0.701
8	0.009	1.260	1.403
11	0.009	2.520	0.701
14	0.004	1.260	0.701
17	0.011	2.100	1.052
18	0.039	1.648	4.561
20	0.006	1.260	1.052
21	0.011	1.260	1.754
22	0.002	1.260	0.350
23	0.016	1.470	2.105
24	0.025	2.772	1.754
25	0.002	1.260	0.350
26	0.004	1.260	0.701
27	0.041	1.890	4.210
29	0.004	1.260	0.701
30	0.016	1.470	2.105
31	0.002	1.260	0.350
32	0.011	3.150	0.701
34	0.004	1.260	0.701
35	0.080	2.450	6.315
38	0.004	1.260	0.701
39	0.020	1.890	2.105
40	0.002	1.260	0.350
43	0.057	1.969	5.614
45	0.036	2.016	3.508
46	0.004	1.260	0.701
47	0.002	1.260	0.350
48	0.006	1.890	0.701
50	0.011	2.100	1.052
54	0.016	1.764	1.754
55	0.002	1.260	0.350
57	0.025	2.772	1.754
58	0.009	1.260	1.403
60	0.002	1.260	0.350
61	0.011	1.575	1.403
63	0.041	2.062	3.859
66	0.034	1.575	4.210
67	0.002	1.260	0.350
69	0.013	1.260	2.105
70	0.002	1.260	0.350
71	0.002	1.260	0.350
72	0.027	2.520	2.105
73	0.011	1.575	1.403
74	0.004	1.260	0.701
75	0.016	2.205	1.403
76	0.002	1.260	0.350
77	0.004	2.520	0.350
78	0.002	1.260	0.350
1A	0.041	2.062	3.859

Species Code	Relative Density	Relative Abundance	Relative Frequency
1B	0.025	2.772	1.754
1C	0.009	2.520	0.701
1D	0.004	1.260	0.701
1E	0.099	2.852	6.666
1F	0.002	1.260	0.350
1G	0.039	1.785	4.210
1H	0.039	1.648	4.561
Total	100	100	100

Annex 6 Relative Density, Relative Abundance and Relative Frequency of plants (0.5 - 2) m range in the disturbed zone

Species Code	Relative Density	Relative Abundance	Relative Frequency
3	0.947	3.370	0.709
4	8.056	2.387	8.510
8	2.369	2.808	2.127
9	1.421	2.527	1.418
10	0.947	1.685	1.418
13	0.473	1.685	0.709
15	0.473	1.685	0.709
17	3.791	2.696	3.546
18	4.739	2.808	4.255
20	0.947	1.685	1.418
21	1.421	1.685	2.127
23	0.473	1.685	0.709
25	0.947	3.370	0.709
26	1.895	1.685	2.836
27	0.473	1.685	0.709
30	5.213	2.059	6.382
31	0.473	1.685	0.709
35	17.53	4.795	9.219
39	0.473	1.685	0.709
40	0.473	1.685	0.709
42	0.947	1.685	1.418
43	6.161	3.129	4.964
44	0.473	1.685	0.709
45	2.369	2.106	2.836
52	3.317	2.948	2.836
55	0.473	1.685	0.709
61	0.473	1.685	0.709
64	1.421	1.685	2.127
66	0.473	1.685	0.709
68	0.473	1.685	0.709
69	1.421	1.685	2.127
70	0.947	3.370	0.709
72	3.317	2.948	2.836
75	4.265	2.527	4.255
76	1.421	2.527	1.418
77	0.473	1.685	0.709
78	0.473	1.685	0.709
79	0.473	1.685	0.709
80	0.947	3.370	0.709
1A	3.317	1.965	4.255
1B	0.947	3.370	0.709
1C	0.473	1.685	0.709

Species Code	Relative Density	Relative Abundance	Relative Frequency
1E	0.947	1.685	1.418
1G	7.582	2.450	7.801
1H	2.843	2.022	3.546
Total	100	100	100

Annex 7 Relative Density, Relative Abundance and Relative Frequency of plants (0.5 - 2) m range in the less disturbed zone

Species Code	Relative Density	Relative Frequency	Relative Abundance
4	5.904	5.238	2.145
7	1.476	1.904	1.474
8	0.369	0.476	1.474
10	0.369	0.476	1.474
14	0.369	0.476	1.474
17	3.321	3.809	1.659
18	4.797	6.190	1.474
20	0.738	0.952	1.474
21	1.107	1.428	1.474
23	0.738	0.952	1.474
24	2.952	1.428	3.932
25	0.369	0.476	1.474
26	1.476	1.428	1.966
27	1.476	1.904	1.474
30	1.107	1.428	1.474
31	0.369	0.476	1.474
35	11.07	9.047	2.328
38	0.369	0.476	1.474
39	1.107	1.428	1.474
40	1.107	0.952	2.212
43	5.904	5.714	1.966
45	8.118	6.666	2.317
46	0.738	0.476	2.949
50	0.369	0.476	1.474
52	0.369	0.952	0.737
54	0.738	0.476	2.949
56	0.369	3.809	0.184
57	3.690	0.476	14.74
58	0.369	0.476	1.474
59	0.369	0.476	1.474
61	1.107	1.428	1.474
63	0.738	0.952	1.474
64	0.738	0.952	1.474
66	5.904	5.238	2.145
69	0.738	0.952	1.474
72	2.952	2.857	1.966
73	0.369	0.476	1.474
74	0.369	0.476	1.474
75	1.845	1.904	1.843
76	0.369	0.476	1.474
77	1.107	0.952	2.212
78	0.738	0.476	2.949
79	0.369	0.476	1.474
1A	7.380	5.714	2.458
1B	0.369	0.476	1.474
1C	0.738	0.952	1.474

Species Code	Relative Density	Relative Frequency	Relative Abundance
1E	4.428	4.761	1.769
1G	4.059	4.761	1.622
1H	3.690	4.285	1.638
1M	0.369	0.476	1.474
Total	100	100	100

Annex 8 Relative Density, Relative Abundance and Relative Frequency of plants for height range (> 2 m < 6 cm dbh) in the disturbed zone

Species Code	Relative Density	Relative Frequency	Relative Abundance
1	6.060	5.172	2.868
2	0.606	0.862	1.721
3	0.606	0.862	1.721
4	4.848	4.310	2.753
8	1.818	1.724	2.581
9	4.242	3.448	3.012
13	0.606	0.862	1.721
15	1.212	0.862	3.442
16	0.606	0.862	1.721
18	6.060	5.172	2.868
19	3.636	3.448	2.581
20	1.212	1.724	1.721
24	0.606	0.862	1.721
25	1.212	0.862	3.442
26	1.212	1.724	1.721
27	0.606	0.862	1.721
28	3.636	3.448	2.581
30	3.636	4.310	2.065
31	0.606	0.862	1.721
35	3.636	4.310	2.065
37	7.272	5.172	3.442
39	1.212	1.724	1.721
41	2.424	2.586	2.294
43	1.818	1.724	2.581
44	1.212	1.724	1.721
51	3.030	1.724	4.302
52	4.848	4.310	2.753
53	3.030	3.448	2.151
55	1.212	1.724	1.721
58	0.606	0.862	1.721
61	0.606	0.862	1.721
72	1.212	1.724	1.721
74	0.606	0.862	1.721
75	1.818	1.724	2.581
76	0.606	0.862	1.721
78	1.212	1.724	1.721
81	1.818	0.862	5.163
1A	3.636	4.310	2.065
1B	3.030	2.586	2.868
1C	0.606	0.862	1.721
1E	1.818	2.586	1.721
1G	5.454	4.310	3.098
1H	4.242	5.172	2.008
Total	100	100	100

Annex 9 Relative Density, Relative Abundance and Relative Frequency of plants for height range (> 2 m < 6 cm dbh) in the less disturbed zone

Species Code	Relative Density	Relative Frequency	Relative Abundance
4	7.518	6.282	3.109
7	0.375	0.523	1.865
8	0.751	1.047	1.865
14	0.375	0.523	1.865
17	4.135	3.664	2.931
18	4.135	4.188	2.565
20	1.503	1.570	2.487
21	1.503	1.570	2.487
23	1.503	2.094	1.865
24	3.383	3.664	2.398
25	1.127	1.047	2.798
26	0.751	1.047	1.865
27	2.255	2.094	2.798
29	0.375	0.523	1.865
30	2.255	2.617	2.238
31	0.751	1.047	1.865
34	0.375	0.523	1.865
35	12.03	10.99	2.843
39	1.503	2.094	1.865
43	6.015	6.282	2.487
45	6.766	5.235	3.358
50	0.751	1.047	1.865
54	1.127	1.047	2.798
57	3.383	2.617	3.358
58	2.255	1.570	3.731
61	0.375	0.523	1.865
63	0.375	0.523	1.865
66	3.383	3.664	2.398
69	0.751	1.047	1.865
72	3.759	4.188	2.332
73	1.127	1.570	1.865
75	2.255	2.617	2.238
77	1.503	1.047	3.731
78	1.127	1.047	2.798
79	0.375	0.523	1.865
1A	2.631	3.141	2.176
1B	0.375	0.523	1.865
1C	0.375	0.523	1.865
1D	0.751	1.047	1.865
1E	2.255	2.094	2.798
1G	6.390	6.282	2.643
1H	5.263	4.712	2.902
Total	100	100	100

Annex 10 Some photos from field

Bamboo plantation in the Sitakund Botanical Garden and Eco-park

Cane plantation in the Sitakund Botanical Garden and Eco-park

Cycas sp., one of the gymnospermic species of Bangladesh was found in the study area

Podocarpus neriifolius, another gymnospermic species of Baangladesh was found in the study area

Children of local people are going for collecting fuel wood from the study area

Betel leaf cultivation inside the study area

Seedlings at the nursery of the Sitakund Botanical Garden and Eco-park

Clonal propagation of *Podocarpus neriifolius*

Entrance point of the Sitakund Botanical Garden and Eco-park

Hills showing the temple at the top (Photo was taken from the outside of the study area)