Assessment of natural regeneration status: the case of Durgapur hill forest, Netrokona, Bangladesh

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ABSTRACT
Enumeration of regeneration status is an authentic tool to know the actual condition of forest ecosystem. The study was conducted to assess the regeneration status of Durgapur hill forest following stratified random sampling method (2 m × 2 m quadrate) from October 2017 to May 2018. A total of 27 species under 18 families were recorded from the study area. The study revealed maximum (37.78) family importance value (FIV) index was recorded for Euphorbiaceae followed by Moraceae (16.09). Importance value index (IVI) of Grewia nervosa was maximum (23.97 out of 300) followed by Shorea robusta (21.02), and Aporosa wallchii (20.19). Conservation status showed highest (77.78%) plant species were in least concerned (LC) where only one species (Dillenia pentagona) was found as data deficient (DD) category. Seedlings of different height classes showed maximum (33.2%) seedling were within the height range of 50–100 cm. However, different biological diversity indices, i.e., Shannon–Winner index (H) (4.27), species evenness index (E) (1.30), Simpson index (D) (0.15), and Margalef’s species richness index (4.24) were enumerated to know the complete diversity condition of the forest area. Hierarchical cluster of the recorded species also showed that Grewia nervosa is the most dominant species in that area.

Introduction
Tropical forests are the most diverse and complex ecosystems on earth, and are also the most vulnerable and threatened habitats for species (Carson & Schnitzer, 2011; Deb, Roy, & Wahedunnabi, 2015; Sarker, Deb, & Halim, 2011; Schmidt, 2007). In several tropical forests, logging has been reported to have a negative impact on the natural regeneration of commercial and highly valuable rare species (Grogan et al., 2008; Hawthorne, Sheil, Agyeman, Juam, & Marshall, 2012; Schulze, Grogan, Uhl, Lentini, & Vidal, 2008). Therefore, tropical forestry is confronted today with the task of finding suitable strategies and techniques to enhance forest regeneration and restore abandoned lands (Deb et al., 2015; Montagnini & Jordan, 2005).

The total area of Bangladesh’s hill forests is 6,70,000 ha spreading over the region of the Chittagong, Cox’s Bazar, Sylhet and Chittagong Hill Tracts where 44% of these managed by the Forest Department (Khan, Uddin, Chowdhury, & Mukul, 2007). Countries forest inventory indicated a growing stock of 23.93 million cubic meters of wood with rich faunal diversity conserve by the hill forests area (Rana et al., 2009; Roy, 2004). Traditionally, the management approach of those forests was clear felling followed by artificial regeneration of valuable species. Nowadays, the forest management in different hill forest Divisions is totally based on a participatory approach (Chowdhury, 2006). Nevertheless, Bangladesh Forest Department still lacks the resources capabilities for sustainable management of such forest area (Sayed, 2017).

Limited tree regeneration creates a major threat to forests which makes the opportunity to clearing for agricultural expansion (McDermott, Cashore, & Kanowski, 2010; Pröpper et al., 2010; Rudel, 2013). However, the knowledge base of plant regeneration status helps in developing management options and setting priorities (Haider, Alam, & Mohiuddin, 2017; Zegeye, Teketay, & Kelbessa, 2011). Regeneration is essential for conservation and maintenance of biodiversity in natural forests (Hossain, Rahman, Hoque, & Alam, 2004; Rahman, Khan, Roy, & Fardusi, 2011). Hence, forest natural regeneration is a natural biological process of forest resource restoration in ecosystem dynamics (Wang, Li, Yu, & Chen, 2008) which involves asexual and sexual reproduction, dispersal and establishment in relation to environmental factors (Barnes, Zak, Denton, & Spurr, 1997). During this process tree dominant plant communities developed and evolved, which has far-reaching impact on the structure of forest in the future (Han & Wang, 2002).

Durgapur hill forest is one of the remnant places of Sal forest patches in Bangladesh where economically and ecologically valuable tree species are needs to be prioritized for conservation and scientific management.
The forest has been cleared brutally within the last 30 to 50 years as the demand for energy, construction, wood, food, fodder has increased as a result of the increase in both human and livestock. The main causes of deforestation and forest degradation in this area were tree cutting for fuelwood, and construction materials production for sale especially. A number of studies are available focused on natural regeneration status in different natural forests of Bangladesh provide potential information for many native tree species (Haider et al., 2017; Hossain, Hossain, Salam, & Rahman, 2013; Hossain, Azad, & Alam, 1999; Hossain & Hossain, 2014; Motaleb & Hossain, 2007; Miah, Udin, & Bhuiyan, 1999; Nur, Nandi, Jashimuddin, & Hossain, 2016; Rahman, Rahman, Chowdhury, & Akhter, 2019; Rahman et al., 2011) and diversity in forest (Chowdhury, Islam, Hafig, & Islam, 2018; Rahman et al., 2019), but research work on regeneration aspect of forest is not available where Durgapur hill forest lacks information regarding natural regeneration, stocking, and conservation issues. This study will enrich the knowledge of natural regeneration and quantitative distribution of plant species in the case of hill forest which may be useful in providing guidelines for future management of forest.

**Materials and methods**

**Study site**

Durgapur is surrounded by Meghalaya state of India on the north, Purbadhala and Netrokona Sadar on the south, Kalmakanda on the east, and Dhobaura sub-district on the west. The study was conducted during October 2017 to May 2018. Durgapur Upazila (small city) of Netrokona District, having an area of 293.42 square kilometers and consists of seven Unions. The study area is located in the most northern part of Durgapur, having the coordinates of 25°7’30” N and 90°41’18” E (Wiki, 2018) (Figure 1). Topographically, the study area is characterized by its large hillocks, known as “tilla” with irregular plain land. The soil pH fluctuates from 6 to 6.5 (Rashid, 1991). The highest temperature reaches to 30°C during May and coldest to around 10°C during January where the annual rainfall in this area is 2712 mm (CLIMATE-DATA.ORG, 2019). However, the temperature here averages 25.2°C and most of the precipitation here falls in June, averaging 581 mm (Figure 2).

**Data collection**

The study area was visited prior to the fieldwork in 2017, to have a general idea of the site, topography, accessibility, and species composition. A complete stratified random quadrat method was adapted for this study. Where, a total of 42 sample plots (2 m × 2 m) were laid within the study area for the assessment of regeneration. Regenerated trees having ≤2 cm diameter at breast height (DBH) was considered as seedlings. Seedlings of all species in each plot were identified and recorded by local and scientific names. The common tree species were identified directly in the field, while the fertile samples of the unknown tree species were collected for the preparation of herbarium specimens. Collected plant specimens were dried in the sun following standard scientific method. Consultation was done with published journals and reference book like (Prain, 1903; Uddin, Hassan, Rahman, & Arefin, 2012) and Encyclopedia of Flora and Fauna of Bangladesh (Ahmed et al., 2008) to determine the unknown

![Figure 1. Study area map of Durgapur, Netrokona District.](image-url)
species. Taxonomist from the Institute of Forestry and Environmental Sciences, University of Chittagong (IFESCU) and the Bangladesh Forest Research Institute (BFRI) also helped for species identification.

### Analysis of field data

For many years, species richness, various diversity indices, species density, stem density, species importance value index are used to assess population dynamics and their diversity (Gimaret-Carpentier, Pelissier, Pascal, & Houllier, 1998). The field data were compiled and analyzed for family relative density (FD%), family relative diversity (Fr%), family importance value (FIV), density, relative density (RD%), frequency, relative frequency (RF%), abundance, relative abundance (RA%), and importance value index (IVI). The equations (1–10) used for calculating phytosociological characters are listed in Table 1. However, the equations (1–7) used for calculating floral diversity indices are listed in Table 2. Conservation status of regenerating trees of Durgapur was assessed following the Encyclopedia of Flora and Fauna of Bangladesh (Ahmed et al., 2008). In addition, to determine the dominance of regenerating seedlings, hierarchical cluster analysis was done using computer software package SPSS (version 23).

Species diversity index \( (S_D) \) starts from 1 when there is only one individuals of one species, the value reach to maximum with the increase of species number (Odum, 1971). Margalef’s index \( (R) \) is high in communities that include a greater number of species and in which the number of individuals of each species decreases relatively slowly on passing from more abundant to less abundant ones (Margalef, 1958). Shannon–Wiener diversity index value is maximum when the number of individuals of all species is equal; value is zero if there is only one species (Michael, 1984). With Simpson’s diversity index \( (D) \), 0 represents infinite diversity and 1, no diversity. Simpson’s diversity index is neither intuitive nor logical, so get over the problem, \( d \) is often subtracted from 1 to give Dominance of Simpson’s index \( (D^\prime) \). The value of this index also ranges between 0 and almost 1, but now, the greater the value, the greater the sample diversity (Magurran, 1988). With increase the value, the greater the diversity. The maximum value is the number of species (or other category being used) in the sample. Species Evenness index \( (E) \) also known as Shannon’s equitable index, assumes a value between 0 and 1 with 1 being complete evenness (Pielou, 1966).

![Figure 2. Mean annual precipitation and temperature at Durgapur.](image)

**Table 1. The list of equations used for calculating phytosociological characters of the vegetation.**

| Phytosociological attributes                | Formula                   | Equation No | References                                      |
|---------------------------------------------|----------------------------|-------------|------------------------------------------------|
| Family relative density (Fd)                | \( Fd = \frac{n}{b} \times 100 \) | 1           | (Mori, Boom, & de Carvalino, 1983)             |
| Family relative diversity (Fr)              | \( Fr = \frac{n}{b} \times 100 \) | 2           | (Rahman et al., 2011)                          |
| Family importance value (FIV)               | \( FIV = Fd + Fr \)        | 3           | (Rahman et al., 2011)                          |
| Density (D)                                 | \( D = \frac{s}{b} \)      | 4           | (Shukla, 2000)                                |
| Relative density (RD)                       | \( RD = \frac{s}{b} \times 100 \) | 5           | (Dallmeier, Kabel, & Rice, 1992; Misra, 1968) |
| Frequency (F)                               | \( F = \frac{s}{b} \)      | 6           | (Shukla, 2000)                                |
| Relative frequency (RF)                     | \( RF = \frac{n}{\sum f_i} \) | 7           | (Dallmeier et al., 1992; Misra, 1968)         |
| Abundance (A)                               | \( A = \frac{n}{b} \)      | 8           | (Shukla, 2000)                                |
| Relative abundance (RA)                     | \( RA = \frac{n}{\sum f_i} \) | 9           | (Misra, 1968)                                |
| Importance value index (IVI)                | \( IVI = RD + RF + RA \)    | 10          | (Misra, 1968; Shukla, 2000)                   |

\( n \): number of individual in a family; \( b \): total number of individuals; \( s \): number of species in a family; \( f_i \): total number of species; \( a \): total number of individuals of a species in all the quadrats; \( b \): total number of quadrats studied; \( n \): total number of individuals of the species; \( N \): total number of individuals of all the species; \( c \): total number of quadrats in which the species occurs; \( b \): total number of quadrats studied; \( Fi \): frequency of one species; \( Ai \): abundance of one species.
Table 2. The list of equations used for calculating biodiversity indices of the vegetation.

| Biodiversity indices               | Formula                                | Equation No. | References |
|------------------------------------|----------------------------------------|--------------|------------|
| Species diversity index ($S_d$)    | $S_d = \frac{S}{N}$                     | 1            | (Odum, 1971) |
| Shannon-Wiener’s diversity index (H) | $H = - \sum_{i=1}^{n} P_i \ln P_i$     | 2            | (Michael, 1984) |
| Shannon’s maximum diversity index ($H_{max}$) | $H_{max} = \ln (S)$                | 3            | (Kent, 2011) |
| Margalef’s species richness index (R) | $R = \frac{(S-1)}{\ln n}$             | 4            | (Margalef, 1958) |
| Simpson’s diversity index (D)      | $D = - \sum_{i=1}^{n} P_i^2$            | 5            | (Magurran, 1988) |
| Dominance of Simpson’s index (D')  | $D' = 1 - D$                           | 6            | (Magurran, 1988) |
| Species (Pielou’s) evenness index (E) | $E = \frac{H}{H_{max}}$               | 7            | (Pielou, 1966)  |

H: Shannon–Wiener’s diversity index; N: total number of individuals of all the species; Pi: number of individuals of ith species/total number of individuals in the samples; S: total number of species; n is the number of individuals of each species.

Results

Regeneration status of tree species observed in Durgapur hill forest

A total of 462 seedlings of 27 species under 18 families were recorded from DHF where maximum five species was found for Euphorbiaceae family followed by Moraceae (3) (Table 3). Highest (19.26%) family relative density was represented by Euphorbiaceae followed by Tiliaceae (10.61%) whereas maximum (18.52%) family relative density index found for Euphorbiaceae followed by Moraceae (11.11%). Similar trends of result showed for family importance value (FIV) index where Euphorbiaceae found maximum (37.78%) followed by Moraceae (16.09), Mimosaceae (15.42), and Caesalpinia (14.98) (Table 3).

Quantitative characters of naturally regenerating tree species of Durgapur hill forest

The quantitative structure of naturally regenerating tree species in the Durgapur hill forest was studied

Table 3. Family composition, number of species, number of individuals under each family, family relative density (FRD), family relative diversity (FRDI), and family importance value (FIV) index of the regenerating trees in Durgapur hill forest.

| SI No. | Family            | No. of seedling | Species No. | FRD (%) | FRDI (%) | FIV  |
|--------|-------------------|-----------------|-------------|---------|----------|------|
| 1      | Annonaceae        | 5               | 1           | 1.08    | 3.70     | 4.79 |
| 2      | Apocynaceae       | 19              | 1           | 4.11    | 3.70     | 7.82 |
| 3      | Bombacaceae       | 16              | 1           | 3.46    | 3.70     | 7.17 |
| 4      | Caesalpinia       | 35              | 2           | 7.58    | 7.41     | 14.98|
| 5      | Combretaceae      | 14              | 1           | 3.03    | 3.70     | 6.73 |
| 6      | Dilleniaceae      | 9               | 1           | 1.95    | 3.70     | 5.65 |
| 7      | Dipterocarpae     | 38              | 1           | 8.23    | 3.70     | 11.93|
| 8      | Euphorbiaceae     | 89              | 5           | 19.26   | 18.52    | 37.78|
| 9      | Lauraceae         | 26              | 1           | 5.63    | 3.70     | 9.33 |
| 10     | Lecythidaceae     | 7               | 1           | 1.52    | 3.70     | 5.22 |
| 11     | Lythraceae        | 7               | 1           | 1.52    | 3.70     | 5.22 |
| 12     | Mimosaceae        | 37              | 2           | 8.01    | 7.41     | 15.42|
| 13     | Moraceae          | 23              | 3           | 4.98    | 11.11    | 16.09|
| 14     | Myrtaceae         | 19              | 1           | 4.11    | 3.70     | 7.82 |
| 15     | Rhamnaceae        | 18              | 1           | 3.90    | 3.70     | 7.60 |
| 16     | Rubiaceae         | 29              | 2           | 6.28    | 7.41     | 13.68|
| 17     | Tiliaceae         | 49              | 1           | 10.61   | 3.70     | 14.31|
| 18     | Verbenaceae       | 22              | 1           | 4.76    | 3.70     | 8.47 |

on the basis of the conservation status, density, relative density, relative frequency, relative abundance and IVI. The regeneration study shows that the number of regenerating seedlings was found higher for G. nervosa (2916 seedlings/ha) followed by S. robusta (2261 seedlings/ha), and A. wallichii (2023 seedlings/ha) (Table 4). Maximum relative density (10.61%) was recorded for G. nervosa followed by S. robusta (8.23%), A. wallichii (7.36%), and A. polystachya (6.28%). Relative frequency of A. wallichii has the highest value (10.36%) followed by S. robusta (9.91%), G. nervosa (9.46%), and H. cordifolia (7.66%). However, the highest (5.50%) relative abundance was calculated for B. tomentosa followed by B. ceiba (5.35%), and Z. mauritiana (5.02%). G. nervosa had the maximum IVI (23.97) followed by S. robusta (21.02), A. wallichii (20.19), H. cordifolia (15.84), and A. polystachya (15.72) (Table 4).

In addition, all the recorded plants were found to be represented by five conservation categories, viz. conservation dependent (CD), data deficient (DD), least concern (LC), not evaluated (NE), not evaluated but seems to be rare (NE but rare). A total of 77.78% plant species (21 species out of 27) were found as LC which represents maximum plant species among all the categories. Only one species (D. pentagyna) conservation status was found in DD category. Moreover, NE and NE but rare plant species were represented by 3.7% and 7%, respectively. Eventually, there were not a single species found which may fall either vulnerable or rare category.

Distribution of seedlings into different height classes

Stratification of regenerated species considering their height indicates the extent of ecological functioning and diversity in the study area. The percentage distribution of all the recorded seedlings of all species is shown in six height (cm) classes, viz. 0–<50 cm, 50–<100 cm, 100–<150 cm, 150–<200 cm, 200–<250 cm, 250–<300 cm. The study revealed maximum (33.2%) seedlings were within a height range of 50–<100 cm whereas
Table 4. Conservation status, seedlings per hectare, relative density (RD), relative frequency (RF), relative abundance (RA), importance value index (IVI), and conservation status of the regenerating tree species of the Durgapur hill forest.

| SL No. | Local name          | Scientific name          | Conservation status | Seedling/ha | RD (%) | RF (%) | RA (%) | IVI |
|-------|---------------------|--------------------------|---------------------|-------------|--------|--------|--------|-----|
| 1     | Chatian             | Alstonia scholaris (L.) R. Br. | LC                  | 1131        | 4.11   | 4.50   | 3.18   | 11.79 |
| 2     | Pitraj              | Aphanamixis polystachya (Wall.) R.N. Parker. | LC                  | 1726        | 6.28   | 5.41   | 4.04   | 15.72 |
| 3     | Kharjon             | Aporosa wallichii Hook.f. | LC                  | 2023        | 7.36   | 10.36  | 2.47   | 20.19 |
| 4     | Borta               | Arctocarpus loucha L.    | LC                  | 535         | 1.95   | 2.25   | 3.01   | 7.21  |
| 5     | Chokakola           | Bauhinia malabarica Roxb. | LC                  | 475         | 1.73   | 2.70   | 2.23   | 6.66  |
| 6     | Kanjai bhadri       | Bischofa javanica Blume  | LC                  | 476         | 1.73   | 1.35   | 4.46   | 7.54  |
| 7     | Shimal              | Bombax ceiba L.          | LC                  | 952         | 3.46   | 2.25   | 5.35   | 11.07 |
| 8     | Sitri               | Bridelia tormentosa Bl.   | LC                  | 1369        | 4.98   | 3.15   | 5.30   | 13.63 |
| 9     | Bormala             | Callicarpa arborea Roxb.  | LC                  | 1309        | 4.76   | 4.05   | 4.09   | 12.90 |
| 10    | Gadilla             | Careya arborea Roxb.      | NE                  | 416         | 1.52   | 1.35   | 3.90   | 6.77  |
| 11    | Sonali              | Cassia fistula L.         | LC                  | 1607        | 5.84   | 5.41   | 3.76   | 15.01 |
| 12    | Ojha                | Cryptocarya myrdalina Nees. | NE but seems to be rare | 1547         | 5.63   | 4.50   | 4.35   | 14.48 |
| 13    | Hargoja             | Dillenia pentagona Roxb.  | DD                  | 535         | 1.95   | 1.80   | 3.76   | 7.51  |
| 14    | Dumur               | Ficus hispida L. f.       | LC                  | 654         | 2.38   | 2.25   | 2.23   | 6.66  |
| 15    | Datoi               | Grewia nervosa (Lour.) Panigr. | LC                  | 2916        | 10.61  | 9.46   | 3.90   | 23.97 |
| 16    | Haldio              | Haldina cordifolia (Roxb.) Ridsdale | CD                  | 1547        | 5.63   | 7.66   | 2.56   | 15.84 |
| 17    | Jarul               | Lagerstroemia speciosa (L.) Pers. | LC                  | 416         | 1.52   | 1.80   | 2.93   | 6.24  |
| 18    | Sinduri             | Mallotus philippensis (Lamk.) Muell.-Arg. | CD                  | 296         | 1.08   | 0.90   | 4.18   | 6.16  |
| 19    | Gandhi gajari       | Miluus velutina (Dunal) Hook. f. & Thom. | NE but seems to be rare | 298         | 1.08   | 1.35   | 2.79   | 5.22  |
| 20    | Kadam               | Neolamarckia cadamba (Roxb.) Bosser | LC                  | 178         | 0.65   | 0.45   | 5.02   | 6.12  |
| 21    | Amlaki              | Phyllanthus emblica L.    | LC                  | 1130        | 4.11   | 3.60   | 3.97   | 11.69 |
| 22    | Rain tree           | Samanea soman (Jacq.) Merr. | LC                  | 460         | 1.73   | 1.35   | 4.46   | 7.54  |
| 23    | Sal                 | Shorea robusta Roxb. ex Gaertn. f. | LC                  | 2261        | 8.23   | 9.91   | 2.89   | 21.02 |
| 24    | Sheora              | Strybals asper Lou.       | LC                  | 178         | 0.65   | 0.90   | 2.51   | 4.06  |
| 25    | Puti-jam            | Syzygium fruticosum DC.   | LC                  | 1130        | 4.11   | 5.41   | 2.65   | 12.17 |
| 26    | Bohera              | Terminalia bellica (Gaertn.) Roxb. | LC                  | 833         | 3.03   | 3.15   | 3.35   | 9.53  |
| 27    | Boroii              | Ziziphus mauritiana Lamk. | LC                  | 1071        | 3.90   | 2.70   | 5.02   | 11.62 |

CD: conservation dependent; DD: data deficient; LC: least concern; NE: not evaluated.

only (0.9%) seedling were found in (250–<300) cm range (Figure 3). It indicates recent disturbances to the regenerating materials in the early stages of the regeneration process. It may due to environmental stress, e.g., exposure to open sunlight, moisture deficient, and/or anthropogenic factors, e.g., grazing, firewood, and litter collection in dry seasons. Moreover, intensive collection of sapling and pole by local community for fencing purpose resulted in reduced the percentage of upper height classes.

**Biological diversity indices of regeneration species**

Enrich ecosystem with maximum species diversity contained high value of Shannon–Wiener diversity index, while a lower value indicates an ecosystem with less diversity (Das, Alam, & Hossain, 2018). Species richness is one of the obvious criteria in recognizing the significance of an area for conservation of biodiversity (Khumbongmayum, Khan, & Tripathi, 2005). Different biological diversity indices, i.e., species diversity index ($S_{D}$), Shannon–Winner index (H), Shannon’s maximum diversity index ($H_{max}$), species evenness index (E), Simpson’s diversity index (D), Margalef’s species richness index (R), and dominance of Simpson’s index (D) were studied for Durgapur hill forest to depict natural regeneration status of recorded tree species (Table 5). However, the results indicated that the regeneration recruitment of the study area was not adequate which may be due to effect of abiotic factors like, lower annual precipitation, increased grazing, and encroachments.

**Hierarchical cluster of the regenerating tree species based on the dominance**

The study revealed species of Durgapur hill forest are grouped into five hierarchical clusters based on their dominance in the study area (Figure 4). The study revealed G. nervosa is the most dominant species and
also the member of first cluster whereas *S. robusta*, and *A. wallichii* are the second most dominant species as well as the member of second cluster. Other species under this research form rest of the clusters (Figure 5). Therefore, it is obvious that all the dominated tree species are of natural origin, while indicates the importance of the forest for native tree diversity conservation.

Discussion

Natural regeneration of flora is critical to the sustainable management of tropical forests (Medjibe, Poulsen, Clark, & Mbani, 2014). Therefore, understanding the plant regeneration processes and dynamics is vital to planning and conveying the management activities (Mwavu & Witkowski, 2009; Puhlick, Laughlin, & Moore, 2012; Yang, Yan, & Liu, 2014). Present study revealed the number of naturally regenerating species (27) and family (18) was lower than that of similar natural forests of Bangladesh. Hossain et al. (2004) reported 64 naturally regenerating tree species from natural forests of Chittagong (south) Forest Division. Motaleb and Hossain (2007) recorded 29 regenerating tree species under 16 families from a semi-evergreen forest of Chittagong (South) Forest Division. Rahman et al. (2011) reported 55 regenerating tree species from Khadimnagar National Park and Tilagor Eco-Park. In addition, Deb et al. (2015) recorded the total regenerated understory species richness was 61 belonging to 27 families, but it is unsuitable to compare with their findings because they have considered not only seedlings but also treelets (2 cm ≤ DBH <10 cm). Besides, the regeneration composition is less than that is of Dudhpukuria-Dhopachari Wildlife Sanctuary (120 species), and Chunati Wildlife Sanctuary (105 species), (Hossain et al., 2013, 2004). Moreover, present study exceeds the findings of Nur et al. (2016) where, they found 36% of the tree species (17 out of 47) are regenerating in the study area, while majority of the tree species (64%) are not getting favorable conditions to regenerate. However, the conservation status of regenerated seedlings of current study is an agreement with the findings of Chowdhury, Hossain et al. (2018) where they found most of the plants were belonged to the Least Concerned (LC) category in Rangamati.

The study revealed height range of regenerating tree species in initial stage (0–<50 cm) is lower than second stage (50–<100), and the scenario is similar to Misbahuzzaman and Alam (2006) who reported highest (617) seedlings in height class 1–<2 m from natural forest of Sitakunda, Chittagong. It may be due to high rate of mortality of seedling in dry soil condition or human interference. Euphorbiaceae, Moraceae, Mimosaceae, and Caesalpiniaceae were found as dominant families probably because of higher regeneration potential and seed dispersal capability of their species and favorable conditions for regenerating in the study area.

According to Dhaulkhandi, Dobhal, Bhatt, and Kumar (2008), the density values of seedling are considered as regeneration potential of the species. Therefore, the study revealed *G. nervosa* (2916 seedlings/ha), *S. robusta* (2261 seedlings/ha), *A. wallichii* (2023 seedlings/ha), A. polystachya (1726 seedlings/ha), C. fistula (1607 seedlings/ha), and *H. cordifolia* (1547 seedlings/ha) were the most dominant regenerated species because of their profuse seed production. However, those results are comparable with the findings of Nur et al. (2016) where they found *Bursera serrata*, *Toona ciliata*, *Stereospermum chelonoides*, *Ficus hispida*, *

Table 5. Different biological diversity indices for regeneration in Durgapur hill forest.

| Sl. No. | Description | Total for DHF |
|---------|-------------|--------------|
| 1       | Species diversity index (\(S_D\)) | 0.06         |
| 2       | Margalef’s Species richness index (\(R\)) | 4.24         |
| 3       | Shannon–Winner index (\(H\)) | 4.27         |
| 4       | Shannon’s maximum diversity index (\(H_{max}\)) | 3.30         |
| 5       | Species evenness index (\(E\)) | 1.30         |
| 6       | Simpson’s diversity index (\(D\)) | 0.15         |
| 7       | Dominance of Simpson’s index(\(D_D\)) | 0.85         |

Figure 4. Agglomeration schedule coefficient to determine the number of cluster for regenerated seedlings.
Macaranga denticulata, Callicarpa macrophylla, and Syzygium fruticosum were dominating (higher numbers of seedlings/ha) among the regenerated tree species at Shitalpur Forest Beat of Chittagong North Forest Division.

The IVI values indicating overall dominance of the species in the study area (Das et al., 2018). Present study showed G. nervosa had the maximum IVI (23.97) value followed by S. robusta (21.02). However, Chowdhury, Hossain, Hossain, and Khan (2018) studied regeneration diversity of Rampahar Natural Forest Reserve in Rangamati South Forest Division, where they recorded the IVI values of regenerating tree species was highest in P. serratum (50.09) followed by B. ceiba (39.37).

Diversity indices indicate vital information about the composition and current status of vegetation in a study area (Chowdhury, Islam et al., 2018). The diversity indices, e.g., species diversity index (0.01), Species richness index (4.92), Shannon–Winner index (3.62), Shannon’s maximum diversity index (3.69), Species evenness index (2.26), Simpson index (0.03) and Dominance of Simpson index (0.97) reported by Rahman et al. (2011) from biodiversity conservation areas of Northeastern Bangladesh and is supported by present findings. However, Nandi (2014) observed less species diversity with trees under DBH > 6 cm category at the Sitakunda Botanical Garden and Eco-Park, Chittagong.

Cluster analysis of the current study showed G. nervosa is the most dominant species in the study area whereas, different ecological studies also find similar trend of results among the floral groups (Chowdhury, Islam et al., 2018; Erenso, Vegetati Marya, & Wendawek, 2014; Flinn & Lechowicz, 2008; Sajib & Uddin, 2016). In addition, the regeneration of the forest is affected not only by environmental factors but also by anthropogenic activities (De Cauwer, 2016; Kuma & Shibru, 2015). In Durgpur hill forest (DHF), some of the anthropogenic activities seriously observed during data collection e.g., introduction of alien invasive species, intentional fire, fuel wood collection, extensive litter collection were the threats to regenerating flora in the study area. Present study is in agreement with the findings of Deribe (2006) and Bharathi and Prasad (2015) where they revealed cutting of trees for charcoal production, constructing wood, fence, litter collection and mowing grasses for fodder and covering roof of house were very obvious in community

Figure 5. Hierarchical cluster of regenerated seedlings in Durgapur hill forest.
managed natural forest. Besides, Gunaga, Rajeshwari, and Vasudeva (2013) found greater protection leads to better regeneration in kaan forests and state-managed reserve forests in India. However, recent co-management initiatives and conservation program with the participation of local people at DHF area seem to be promising for biodiversity conservation.

Conclusion

Present study reveals that DHF possess moderate regeneration potentials for many economically and ecologically important tree species. There are many anthropogenic disturbances which may be lethargic for the occurrence and establishment of natural regeneration in this area. Besides, it came out from the observation that most of the people living close to the forest area are insolvent, so they hardly depended on forest for their livelihood. However, such kind of deleterious act must be stopped by hook or by crook; otherwise such remnant forest will loss its natural forest restoration capacity permanently. The study recommended that species that have low IVI should be given priority for conservation. Assisted natural regeneration (ANR) may be another alternative option for effective natural regeneration of DHF instead of converting this area to man-made plantations. Moreover, adequate information and knowledge on the sustainable management of existing and potential resources in the study area is not available. Therefore, the concern authority could play the leading role for the implementation of conservation measures while enhance further co-management and protection program involving the local people to ensure fruitful conservation practices.

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