

Analysis of Habitat Factors Influencing Natural Forest Regeneration Status of Tilaghor Eco-park in Bangladesh

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Abstract

Natural regeneration is considered as the cheapest and easiest way of regeneration which contributes maintaining ecological balance and biodiversity conservation. Understanding the dynamics of natural regeneration is crucial for predicting future vegetation development and maintaining forest ecosystem stability. This study evaluated the natural regeneration status and the influence of selected habitat factors in Tilaghor Eco Park that will contribute to investigate the resilience capability of the park and provide guidelines to decision makers to prioritize the conservation strategies. A total of 100 (2mx2m) regeneration plots were studied to elucidate the regeneration condition of the site and analyzed the effects of site factors on them. In those plots, we found 314 trees, 102 saplings, and 934 seedlings of 22 individual species. *Dipterocarpus turbinatus* (Garjan) was the most dominant and abundant among tree and seedling species whereas *Calamus longisetus* (Bet) was the most dominant among sapling species. We applied Non-metric Multi-dimensional Scaling (NMDS) and Generalized Linear Model (GLM) to understand the community complexity and specific effect of ecological factors on regeneration, respectively. Our study concluded with the correlation between seedling richness and seedling abundance with 10 selected habitat factors. Among all, tree height and tree richness were significantly correlated with seedling richness and seedling abundance in accordance to the NMDS ordination. The other factors namely elevation, basal area, canopy coverage, canopy height, tree abundance, sapling richness, sapling abundance, sapling average height had no significance with the seedling richness and abundance. The GLM analysis represented that tree and sapling richness and abundance were significantly influenced by the seedling richness where elevation, tree diameter and basal area were influenced the seedling abundance. The study was carried out on the important aspects that will assist the plantation initiatives to decide on an area-specific plantation on indigenous species preference.

Keywords: Species Diversity, Micro-environmental Factors, Natural regeneration, Protected Area

1 **Introduction**

2 Natural regeneration is the predominant regeneration process of the forest (Cheng et al. 2023). It plays a
3 prominent role in large scale landscape restoration in tropics (Chazdon & Guariguata 2016). Natural
4 regeneration often practices frequently when direct planting of seedlings is not efficient economically or
5 logistically (Grebner et al. 2013). There are many advantages of natural regeneration process over
6 artificial plantation. As it is common for plantation manager mismatches species, provenances and
7 genotypes to local site conditions, stand that grows naturally ensures successful establishment. In
8 addition, transplanted plantation shows high mortality rates, slow growth and deformed stems for poor
9 planting techniques (Burley 2004). It is thought one of the major reasons for deforestation in tropical
10 forests.

11
12 Tropical forests, under immense pressure from deforestation, harbor significant biodiversity, regulate
13 climate change, and provide key ecosystem services. (Uriarte & Chazdon 2016). This forest is storing
14 about 46% world's living terrestrial carbon pool (Löf et al. 2019). It regulates hydrologic cycle by
15 affecting the evapotranspiration process which takes place in soil and leaves. On the other hand, this
16 forest is the habitat of the two-thirds of the biodiversity in the world (Giam 2017). In tropics, natural
17 regeneration is important vegetation strategies in many regions of the world to sequester soil organic
18 materials as well as soil quality improvement (Cheng et al. 2023). It is obvious that, this type of
19 regeneration is the cheapest mechanisms of sequestration almost 24%-35% carbon from fossil fuels and
20 industrial emissions (Chazdon et al. 2016). Again, naturally regenerating plots shows higher probability
21 of achieving reproductive maturity and improve demographic performance that ensures long term forest
22 success (Uriarte & Chazdon 2016). Reid et al. (2018) showed that for attaining better biodiversity and
23 forest structural attributes natural regeneration is preferred than plantings. Through self-producing
24 process a forest can secure its genetic diversity. Species those are found in particular forest by re-
25 producing through seeds, coppices and root suckers can avoid their danger of extinction in the forest
26 (Reid et al. 2018). Furthermore, it is claimed that, naturally regenerating forests have complex adaptive
27 system that possess some key properties that promote better resilience to disturbance (Filotas 2014).

28
29 Increasing deforestation (almost 64,000 km²yr⁻¹ for the entire tropical biome) makes researchers study
30 in depth about restoration of abandoned land. Wright (2010) predicted the future of tropical forests
31 where he mentioned about five anthropogenic drivers namely land use change, wood extraction, hunting,

1 atmospheric change, climate change would contribute to the dimension of tropical forests. Previous
2 studies examined different impact of natural regeneration for ecological restoration, biodiversity loss
3 minimization and nutrient cycling regulation over other regenerating processes (Chazdon et al. 2016,
4 Poorter et al. 2016, Crouzeilles et al. 2017, Taylor et al. 2019, Reid et al. 2018, Pillay et al. 2022,
5 Chazdon et al. 2023). Moeslund et al. (2013), Dyderski et al. (2018), Rodriguez-Garcia et al. (2011),
6 Osuri et al. (2022) evaluated the effect of different drivers on natural regeneration in tropical forests.

7
8 The regeneration process of the forests is regulated by a number of factors (Moeslund et al. 2013). It
9 involves dynamic life cycle of plants and the mortality is higher in the early stage of life. Transition to
10 the next stage of life affected greatly by the site factors upon which success of the establishment
11 depends (Rodriguez-Garcia et al. 2011). Canopy coverage has mix influence on regeneration process
12 (Osuri et al. 2022). Where it favors species establishment to protect from harsh condition for moderate
13 shade tolerant and shade tolerant species, it also can hinder the growth of shade intolerant species by
14 affecting the temperature and sunlight in the forest floor. In contrary, many studies claimed that
15 regeneration degrades with the increase of elevation because the temperature, precipitation, humidity
16 and nutrient availability greatly alter with gradients (Cagnacci 2020). Again, canopy height of the forests
17 in one hand promotes microhabitats, on the other hand it paves the way of light exposure on forest floor
18 (Ramos de Andrade 2015). Despite, tree richness, and abundance assist more self-producing forest
19 through seed availability but these factors ignite more competition among the regenerating plants
20 (Hammond 2021). However, tree height influences regeneration dynamics by controlling light
21 penetration in the forests. Furthermore, sapling richness, abundance and height are good indicators for
22 maintaining favorable condition for future generation but they also facilitate competition. As like trees
23 and saplings seedling richness ensures future diversity of the forest that is more resilient to disturbances
24 where their abundance increases competition that leads to less survival rate.

25
26 Through the decades, Tropical forests suffer the risk of degradation as a result of human interventions.
27 The dynamics of this forest is changing over time through human management system and land-use
28 pattern (Löf et al. 2019). Fast conversion of forest lands into other land uses emerge a global concern
29 that leads the international organizations to install methods to restore the forest lands (Masum et al.
30 2017). Growing concern about the deforestation influences researcher and foresters to identify most time
31 and cost-effective process for forest restoration. All of them are identified natural regeneration as the

most cost-efficient process to forest improvement (Grebner et al. 2013, Moeslund et al. 2013). Lack of natural regeneration often produces low products which fail to fulfill the market demands. In the aftermath, investors lack interest in forest sector which indirectly impact on the conversion of forest lands in another land use system (Mattsson et al. 2010). Assessing species diversity is fundamental to understand the interaction among biodiversity recovery, ecosystem functions and ecosystem services (Chazdon et al. 2023). A number of recent studies focused on the natural regeneration dynamics of differential ecological types of forest (Rahman et al. 2011, Sultana & Rahaman 2019, Rahman et al. 2020, Azad et al. 2021, Baul et al. 2022) of Bangladesh. There are studies on species diversity in national parks of the Sylhet division but study about the effect of ecological factors on natural regeneration of the Tilaghor Eco-park is scanty. The aim of this study is to explore the effect of ecological factors of the park on natural regeneration. The imminent degradation of vast areas of the tropics influenced us to analyze the statistical relations among regeneration status with habitat related ecological variables. This study hypothesized that ecological factors like basal area, canopy coverage of each plot, canopy height, elevation, and dominant (taller) tree-related factors like tree richness, abundance, average tree height, sapling richness, sapling abundance, and average sapling height can have a significant effect on regeneration establishment by producing more seeds and recruitment in the Tilaghor Eco-park. We also predicted that these factors greatly would contribute to shape the future community structure of the area. This study will fill up the gap of knowledge in taking decision on the restoration of the protected forest area that are in the vicinity of urban area as it is vulnerable to disturbance but has a great impact on developing general people's empathy to the nature. We assumed this study will be a valuable addition for studying natural regeneration regulating factors in the north eastern urban hill forest area of Bangladesh.

Materials

Site Orientation

Tilaghor eco-park is a well-known ecological park in Sylhet district which serves as an important recreational place for the Sylhet city dwellers. Since 2006, this park has been serving for the preservation, development and protection of extinct, rare and local flora and fauna (Mojaharul 2021). It is promoting local livelihood improvement through eco-tourism and scope for research. It is the third eco-park of Bangladesh which consists 112 acres (45.3 ha) of Tilaghor Reserve Forest. Geographically, this region lies between 23°55' and 25°02' N, and 90°55' and 92°30' E coordination (Figure 1). The

climate of the place is humid subtropical with a predominantly hot and humid summer and a relatively cool winter. The annual average highest temperature is 23 °C (August–October) with an average lowest temperature of 7 °C (January). Nearly 80% of the annual average rainfall of 3334 mm occurs between May and September. The eco-park comprises several hillocks of different elevations and low-lying valleys (Deb et al. 2014). This eco-park has been developed with some hillocks, a stream that has passed through the small hills of the site. These features make this site ideal for some species distribution and habitation.

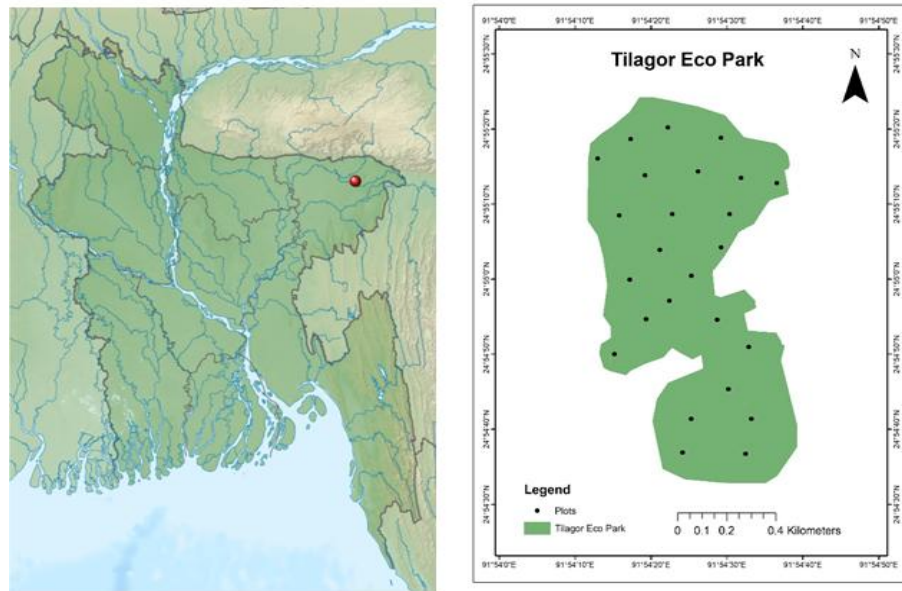


Figure 1: Study area including sampling plots

Data Collection

Vegetation data collection

To assess current tree species (> 5m height and > 5cm DBH) diversity 25 systematic sampling plots (10m × 10m) of 100 sq. m were taken within the study area which covers 0.25 ha area in total. The plots were spaced minimum 200 meters apart in a scientific design avoiding setting plots in cliffs and on foot trails. In each plot we had assessed sapling species (1.3 m < Height ≤ 5 m; 2 cm < DBH ≤ 5 cm) diversity. To assess the natural regeneration, we divided the plots into 4 subplots (2m × 2 m) which were taken four corners in each plot. So, 100 plots of 2 m × 2 m (a total of 400 sq. m) were sampled for seedling following Masum et al. (2025). Regenerated trees (≤ 1.3 m height; ≤ 2 cm DBH) were

considered as seedlings. Seedlings of all species in each plot were identified and recorded by local and scientific names. All plant species were identified directly in the field by Lubaba Noshin based on Dey (2018) and ‘BGD Trees App’ that was developed by Bangladesh Forest Department and Bangladesh National Herbarium. It is mentionable that we found only one unknown species in the study area.

Table 1: List of formulae used for calculating the phytosociological characteristics of the vegetation and diversity indices to quantify the species attributes

No.	Formulae
1	Density (D) = $\frac{a}{b}$
2	Relative Density (RD) = $\frac{n}{N}$
3	Basal Area (BA) = $\pi \left(\frac{DBH}{2} \right)^2$
4	Frequency (F) = $\frac{c}{b}$
5	Relative Frequency (RF) = $\frac{Fi}{\sum_{i=1}^s Fi}$
6	Abundance (A) = $\frac{n}{c}$
7	Relative Abundance (RA) = $\frac{Ai}{\sum_{i=1}^s Ai}$
8	Important Value Index (IVI) = RD + RF + RA
9	Species Diversity Index, $S_{Di} = S/N$
10	Shannon- Winner diversity Index, $H = - \sum_{i=1}^n P_i \ln P_i$
11	Species evenness index, $E = H / \ln (S)$
12	Simpson’s diversity index, $D = 1 / \sum_{i=1}^n P_i^2$

a = Total no. of individuals of a spp. in all the quadrat, b= Total no. of quadrat studies, n = Density of all species, N= Total density of all species, c = the number of quadrats in which the species occurs, Fi= number of frequency of one species, Ai = total number of individuals of a specific species, S= Total number of species, N= Total number of individuals of all the species, Pi = No. of individuals of one species/Total no. of individuals in all the samples, H= Shannon-Winner’s diversity index

Phytosociological attributes and statistical data Analysis

For evaluating site factors, we measured variables namely basal area, canopy coverage of each plot, canopy height, elevation. We also calculated variables like tree richness, abundance, tree average height, sapling richness, sapling abundance, sapling average height, seedling richness and seedling abundance for understanding the Important value index(IVI), biodiversity indices of the species and understand the stand structure. We used spherical crown densitometer for measuring canopy coverage of each plot following Masum et al. (2025). For estimating elevation, we used hand-held GPS navigator at the center of each plot. The canopy height was calculated by averaging tree heights of each plot. Data regarding tree height, sapling height were measured by range finder. For calculating IVI, we calculated density of species, relative density, frequency of a species, relative frequency, abundance of a species and relative abundance by the formulae mentioned in Chowdhury et al. (2018) (Table 1). Species richness and diversity were calculated by the formulae mentioned in Sultana & Rahaman (2019) (Table 1).

For data analysis we used PAST 4.10, R 4.2.2 (R Core Team 2022), Excel (office 2019) software and for mapping we used ArcMap 10.8 (Jaiswal & Jayakumar 2024). In the current study, four measures of plant diversity, namely species diversity index, Simpson diversity index, evenness index and the Shannon diversity index, were calculated and utilized to reflect regeneration diversity. The number of species seen in each plot was used to calculate the species richness. We conducted this study using individual-based (abundance) regeneration data. Confidence ranges for the estimates were created using 50 bootstrap repeats, and they were then used to determine if there was a significant difference between the estimated species richness in the plots. Nonmetric multidimensional scaling (NMDS) ordination have been performed for seedling richness and seedling abundance as response variables where other factors were considered as environmental factors. and Generalized Linear Model (GLM) was implied to understand the specific effect of environmental factors on regeneration dimensions. For the analysis we used R packages like tidyverse, ggplot2, ggrepel, grid, vegan, dplyr, MASS and readr. Study area map was created by ArcMap 10.8.

Results

Qualitative characteristics

In our study we found total 314 individual from 22 tree species, 102 individual saplings of 11 species and 935 individual seedlings species belong from 10 species. From our investigation we observed that

Dipterocarpus turbinatus was the most abundant and *Shorea robusta* and *Magolia champaca* was the second and third abundant tree species, respectively. *Calamus longisetus* was the most abundant where *Dipterocarpus turbinatus* was the second abundant sapling species in the studied site. Like tree species, *Dipterocarpus turbinatus* was the most abundant seedling species where *Shorea robusta* was the second abundant in this eco-park. We listed the name of the species in the table below (Table 2).

Table 2: Name and abundance of the tree, sapling and seedling species found in Tilaghor Eco-park

Tree Scientific Name	Tree abundance	Sapling scientific name	Sapling abundance	Seedling scientific name	Seedling abundance
<i>Dipterocarpus turbinatus</i>	76	<i>Calamus longisetus</i>	75	<i>Dipterocarpus turbinatus</i>	376
<i>Shorea robusta</i>	54	<i>Dipterocarpus turbinatus</i>	10	<i>Shorea robusta</i>	346
<i>Magnolia champaca</i>	52	<i>Artocarpus chama</i>	4	<i>Calamus longisetus</i>	87
<i>Artocarpus chama</i>	31	<i>Hibiscus rosa-sinensis</i>	4	<i>Magnolia champaca</i>	86
<i>Lagerstroemia speciosa</i>	23	<i>Areca catechu</i>	2	<i>Artocarpus chama</i>	23
<i>Delonix regia</i>	22	<i>Polyalthia longifolia</i>	2	<i>Bryophyllum calycium salisb</i>	7
<i>Aquilaria nmalaccensis Lamk</i>	14	<i>Baccaurea motleyana</i>	1	<i>Streblus asper</i>	6
<i>Elaeocarpus serratus</i>	10	<i>Diospyros malabarica</i>	1	<i>Mangifera indica</i>	2
<i>Tectona grandis</i>	5	<i>Ficus racemosa</i>	1	<i>Albizia procera</i>	1
<i>Barringtonia acutangula</i>	7	<i>Magnolia champaca</i>	1	<i>Terminalia chebula</i>	1
<i>Areca catechu</i>	3	<i>Mimusops elengi</i>	1		
<i>Averrhoa carambola</i>	4				
<i>Swietenia mahagoni</i>	3				
<i>Acacia mangium</i>	2				
<i>Albizia procera</i>	1				
<i>Eucalyptus hybrida</i>	1				
<i>Mangifera indica</i>	1				
<i>Mimusops elengi</i>	1				

<i>Polyalthia longifolia</i>	1				
<i>Schima wallachii</i>	1				
<i>Tamarindus indica</i>	1				
Unknown	1				

Important Value Index (IVI)

Important Value Index (IVI) represents how dominant a species is in a forest. From our estimation, we saw Garjan (*Dipterocarpus turbinatus*) was the most dominant tree species. Champa (*Magnolia champaca*) was the second dominant one where Sal (*Shorea robusta*) placed the third one. For sapling the most dominant species was Bet (*Calamus longisetus*), then Garjan (*Dipterocarpus turbinatus*) was the second most important sapling species (Table 3).

Table 3: Calculated Important Value Index (IVI) for Tree and Sapling Species for Quantifying Ecological Importance of Species

Tree Scientific name	IVI	Sapling scientific name	IVI
<i>Dipterocarpus turbinatus</i>	72.65	<i>Calamus longisetus</i>	182.06
<i>Magnolia champaca</i>	42.21	<i>Dipterocarpus turbinatus</i>	34.61
<i>Shorea robusta</i>	41.97	<i>Artocarpus chama</i>	17.84
<i>Artocarpus chama</i>	37.93	<i>Hibiscus rosa-sinensis</i>	12.84
<i>Lagerstroemia speciosa</i>	23.74	<i>Areca catechu</i>	8.92
<i>Delonix regia</i>	18.56	<i>Polyalthia longifolia</i>	8.92
<i>Aquilaria nmalaccensis</i>	10.43	<i>Baccaurea motleyana</i>	6.96
<i>Elaeocarpus serratus</i>	7.88	<i>Diospyros malabarica</i>	6.96
<i>Tectona grandis</i>	6.2	<i>Ficus racemosa</i>	6.96
<i>Barringtonia acutangula</i>	5.97	<i>Magnolia champaca</i>	6.96
<i>Areca catechu</i>	4.94	<i>Mimusops elengi</i>	6.96
<i>Averrhoa carambola</i>	4.06		
<i>Swietenia mahagoni</i>	3.43		
<i>Acacia mangium</i>	2.79		
<i>Albizia procera</i>	2.15		
<i>Eucalyptus hybrida</i>	2.15		
<i>Mangifera indica</i>	2.15		
<i>Mimusops elengi</i>	2.15		
<i>Polyalthia longifolia</i>	2.15		
<i>Schima wallachii</i>	2.15		
<i>Tamarindus indica</i>	2.15		
Unknown	2.15		

Species Diversity Index

With the help of different biological diversity, we estimated the richness and abundance of the species of the eco-park as it is the prior criteria for considering an ecosystem for conservation. We mentioned all the diversity of the species that we found in our study area (Table 4). Simpson diversity index measure both richness and abundance of species in a forest. It ranges from 0 to 1. The higher the value the greater the diversity is. Here, Simpson diversity index for tree was 0.86, sapling was 0.45 and seedling was 0.68. So, it can be said that here tree diversity was in higher level of condition, sapling diversity was in moderate to lower condition and seedling diversity was moderate condition.

Shannon diversity index also tells us about the forest richness and abundance condition of species. This index range is 1.5 to 3.5. The high value indicates high diversity. Shannon diversity index for tree, sapling and seedling was 2.27, 1.08 and 1.37, respectively. From this value it can be said that tree diversity was in high, sapling was in moderate to lower and seedling was in moderately good conditions. Evenness index is the relative abundance of species in a forest. Evenness index range is 0 to 1.1 means perfect evenness and 0 is perfect unevenness. Here, the evenness index was for tree, sapling and seedling 0.73, 0.24 and 0.36 respectively. It can be said that tree was in more even condition than sapling and seedling in this area. From the rank abundance curve (Figure 2), it was evident that Garjan (*Dipterocarpus turbinatus*) was the most abundant tree and seedling species where Bet (*Calamnus longisetus*) was the most abundant sapling species in the study area.

Table 4: Species Diversity Indices of the Study Area

Parameter	Tree	Sapling	Seedling
Taxa_S	22	11	10
Individuals	314	102	935
Simpson_1-D	0.8629	0.4498	0.6837
Shannon_H	2.273	1.087	1.368
Evenness_e^H/S	0.735	0.2354	0.3572

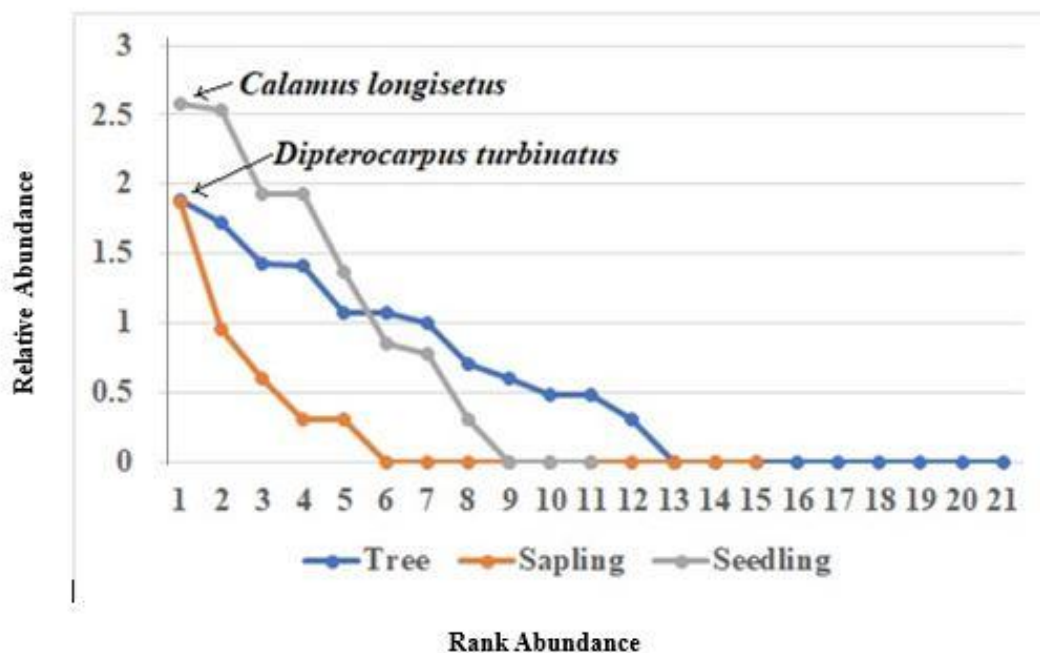


Figure 2: Rank Abundance curve for Tree, Sapling and Seedling species representing the community structure of the study area

3.4 Non-metric Multidimensional Scaling (NMDS) Analysis

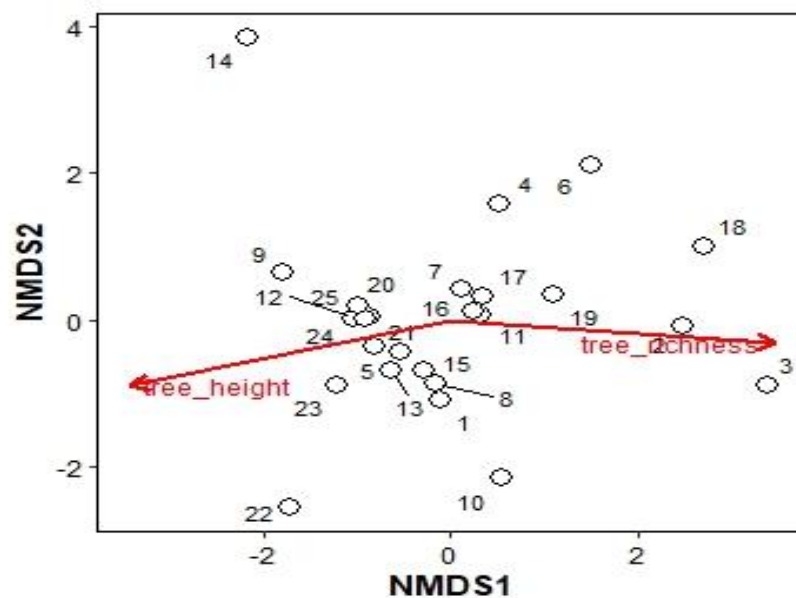


Figure 3: Nonmetric Multidimensional Scaling (NMDS) Ordination for multivariate species composition analysis

The NMDS analysis illustrates the diverse pattern among all the factors in the study site. It is used generally to rank among factors based on their similarities and differences. The stress value 0.13 which is lower than 0.2 indicates the reliability of the analysis. From the graph, it can be seen that tree height and tree richness were the major two drivers of seedling community (figure 3). Among these two factors, tree height had the strongest effect on seedling establishment ($r^2 = 0.30$, $p = 0.020$) as well as tree richness had the significant effect on them ($r^2 = 0.29$, $p = 0.035$). Alternatively, elevation had shown non-significant trend on seedling species ($r^2 = 0.21$, $p = 0.080$) along with the factors like basal area $r^2 = 0.13$, $p = 0.23$, canopy coverage $r^2 = 0.09$, $p = 0.35$ of each plot, canopy height $r^2 = 0.06$, $p = 0.48$, tree abundance $r^2 = 0.005$, $p = 0.95$, sapling richness $r^2 = 0.10$, $p = 0.29$, sapling abundance $r^2 = 0.12$, $p = 0.24$, sapling average height $r^2 = 0.02$, $p = 0.79$ on regenerating species.

Generalized Linear Model (GLM) Analysis

We implied the generalized linear model (Poisson and negative binomial negative family distribution, respectively) to examine the effect of ecological variables on seedling richness and seedling abundance (figure 4). The model for explaining the effect of variables on seedling richness explained a substantial proportion of variation in regeneration (null deviance = 33.04, residual deviance = 7.55) which indicated a strong fit. In contrast, the model for seedling abundance showed best fit after reducing collinearity (null deviance = 49.34, residual deviance = 28.27).

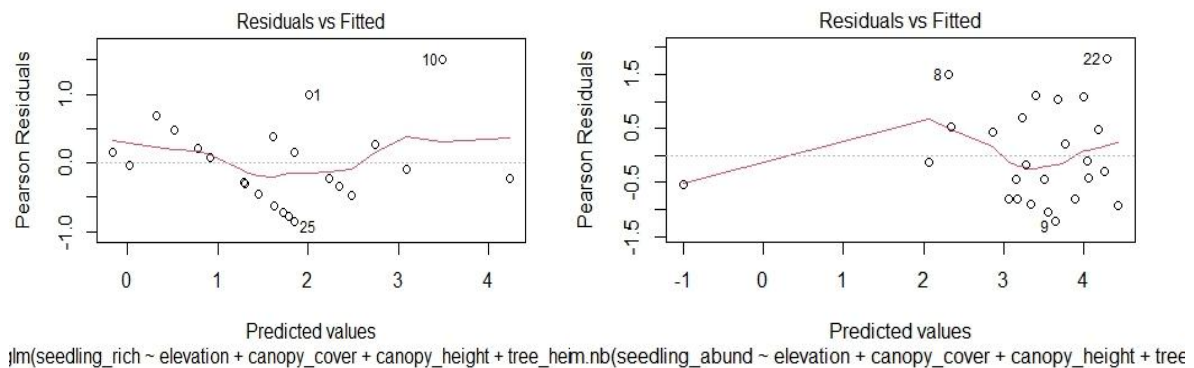


Figure 4: Generalized Linear Model represents specific effect of variables on regeneration

According to the GLM model it was seen that tree richness ($p = 0.02$), tree abundance ($p = 0.04$), sapling richness ($p = 0.01$) and sapling abundance ($p = 0.04$) had significantly affect the seedling richness. The other factors like elevation ($p = 0.62$), canopy coverage ($p = 0.12$), canopy height ($p = 0.97$), tree height

($p = 1.18$), tree diameter ($p = 0.68$), basal area ($p = 0.71$), sapling height ($p = 0.32$) and sapling diameter ($p = 0.51$) had no significance on the seedling richness of the study area. After reducing collinearity, elevation ($p = 0.07$), tree diameter ($p = 0.06$) and basal area ($p = 0.05$) showed marginally significant to seedling abundance. As well as, other variables including canopy coverage ($p = 0.11$), canopy height ($p = 0.33$), tree height ($p = 0.34$), tree richness ($p = 0.17$), tree abundance ($p = 0.97$), sapling height ($p = 0.19$), sapling diameter ($p = 0.46$), sapling richness ($p = 0.11$), sapling abundance ($p = 0.12$) had no significant effect on seedling abundance.

Discussion

The study had been conducted in the Tilaghor Eco-park which is considered as a major recreational eco-tourism site for the northern region of Bangladesh. It appeared that *Dipterocarpus turbinatus* solely dominate the forest in terms of number of trees and seedlings. Though, earlier studies claimed other species had high IVI rate than *Dipterocarpus turbinatus* (Alamgir and Al-Amin 2007, Rahman et al. 2011) in this region. Reportedly, this region was dominated by species like *Shorea robusta* and *Dipterocarpus turbinatus* (Choudhury 2004). In addition, trees and seedlings diversity were mentionable according to our analysis. The number of tree species was lower than the number mentioned in Rahman et al. (2011). Besides, the number of tree species and diversity of natural regeneration species in this place was lower than the other forests of the Sylhet region (Rahman et al. 2011, Sultana & Rahaman 2019). Moreover, the amount of tree species was noticeably poor than the other region of hill forests of Bangladesh (Baul et al. 2022, Alamgir & Al-Amin 2007). The correlation among seedling richness and seedling abundance with 10 habitat drivers had been examined where we found that tree height and tree richness were mostly influenced seedling richness as well as seedling abundance.

Species Composition and effect of dominant species on regeneration

From our findings, we enlisted 22 tree species, 11 sapling species and 10 seedling species. There is no such documentation of consistent plantation program in the studied eco-park after 1922 (Choudhury 2004). Although the area is considered as potential region for eco-tourism and biodiversity conservation, it is in threat of edge effect and urbanization (Choudhury 2004). We concluded that *Dipterocarpus turbinatus* was the major tree and regenerating species in this eco-park. This finding represented the effect of dominant species in regeneration establishment. Previously, Singh et al. (2018) mentioned dominant species showed good regeneration quantity where it is either the dominant one or associated

1 with other co-dominant species. Pham et al. (2022) also mentioned that about 70% overstorey species
2 generated offspring in the forest. Whereas, Bartha (2014) mentioned the effect of dominant species on
3 regeneration species that it has negative effect on species diversity. In the study plots, there had been
4 seen a few or no regenerations where saplings of Bet (*Calamnus longisetus*) were abundant. This
5 degradation in sapling diversity was a clear statement that this forest would be less diverse in near
6 future. Lesser number of regeneration species indicated that immediate conservation measurement
7 should be taken in this forest. We also suggest that continuous plantation program as well as assisted
8 natural regeneration (ANP) program can contribute in ensuring the diversity of the eco-park.

10 ***Effect of tree height and tree richness on regeneration***

11 According to the outcomes, seedling richness and abundance had significantly influenced by tree height
12 and richness. This situation suggested that these factors had mentionable effect on regeneration by
13 changing microclimate. We observed tree height can influence the regeneration dynamics through litter
14 deposition, fluctuation of temperature and light. This finding contradicted with the results of Hammond
15 et al. (2021) that claimed there was no significant relationship between regeneration and average height
16 of trees. We found the other habitat factors basal area, canopy coverage of each plot, canopy height,
17 elevation, tree abundance, sapling richness, sapling abundance, sapling average height had no effect on
18 regeneration. De Lombaerde et al. (2019) also said understory and over story species competition is
19 more important than species abundance. However, Singh et al. (2016) showed that understory species
20 has minimal role in regeneration abundance. In addition, we found that tree richness played major role in
21 regeneration species diversity (figure 3). Tree richness could help regeneration process by varying
22 habitat heterogeneity, patchy soil nutrient conditions and seed availability. Besides, we found that all the
23 tree species were not showing for regeneration that is similar with the study done by Rahman et al.
24 (2011).

25 From the NDMS analysis it was seen that, factors like basal area, canopy coverage of each plot, canopy
26 height, tree average height, sapling richness, sapling abundance, sapling average height did not have any
27 significance on seedling richness and abundance. Our result supported the previous findings by Cazzolla
28 Gatti et al. (2017) who stated that canopy height does not have any correlation with species richness. In
29 their studies, they claimed canopy gap has immense effect on species richness as well as diversity
30 because it influences the radiation and precipitation. On the other hand, the GLM analysis showed
31 different results which indicated seedling richness had affected by the tree richness, tree abundance,

sapling richness and abundance. Tree richness and sapling richness influenced the seedling richness positively where tree abundance and sapling abundance negatively influenced the regeneration richness which could be density dependent suppression. The other factors had no significance on tree richness. In contrast, seedling abundance had marginally influenced by the elevation, tree diameter and basal area. The results showed positive interaction with elevation and tree diameter reflected the possibility of reducing disturbance as well as canopy gaps created by large trees. McIntire et al. (2016) showed among the several concurrent factors, elevation plays negligible role by dropping temperature in limiting seedling abundance. Our study supports the findings of Cagnacci et al. (2020) and Sharma et al. (2018) who claimed the effect of topography always has been a major factor for regrowth of species. All the other factors showed zero impact on seedling abundance.

Conclusion

The result of the current study shows the state of regeneration in Tilaghor Eco park regenerating species and their relationship with several micro-environmental habitat factors. As Tilaghor Eco park is situated within Sylhet City Corporation area, as an urban forest it is getting attention now-a-days to conserve and understand the value of forestry. The study assessed that the tree height, tree richness of the park has significant effect on its regeneration composition. Moreover, the maintenance of the existing tree richness is important to make the regeneration successful and sustainable. Thus, proper care should be given to all existing species to remain in good condition. As a part of urban area this eco-park plays a vital role for recreation and research purposes. This study will help the management authority to better understand the regeneration process of the forest and promote their importance of conservation. Further study on the management system can be done to modify microclimates for better regeneration in this site. Our study did not analyze the soil properties and anthropogenic influence of the eco park which limited our understanding about the soil and disturbance effects on natural regeneration. We also suggest further studies on these factors to understand the regeneration dynamics of the eco park.

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Declarations

Ethical Approval: Not applicable.

Consent to participate: Not applicable.

Consent to publish: Not applicable.

Name of plant/plant part identifier: Species identification was carried out by the first author Lubaba Noshin and co-operated by Kazi Mohammad Masum

Permission statement: Permission to conduct field survey and collect data was obtained from the Bangladesh Forest Department (Attached as related file).

Plant guidelines: This study was based on non-destructive field observations. No protected species or plants were collected. The research complied with Bangladesh forest and biodiversity conservation regulations named 'Bangladesh Biodiversity Act 2017'.

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Data availability

All data generated or analyzed during this study are included in this published article.

The authors declare no competing interests.

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