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Natural Regeneration in Harvested and Unharvested Forest Plantations - Case Study in Chittagong University Forest, Bangladesh

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Abstract

This study was aimed to identify the dominant species establishing during regeneration, their species diversity and whether selection thinning could enhance the regeneration of secondary forest species. Chittagong University Forest was selected for the study and harvested and unharvested sites of forest plantations were demarcated and set 30 quadratic plots (3m × 3m) for each site. Ten percent selection thinning was done in harvested site although a little anthropogenic disturbance was noticed in both the plantations. Regenerations were identified into species level and their numbers were counted. Shannon-Weiner diversity index for unharvested plantation was 2.21 and it was 1.45 for harvested plantation. Species evenness index was recorded as 0.81 and 0.74 for unharvested and harvested plantation respectively. Both the plantations did not show significant difference in diversity of species. According to Important Value Index (IVI) the dominant species in the harvested site were *Acacia auriculiformis* followed by *Acacia mangium* and *Albizia lebbeck*. In the unharvested site IVI was the highest for *Acacia auriculiformis* followed by *Aphanamixis polystachya* and *Lagerstroemia speciosa*. In both the sites *Acacia auriculiformis* had significantly ($p<0.05$) higher number of regeneration in harvested plantation than those of unharvested plantations. Therefore, thinning has positive impact on natural regeneration and *Acacia auriculiformis* is the best for natural regeneration in plantations.

1. Introduction

Many studies have indicated the ability of forest plantations to foster the regeneration of woody species under their canopy and to catalyze the subsequent succession processes (Lugo, 1992; Bone et al., 1997; Fang & Peng, 1997; Feyera et al., 2002; Fimbel & Fimbel, 1996; Zegeye et al., 2011; Neelo et al., 2015). Moreover, forest plantations improve soil stability, soil nutrient status and soil organic matter content in the degraded lands (Jordan & Farnworth, 1982; Zegeye et al., 2011; Neelo et al., 2013). Although the catalytic role of plantations in enhancing woody regeneration and improving degraded lands has been extensively studied in many countries, the understanding of the process involved in catalyzing the regeneration is scarce.

The species composition of forests depends on the regeneration of forest species in space and time. Disturbances affect the abundance and composition of seedlings in the forest understory (Benitez-Malvido, 1998; Neelo et al., 2015). In the recent past, an interest in the development and management of mixed plantations and natural forests in degraded sites has been raised to understand the regenerative process that ensures maintenance of the community structure and ecosystem stability (Moravie et al., 1997; Neelo et al., 2013). As floristic and structural composition change, the competitive relationship of species may change with corresponding changes in opportunities for regeneration (Barker & Kirkpatrick, 1994).

The reforestation strategies adopted by a country depend inter alia upon the biophysical conditions and the socio-cultural environment of a particular country (Ahmed & Bhuiyan, 1994). Depending on the management objectives, it is important to maintain the process of forest renewal by appropriate natural and artificial regeneration. Under tropical conditions regeneration of forests by seeds or vegetative means is completed rapidly within a few months which results in high species diversity. Successful regeneration ensures ecosystem stability, efficiency and flexibility (Mukul, 2007; Neelo et al., 2013). In proper forest management, stands are never harvested without careful consideration on adequate regeneration rates (Islam, 2003). Plantations do not provide all the desirable demands for humans such as fuel wood, timber, food, cloth as well as to conserve the whole ecosystem and biodiversity of the forest (Ahmed et al., 1992).

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In plantation forest, light and moisture are essential elements for seedling establishment. More light will evaporate moisture resulting in less moisture content. Canopy gap varies according to the requirement of light for the plants. Natural forest sites also had higher mature tree, pole, sapling and seedling densities compared with planted forests (Chauhan et al., 2008). The importance of advanced regeneration has been highlighted in forest recovery after natural and human disturbances in the tropics (Higo, 1994; Zegeye et al., 2011). Various studies have shown that plantation of native or exotic timber species can increase biodiversity by promoting woody understory regeneration (Ashton & Hall, 1992; Zegeye et al., 2011; Neelo et al., 2015).

Quantitative comparisons of the contribution of different regeneration sources or the importance of different origins of regenerated trees are necessary for meeting forest recovery goals through appropriate and informed management practices (Kamada, 2004). However, studies to this end have not been fully performed. The highest number of regenerating tree individuals and the highest mean number of species were found in the understory of mixed plantations compared to mono plantations (Nelida & Florencia, 2002). Establishing timber plantations on degraded lands can facilitate forest succession by providing an understory environment favorable for native plant recruitment (Pickett, 1983; Lugo, 1992).

The plantations may facilitate forest succession through effects on soil fertility and understory microclimate (Pickett, 1983; Lugo, 1992; Fimbel & Fimbel, 1996). However, as difference in tree canopy structure affects light availability at the forest floor and subsequently regeneration process (Fimbel & Fimbel, 1996), the success of plantations in promoting native understory biodiversity depends partly on the tree species planted (Pickett, 1983; Fimbel & Fimbel, 1996; Zegeye et al., 2011). Tree regeneration has often been studied in the tropics after a disturbance has created a canopy gap which has generally concentrated on population or community level responses within gaps of varying size; often with an objective of explaining processes that affect tree species diversity in forests subject in small-scale disturbance (Denslow, 1987; Neelo et al., 2013).

Plantations attracted the attention of many tropical restoration ecologists; yet there has been little investigation of how plantation harvest affects subsequent forest regeneration. In Bangladesh both indigenous and exotic species are planted in degraded forest lands, roadsides, marginal lands etc. for conservation and commercial purposes. Leaving trees for longer time in a plantation may not be economically feasible for a particular area because competition increases and tree growth decreases in the long run. Cultural operations could be an option for managing ecosystem sustainability. There is little information on species that regenerate naturally in plantations and the effect of selection thinning on regeneration of species in plantations.

Despite the fact that plantation forestry has a long history in Bangladesh, the ecology of plantations and their management have not been extensively investigated. Natural regeneration is essential for preservation and maintenance of biodiversity. Depending on management objectives it is important to maintain the process of forest renewal through artificial and natural regeneration. Clear felling accelerates loss of seedlings and saplings as well as disturbs the natural condition for forest renewal (Haque et al., 1997). Therefore, for the sustainable management of forest plantations this study was intended to answer the questions (i) Which species regenerate dominantly in forest plantations in the southern part of Bangladesh and what are their diversities? (ii) Whether the forest plantations could catalyze the regeneration of secondary natural vegetation by adopting cultural operation like selection thinning?

2. Materials and Methods

2.1. Study Sites

University of Chittagong (lies approximately at the intersection of $91^{0}50´$ E and $22^{0}30´$ N) comprises of 1754 acres of beautiful hilly land of Hathazari Upazila (administrative area) in the district of Chittagong, Bangladesh (Osman et al., 2001; Khan et al., 2014). Tropical moist climate prevails in the area with distinct summer (March to May), monsoon (June to October) followed by a short, cool or dry winter (November to February). The mean annual maximum and minimum temperature are 30.9°C and 24.4°C respectively. The highest monthly rainfall occurs during the period from June to September with pre and post monsoon periods of rain during April, May and October, respectively. Average annual rainfall is to be 2687 mm.

Exotic and indigenous tree species were planted in the Chittagong University Forest since 1976. Most of those species, both exotic and indigenous, are also widely planted across the country as roadside plantation, in the degraded/marginal lands for quick recovery of forest cover, for woodlot plantations etc. The gently sloping hills are distributed within the campus area where the soils are sandy-clay-loam to clay-loam (Chowdhury et al., 2008; Khan et al., 2014). The brown hill soils (Rashid, 1991) are also moderately to strongly acidic and poorly fertile with pH <5.5, organic matter <2.0%, CEC <10 me/100g, BSP <40% (Osman et al., 2001; Akhtaruzzaman et al., 2014). The cycling of nutrients and decomposition of forest litter is limited due to removal of leaf, litter, regenerations by the nearby villagers (Chowdhury et al., 2008) for fuel purposes. The study plantations are semi-deciduous tropical mixed forest type. There are harvested and unharvested sites in the

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plantations. Selection thinning was done in harvested site as 10% intensity in the last two decades irrespective of maintaining regular interval. The plantations of Chittagong University Forests were mostly isolated from the natural forests by canals and departmental structures. Seed dispersal occurred in the plantations generally by wind.

2.2. Sample collection

Harvested and unharvested forest plantation sites were demarcated (Table 1, Figure 1) and thirty quadratic sample plots, each 3 × 3m, for every plantation site were set. Five locations for each type of plantation were identified and in each location six quadratic sample plots (3 × 3m) were set. The criteria for plot location depended on homogenous plantation, less anthropogenic disturbance and the suitability of the study to conduct in the field. Plots were laid out in different valleys, slopes and aspects. Within each plot, the species and number of regeneration with height classes ≤20 cm, >20-≤40 cm, >40-≤60 cm, >60-≤80 cm, >80-≤100 cm were counted. Equations 1-9 were used.

$$D = T / T_1, \quad (1)$$

$$RD = (D / D_1) \times 100, \quad (2)$$

$$F = (T_2 / T_1) \times 100, \quad (3)$$

$$RF = (F / F_1) \times 100, \quad (4)$$

$$A = T / T_2, \quad (5)$$

$$RA = (A / A_1) \times 100, \quad (6)$$

$$IVI = RF + RD + RA. \quad (7)$$

Shanon-Weiner Diversity Index,

$$H = -\sum P_i * \ln (P_i) \quad (8)$$

Evenness Index,

$$E_H = H / \ln(S) \quad (9)$$

Where, D is density of a species, T is total number of individuals of a species in all the quadrates, T_1 is total number of quadrates studied, D_1 is total density of all species, RD is relative density of a species, T_2 is total number of quadrates in which the species occurs, F is frequency of a species, RF is relative frequency of a species, F_1 is total frequency of all species, A is abundance of a species, RA is relative abundance of a species, A_1 is total abundance of all species and IVI is important value index of a species. S= species count, P_i = proportion of S made up of the ith species, E_H = Evenness index.

Table 1: Different plantation sites of Chittagong University Forest, Bangladesh

Major species in mixed plantation	Location at Chittagong University Campus	Site characteristics	Cultural operation
Acacia auriculiformis	East side of the University Godown	Very steep slope, medium hill	Harvested
Eucalyptus camaldulensis	Beside University play ground	Steep slope, medium hill	Harvested
Lagerstroemia speciosa	Water pump house of the University	Steep slope, medium hill	Unharvested
Tectona grandis	East side of the Science Faculty Cafeteria	Flat top, steep slope, high hill	Unharvested
Acacia mangium	West side of the Institute of Forestry and Environmental Sciences	Gentle slope, low hill	Harvested
Dipterocarpus turbinatus	South side of the Shahjalal Residential Hall	Steep slope, medium hill	Unharvested

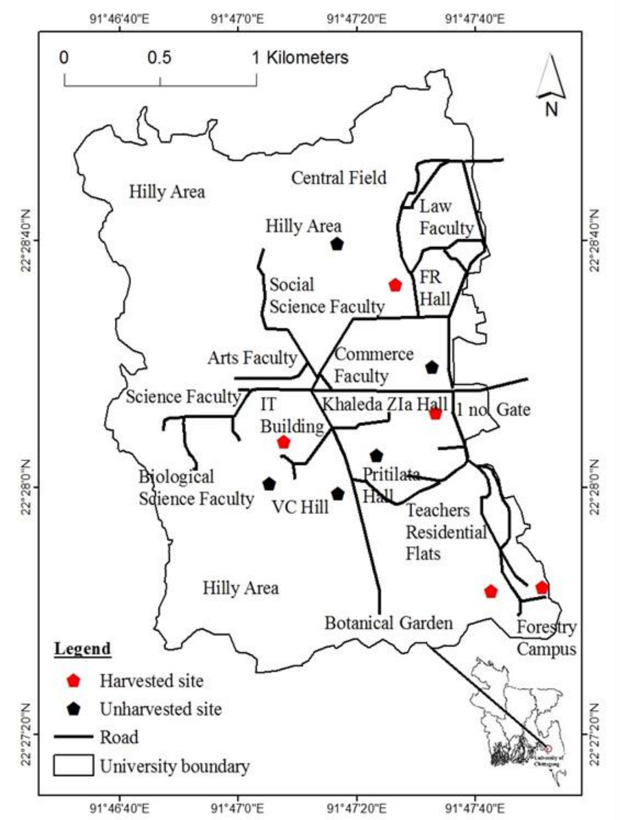

Figure 1: Map of study area showing harvested and unharvested sites at Chittagong University Forest, Bangladesh

2.3. Data Analysis

Data were analyzed by using different formulae in MS Excel and R 3.3.1 program. In order to know the performance of natural regeneration of common dominant species in both the sites, t-test was done for the total number of common dominant species between harvested and unharvested plantations at $\alpha=0.05$. Whether there is significant difference of species regeneration between the plantation sites paired t-test was also conducted for total number of regeneration at different height classes for all the species of harvested and unharvested plantations.

3. Results and Discussion

In the unharvested plantations of the Chittagong University Forest it was evident that there were 15 tree species regenerated while it was 7 species in the harvested plantations (Table 2 and 3). The number of regenerated species varied with the number of species planted in the forest ecosystem while other factors influencing the success of regeneration remain favorable. Among the plantation species *Acacia auriculiformis* and *Albizia saman* were widely planted in Bangladesh and they showed rigorous seed production and germination. *Acacia auriculiformis* ranked the highest IVI (59.1%) followed by *Aphanamixis polystachya* (48.1%) and *Legerstroemia speciosa* (30.9%) (Table 2).

Table 2: Species composition, frequency (*F*), relative frequency (*RF*), density (*D*), relative density (*RD*), abundance (*A*), relative abundance (*RA*), Shanon Weiner diversity index (H) and important value index (*IVI*) of tree seedlings in unharvested plantations

Scientific Name	*E/I**	No. of individual	*F* (%)	*RF*	*D* (%)	*RD*	*A* (%)	*RD*	*IVI*	*H*
Acacia auriculiformis	E	200	33.3	18.0	3.33	28.7	10	12.4	59.1	-0.36
Albizia saman	I	25	16.7	9.0	0.41	3.5	2.5	3.1	15.7	-0.12
Anthocephalus chinensis	I	13	10.0	5.4	0.21	1.8	2.1	2.6	9.9	-0.07
Aphanamixis polystachya	I	146	16.7	9.0	2.43	20.9	14.6	18.1	48.1	-0.33
Cassia fistula	I	12	5.0	2.7	0.20	1.7	4	4.9	9.3	-0.07
Cassia nodosa	E	11	5.0	2.7	0.18	1.5	3.6	4.5	8.8	-0.07
Cassia siamea	I	14	11.7	6.3	0.23	2.0	2	2.4	10.8	-0.08
Dipterocarpus turbinatus	E	24	8.3	4.5	0.40	3.4	4.8	5.9	13.9	-0.12
Eucalyptus camaldulensis	E	45	16.7	9.0	0.75	6.4	4.5	5.5	21.0	-0.18
Hopea odorata	I	15	8.3	4.5	0.25	2.1	3	3.7	10.3	-0.08
Legerstroemia speciosa	E	82	16.7	9.0	1.36	11.7	8.2	10.1	30.9	-0.25
Syzygium cumini	I	45	8.3	4.5	0.75	6.4	9	11.1	22.1	-0.18
Syzygium fruticosum	I	34	8.3	4.5	0.56	4.8	6.8	8.4	17.8	-0.15
Syzygium grande	I	18	8.3	4.5	0.30	2.5	3.6	4.4	11.5	-0.09
Tamarindus indica	I	12	11.7	6.3	0.20	1.7	1.7	2.1	10.1	-0.07
Total = -2.21										

Note: * *E* = exotic and *I* = indigenous species

On the other hand, the highest IVI was for *Acacia auriculiformis* (106.5%) followed by *Acacia mangium* (68.4%) and *Albizia lebbeck* (34.9%) in the harvested plantations (Table 3). The IVI value of *Acacia auriculiformis* (106.5%) in harvested plantation was significantly ($P<0.05$) higher than that of unthinned (59.1%) plantation. IVI in unharvested and harvested plantations ranged from 8.8% to 59.1% and 14.4% to 106.5% respectively which implied that IVI of regenerated species in harvested plantation was greater than those of unharvested plantations. Shannon Weiner diversity index of unharvested plantation was 2.21 which are higher than that of harvested plantation (1.45) but there was no significant difference of indices between the two plantations. Evenness index was also higher in unharvested plantation as 0.81 which is a little higher than that of harvested plantation (0.74). Harvesting or selection thinning created canopy gaps which made sunlight to reach the forest floor which might have provided favorable conditions for seed germination and regeneration establishment in harvested plantations. The number of emerged regeneration of *Acacia auriculiformis* was significantly ($P<0.05$) higher than other species in both plantation types. Other than *Acacia auriculiformis*, there was no remarkable difference of the number of regenerations in both harvested and unharvested plantations.

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Table 3: Species composition, frequency (*F*), relative frequency (*RF*), density (*D*), relative density (*RD*), abundance (*A*), relative abundance (*RA*), Shanon Weiner diversity index (*H*) and important value index (*IVI*) of tree seedlings in harvested plantations

Scientific Name	*E/I**	No. of individual	*F* (%)	*RF*	*D* (%)	*RD*	*A* (%)	*RA*	*IVI*	*H*
Acacia auriculiformis	E	375	66.7	20	0.33	46.9	9.4	39.5	106.5	-0.36
Acacia mangium	E	210	66.7	20	0.33	26.3	5.3	22.1	68.4	-0.35
Albizia lebbeck	I	75	50	15	0.25	9.4	2.5	10.5	34.9	-0.22
Albizia saman	I	45	50	15	0.25	5.6	1.5	6.3	27.0	-0.16
Anthocephalus chinensis	I	30	38.3	11.5	0.19	3.8	1.3	5.5	20.8	-0.12
Cassia fistula	I	15	11.7	3.5	0.06	1.9	2.1	9.0	14.4	-0.07
Syzygium cumini	I	49	50	15	0.25	6.1	1.6	6.9	28.0	-0.17
Total = -1.45										

Note: * *E* = exotic and *I* = indigenous species

It was evident that IVI of common dominant species in harvested plantation was higher than unharvested plantation (Table 2 and 3). It was also revealed that common dominant species showed better growth performance than other species. The number of regenerations of common dominant species in both the plantations under different height classes did not show significant difference of regeneration except *Acacia auriculiformis* (Table 4). Therefore, it can be said that *Acacia auriculiformis* regenerated significantly (P<0.05) than all other common dominant species in harvested and unharvested plantations (Table 4).

Table 4: *P* values for the total number of common dominant species regenerated in harvested and unharvested plantations (α = 0.05, * significant)

Species	*P* value at α=0.05
Acacia auriculiformis	0.037*
Albizia saman	0.121
Anthocephalus chinensis	0.137
Syzygium cumini	0.062
Cassia fistula	0.085

The higher number of individuals under different height classes was for *Acacia auriculiformis*, *Aphanamixis polystachya* and *Lagerstroemia speciosa*. More species regeneration emerged from the lower height ranges in the harvested plantations (Figure 2). It was also observed that frequency of regeneration was more at the early age (lower height class) of the species and gradually the frequency of a species decreased when the height class increased in both unharvested and harvested plantations (Figure 2 and 3). A few species showed different trend of regeneration in unharvested plantations (Figure 2) like *Aphanamixis polystachya*, *Acacia auriculiformis* which were seen in higher height classes. The total number of regeneration at ≤20 cm height class showed rigorous regeneration in harvested plantation than unharvested plantation (Figures 2 and 3). As the height class of regenerations increased the total number of regenerations decreased accordingly in both the plantations (Figures 2 and 3). There was no significant difference of regeneration in both the plantations (P<0.05). Due to the canopy gap created by thinning may enhanced regenerations at the early stage of their emergence in harvested plantation but anthropogenic activities in harvested plantation may hamper the survivality of regeneration in the plantations.

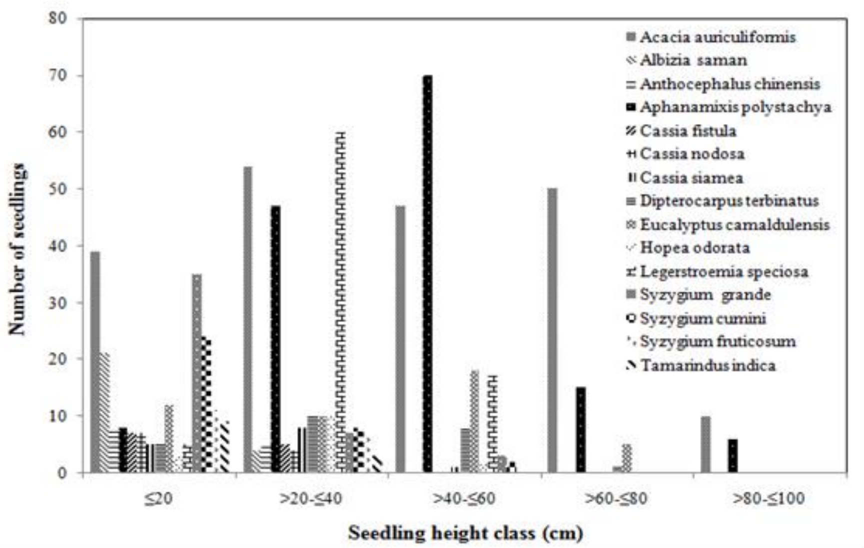

Figure 2: Height class distribution (cm) of regenerated species in unharvested plantation

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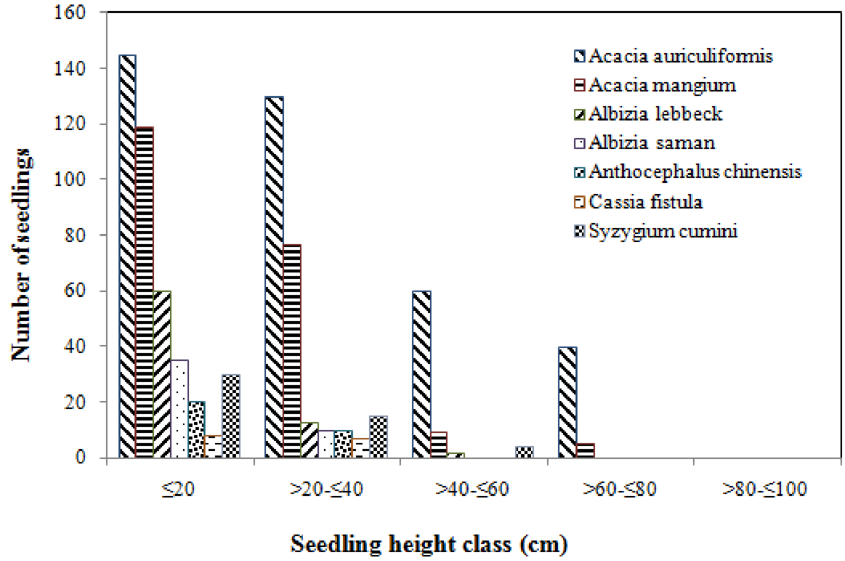

Figure 3: Height class distribution (cm) of different regenerated species in harvested plantations

Although the number of regenerations at ≤20 cm height class was less in unharvested plantation than that of harvested plantation, the number of regeneration, after >20-≤40 cm height class, were more than those of harvested plantations (Figure 4). As there were more tree species (15 species) in unharvested plantation than that of harvested plantation (7 species) there was diversity of species regeneration in unharvested plantation. Harvested plantation showed less species diversity in terms of regeneration (Figure 4). For the sustainability of forest ecosystem more diversity of species is desirable.

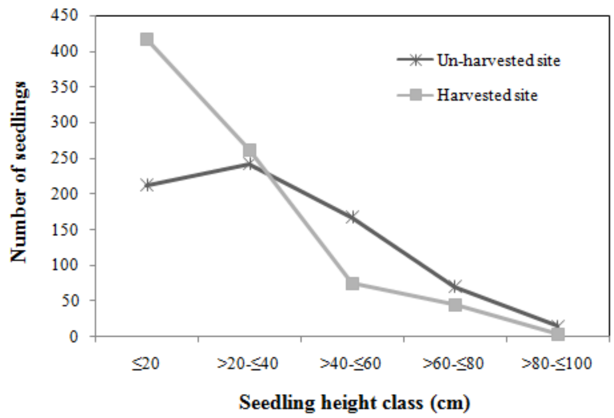

Figure 4: Total number of seedlings in harvested and unharvested plantations under different height classes

Therefore, it was revealed from the study that thinning enhanced regeneration of species at the early stage in harvested plantation and diversity of species regeneration was observed in unharvested plantation where there were less anthropogenic activities. Natural regeneration potential is an important indicator for any forest ecosystem sustainability. Management of species composition of a forest is important to increase the economic value and regeneration potential of forest (Wyatt-Smith, 1987) and for biodiversity conservation (Verma et al., 1999). Seasonally varying micro environmental factors, cultural operations, and anthropogenic activities affect the population structure by regulating trees at different growth stages i.e. seedling, sapling, coppice (Khumbongmayun et al., 2006).

This study showed higher regeneration of species in harvested plantations than unharvested ones. Among the regenerations, we found higher regeneration of *Acacia auriculiformis* and *Albizia saman* in unharvested plantations and higher regeneration of *Acacia auriculiformis*, *Acacia mangium* and *Albizia lebbeck* in harvested plantations. *Acacia auriculiformis* had significantly (P<0.05) higher natural regeneration in harvested plantation than unharvested plantation due to its profuse seed production and survival over a wide range of soil p^H (4-9). The important value index (IVI) of any species indicates the dominance of species in a mixed population (Sharma et al., 1986; Zegeye et al., 2011; Neelo et al., 2013). The five dominant species common to both plantations were *Acacia auriculiformis*, *Albizia saman*, *Anthocephalus chinensis*, *Syzygium cumini* and *Cassia fistula*. These five species showed significantly higher (P<0.05) IVI in harvested plantation than unharvested ones. The cultural operations like selection thinning allowed penetration of solar radiation to the forest floor by creation of canopy gaps. It resulted in higher germination rates in harvested plantations than unharvested ones. Intermediate percentage of canopy gaps had higher understory regeneration than low or high percentage of canopy gaps (Daniela & Florencia, 2004; Neelo et al., 2015).

This phenomenon indicated that the selection thinning created some canopy gaps through which sunlight penetrated and turned the condition in the forest floor favorable to seed germination and seedling growth. Same result was reported by Popma and Bongers (1988) who studied seedlings growth from seeds of tropical tree species in Los Tuxtlas, Mexico under different light

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conditions in forest understory and found that growth of all species was enhanced in gaps. It was also reported by Brokaw (1985) in his study on tropical moist forest in Barro Colorado Island, Panama that gap formation fostered regeneration of pioneer and primary species. It was seen from our study that seed germination and regenerations growth was successful at early stage (lower height classes) but at higher height classes it became difficult to survive the regenerations because of some anthropogenic activities in the plantations. Young regenerations face many challenges due to anthropogenic disturbances and inter and intra specific competitions between regenerations resulting in lower survival rate. Information of IVI, number of regenerated species among five common dominant species and height of species for different height classes indicated that favorable conditions created by selection thinning influenced the seed germination and seedling growth in the forest floor of harvested plantations than unharvested plantations.

4. Conclusion

This study showed that *Acacia auriculiformis*, *Albizia saman*, *Anthocephalus chinensis*, *Syzygium cumini* and *Cassia fistula* are dominant tree species, better suited for forest renewal in the southern part of Bangladesh. There was no significant difference of species diversity between the unharvested and harvested sites. Among the common dominant species *Acacia auriculiformis* is the best for natural regeneration. At the early stage of regeneration profuse numbers of seedlings are found and gradually it became less in the higher height classes. Disturbance like extraction of litters, regenerations, leaves for fuel purposes by local people had brought a decline in species regeneration status in plantations. Public awareness and special priority must be given to conserve the regeneration of tree species in plantations.

Although this study had limited scope to investigate the impact of thinning on regeneration but the regeneration of species in harvested plantation showed higher number of species than that of unharvested plantation which indicated that thinning made some canopy opening to enhance the regeneration on the forest floor. Light thinning enhanced the regeneration of tree species in the plantation forest. Intermediate percentage of canopy openness had greater abundance of understory regeneration than low or high percentage of canopy openness (Daniela & Florencia, 2004).The forest managers could use the information to further investigate the optimum thinning impact on regeneration for a particular plantation management.

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