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Article

Assessing restoration potential of fragmented and degraded Fagaceae forests in Meghalaya, North-East India

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Abstract: The montane subtropical broadleaved humid forests of Meghalaya (Northeast India) are highly diverse and situated at the transition zone between the Eastern Himalayas and Indo-Burma biodiversity hotspots. Fagaceae family are the keystone species forms an important component of these forests. These forests in Meghalaya are highly degraded and fragmented due to anthropogenic disturbances (e.g., mining, unsustainable forest utilization, shifting cultivation, browsing, etc.). In this study, we assessed for the first time, the restoration potential (i.e. capacity to naturally regenerate and sustain desired forest structure) of Fagaceae species (2 *Lithocarpus*, 4 *Castanopsis*, and 4 *Quercus* species) in Meghalaya and how the biotic and abiotic factors, as well as anthropogenic disturbances, influence the restoration potential of these species. We selected fragmented forest patches in six locations on an elevational gradient on south-facing slopes in the Khasi Hills, Meghalaya. Fagaceae was the most dominant family in all sites except one site (Laitkynsew) where Fagaceae was co-dominant with Lauraceae. The family also had high natural regeneration (i.e., a high number of seedlings and saplings) but low recruitment to adult trees (DBH ≥ 10cm) at all sites. This study provides a means for assessing regeneration and a basis for forest management strategies in degraded and fragmented forests of Meghalaya.

Keywords: species composition; fagaceae; keystone; restoration potential; anthropogenic disturbance; fragmented forests; coppicing

1. Introduction

Current rates of anthropogenic destruction and degradation of natural ecosystems have severely fragmented natural landscapes worldwide leading to loss of global biodiversity [1,2], reduced ecosystem services [3], and increased carbon emission [4]. The need for restoring degraded forest landscapes was recognized by various National and International conservation agencies around the globe who started corresponding initiatives to foster reforestation and forest restoration [5–10]. Such initiatives – if successful - provide many co-benefits, such as income opportunities for rural households, enhancement of biodiversity conservation, sustainable production of raw materials for forest industries, and a wide array of supporting and regulating ecosystem services [6,11].

Natural regeneration – as a inherent component of forest ecosystem dynamics [12] - is essential for the preservation and maintenance of biodiversity [13], forest sustainability [14], and also plays a key role in forest restoration. Approaches to restoring natural ecosystems largely depend on the level of forest and soil degradation, residual vegetation, and desired restoration outcomes [6]; and the ability to implement restoration practices. The residual vegetation plays a critical role in forest restoration by providing reproduction from seed and from vegetative sprouting, which varies from species. During regeneration, there is a rapid increase in tree density, competing vegetation, and species richness [15,16]. Recent studies in tropical forests showed that ecological restoration achieved through natural regeneration was more successful than active restoration [3,7]. Successful regeneration is achieved when there is a significant number of seedlings, saplings, and pole-size trees of a species in competitive positions in the forest that culminates in recruitment into overstory dominance at maturity. It can be assessed by evaluating the population structure [17,18]. The regeneration potential of a species must be high enough to ensure its long-term sustainability in future forests [19]. Regeneration, growth, and survival of tree species through their seedlings and sprouts largely depends on the interaction between biotic and abiotic factors in relation to its environment and the level of disturbances that alters the balance of resources in favor of the desired species [20].

Fagaceae is a major component of forests in the northern hemisphere from tropical to temperate regions [21–23]. Besides their valuable contribution to the economy, Fagaceae forests play a vital ecological role as keystone species in forest ecosystems [24–26]. Fagaceae-dominated forests harbors a high diversity of seed-eating wild vertebrates and diverse plant groups [24,27] and contribute significantly to global ecosystem services and standing biomass [28]. However, on a global scale, species in the Fagaceae family are declining due to land-use changes, population growth, herbivory, increasing forest density and competing vegetation, invasive species, climate change and other factors that inhibit regeneration and recruitment into the overstory [14,29–33].

In Northeast India, Fagaceae tree species are the dominant climax tree species of the moist subtropical and temperate forests [34–36]. The subtropical broadleaved wet hill forests of Meghalaya are highly diverse, and part of the Indo-Burma biodiversity hotspot, which is primarily dominated by broad-leaved oak-laurel forests [37–40]. Various studies have been conducted in these forests to study species diversity, composition and structure [37,39–41], natural regeneration [42–44], nutrient dynamics [45,46], and litter decomposition [47,48].

The state of Meghalaya is also bestowed with a large reserve of minerals, coal and limestones deposits. In the last few decades, due to increasing demands for meeting the needs of the fast-growing population of the state, mining activities have increased rapidly causing large-scale deforestation and degradation of the environment [49]. In addition to this, the state also receives very heavy rainfall (averaging > 11,000 mm a year) which have eroded a large proportion of the topsoil layer. The remaining shallow soil layer is nutrient-poor, acidic and provides less mechanic stability [46,50]. Consequently, in the last decade, the state has lost 202 km^2 of forest cover [51,52]. Once continuous old-growth forests covered the region, but today forests are fragmented into small remnant patches, which are often in a degraded state [46,53]. About 6967 patches or forest fragments of varying sizes have been identified in Meghalaya [54]. The collapse of the traditional way of management of forest resources triggered by the rapid population increase in the state from the 1960s and unsustainable land-use practices such as the reduced cycle of shifting cultivation have severely degraded and fragmented the entire landscape [55]. Only 6.5 % of forests are protected under state management [52], while the remaining forests are mostly owned by private individuals or clan/community organizations [56]. These lands are not protected or under a sustainable forest management plan and are vulnerable to further degradation from high-grading of vegetation and exploitation of rock, coal and mineral resources.

About 80% of the population in Meghalaya still lives in a rural area and are entirely dependent on agriculture and other related activities to support their livelihood [57]. Trees of the Fagaceae family are the most preferred species for firewood, construction timber, and charcoal by the local community of the state. The acorn of *Castanopsis* species is consumed locally. Thus, Fagaceae trees are an economically, socially and culturally significant part of the local community. However, due to the overexploitation of this valuable forest resource the remnant forest is degraded and shrinking day by day. The key drivers of deforestation in the state are forest fires, unsustainable collection of firewood, uncontrolled grazing, charcoal making and changes in land use [58].

The present study is aimed at determining the potential of recovery and sustenance of dominant Fagaceae species in the fragmented and degraded subtropical broadleaved wet hill forests of Meghalaya. We assessed the plant diversity, community structure, and potential of Fagaceae species to regenerate and recruit into the overstory in Fagaceae dominated forests of Meghalaya in relation to abiotic factors and anthropogenic disturbances.

2. Materials and Methods

2.1. Study area description

The study was conducted in the Khasi-Jaintia hills district in the montane sub-tropical broadleaved wet hill forests of Meghalaya, India. It reaches from approximately 25°07″ to 25°41″ N of latitude and from 91°21″ to 92°09″ E of longitude (Figure 1 and Table 1). This state receives the heaviest rainfall in the world (annually 11873 mm) as it is the initial landfall in the pathway of the Indian monsoon and falls under Indo-Burma biodiversity hotspot [59]. The climate of the area is monsoon type with a distinct wet and dry period. The wet summer period extends from April to October in which more than 90% of the total rainfall is received. The mean annual maximum and minimum temperatures are 22 °C and 16 °C, respectively. In general, the soil is laterite, loam to loamy silt in texture and acidic. The state is home to more than a thousand endemic species and with a large number of sacred groves where biodiversity is very high due to nature conservation efforts [17].

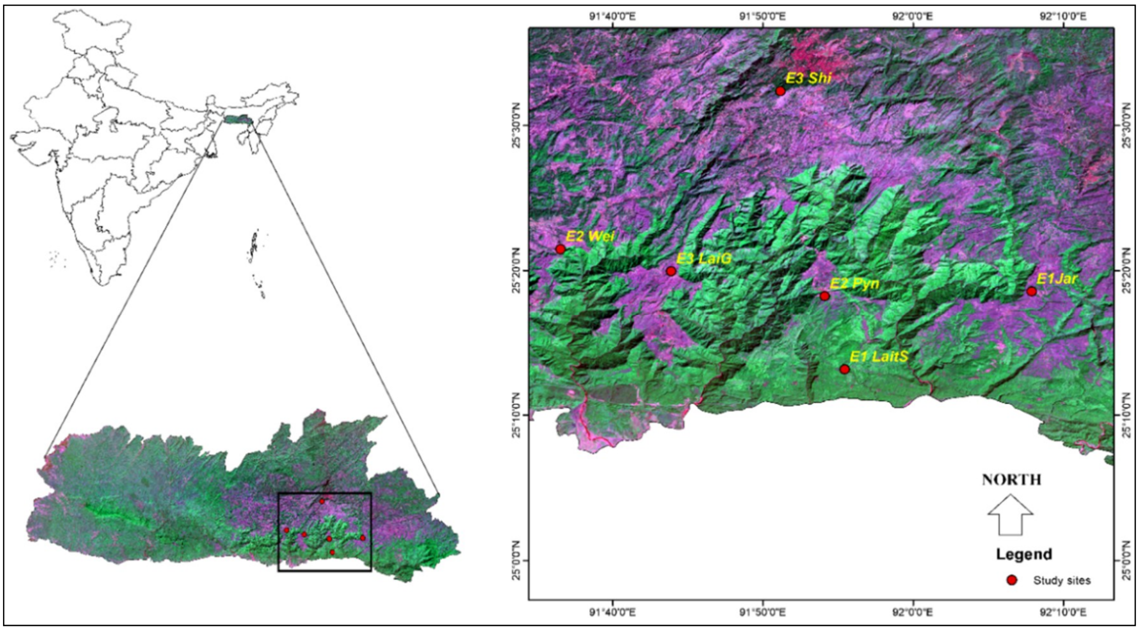

Figure 1: Location of the six study sites in Khasi-Jaintia Hills district of Meghalaya (E1Jar = Jarain, E1LaitS = Laitkynsew, E2Pyn = Pynursla, E2Wei = Weiloi, E3LaiG = Laitryngew, E3Shi = Upper Shillong)

Table 1: Description of six study sites located in Khasi-Jaintia hills divided into three elevational zones

Site	Laitkynsew	Jarain	Pynursla	Weiloi	Laitryngew	Upper
Abbreviation	E1-LK	E1-J	E2-P	E2-W	E3-LR	E3-US
Elevation range	800-1200		1200-1600		1600-2000	
Elevation (m.a.s.l.)	903	1132	1368	1595	1636	1873
Approximate Stand	7.8	2.4	15.7	17.6	11.7	60.4
Latitude (N)	25°13.16'	25°18.55'	25°18.26'	25°21.32'	25°19.94'	25°32.35'
Longitude (E)	91°40.27'	92°7.88'	91°54.1'	91°36.53'	91°43.89'	91°51.18'

Distance from the	0.83	1.26	0.47	0.59	0.51	1.07

Forested areas of the two hills namely Khasi hill and Jaintia hill were chosen as the study area in the East Khasi hill district where montane sub-tropical wet broadleaved forests are found (Figure 1). From the management point, the local people of the community, mainly the Khasi and Jaintia tribes, manage these forests. By that, we were only capable of selecting our area with the permission of the community chairperson. The Fagaceae family forms the dominant component of these degraded and fragmented forests which were all located close to human settlements. Chief anthropogenic disturbances were logging, slash and burning for shifting cultivation, extended grazing, and mining. Overall, our study area is composed of human-disturbed fragmented forest patches.

2.2. Sampling design

Systematic sampling was done along an altitudinal gradient. Six fragmented forest patches were selected for vegetation sampling. These locations were chosen within an altitudinal gradient ranging between 800-2000 m (Table 1). We defined three altitudinal classes from 800 to 1200 m, 1200 to 1600 m and 1600 to 2000 m with two study sites in each altitudinal class. Five sites are located in the Khasi hill and one in the border of the Khasi and Jaintia hills of the Meghalaya plateau. All of these sites are located at the south-facing slopes and on the windward sides of the hills, which receive the highest amount of rainfall. We ensured that each site consisted of a continuous forest patch of at least one hectare. We avoided forest roads to minimize the effects of external disturbances and very steep slopes that made data collection unsafe and problematic. In each of the six selected study sites, we randomly demarcated two 50 m x 50 m plots for data collection, resulting in a total of 12 plots for the study.

2.3. Field data collection

2.3.1. Species composition

The vegetation sampling in the study area was completed in 2016. In each of the plots (50 x 50 m), the circumference at breast height (cbh at 1.37 m) was measured to the nearest 0.1 cm using a meter tape for all trees > 31.5 cm in circumference. Cbh was later converted to the diameter at breast height (DBH) using the formula dbh=cbh/pi (pi=3.14) assuming a circular stem cross-section at the point of measurement. In the case of multiple stems, the circumference of every single stem was recorded and converted into DBH and later converted to a single DBH by taking the square root of the sum of all squared stem DBHs. The plant specimens were identified to species when possible with the help of a regional flora list [60–63], and by consulting the herbaria at Botanical Survey of India, Eastern Circle, Shillong.

Information on the damage of trees was recorded under four category class viz., “no damage”, “cut”, “broken stem” and “sign of pathogen attack” to assess their vitality. Additionally, signs of cuts on trees, grazing, burning, and trampling were recorded as present or absent (i.e., 0 and 1). Damage scores were summed to represent three levels of anthropogenic disturbance intensity (score class of 1, 2 and 3 representing Mild, Moderate and High levels of disturbance, respectively). The distance of the forest from the nearest forest-dependent village (km), the proportion of the number of cut stumps to the total number of standing and cut trees (%), the proportion of number of trees de-branched to the total number of trees (%) and the Gini index of structural diversity were used as variables for quantifying disturbance.

The GPS position and elevation were recorded at each corner and the center of the 50 m x 50 m plots. Soil bulk density was estimated following [64]. Metal corers were driven into the soil and for each plot, six soil cores were randomly collected from 0-20 cm soil layer. They were then combined to one composite sample.

2.4. Compositional and structural diversity assessment

The data collected in the field were used to determine dominance and diversity indices.

2.4.1. Dominance

The DBH of all trees and saplings occurring within the 50 m x 50 m plot were measured at 1.37 m above the ground level. Frequency, density, basal cover and importance value index (IVI) of tree species were calculated following [65,66]. Importance Value Index (IVI) for trees was computed by summing the relative frequency, relative density, and relative basal area.

2.4.2. Diversity indices

Several measures of diversity were used to characterize the vegetation.
Species richness (S), the total number of species was recorded for each forest site.
Shannon's diversity index (H_{BA}) was estimated using the following formula [67]:

$$H_{BA} = -\sum_{i=1}^{S} \frac{bi}{BA} \ln \left(\frac{bi}{BA}\right)$$

Where S is the total number of species, *BA* is the total basal area; *bi* is the basal area of species *i*.
Simpson's dominance index (D) was estimated using the Simpson index [67] and was calculated as:

$$D = \sum\left(\frac{Ni}{N}\right)^2$$

Where '*Ni*' is the IVI of i^{th} species, and '*N*' is the total IVI of all species.
Pielou's Evenness index 'e', was calculated using the following formula [67]:

$$e = \frac{H_{BA}}{\ln S}$$

Where, 'H_{BA}' represents Shannon -Weiner diversity index, and '*S*' represents the total number of species.
Gini structural diversity in the plots was quantified as follows:

$$Gini_{DBH} = \frac{\sum_{1}^{n}(2i-n-1)x}{n^2\mu}$$

Where n is the total number of trees in the plot, x is the diameter of tree number i and μ is the mean tree diameter. (A Gini Index of 0 represents perfect size equality, whereas values of 1 represent maximum size inequality [67].

2.5. Data analysis

2.5.1. Population structure and Regeneration potential

Population structure of the oak species was assessed using the diameter distribution. Individuals of the oak species were tallied into 10 diameter classes i.e., 0-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, 90-100 and 100-110 cm. The density data for each size class was used to depict the population structure.

Regeneration potential is the capacity or the potential of the dominant species (Fagaceae family members in the present study) in these forests to regenerate naturally under existing environmental conditions and disturbances. To assess regeneration potential of Fagaceae trees, the following size classification was used to define the structure of each Fagaceae population: seedlings (<20 cm height), small saplings (20 – 150 cm height), large saplings (>150 cm height but <10 cm DBH), pole- size trees (10-30 cm DBH) and large trees (>30 cm DBH). Thereby, the different size classes represent the biological life stages of Fagaceae species from the seedling stage, through the sapling and pole stages, until trees enter the overstory canopy at maturity. Regeneration status or potential of the Fagaceae species was determined based on the number of seedlings, saplings, and adults [68]: (a) 'good or strong' if seedlings > or < saplings > adults; (b) 'fair' if seedlings > or ≤ saplings ≤ adults; (c) 'poor' if a species survives only in sapling stage, but no seedlings (though saplings may be <, > or = adults); (d) 'none', if it is absent both in sapling and seedlings stages, but found only in adults and (e) 'new or early regeneration' if a species has no adults, but only saplings and/or seedlings.

Regeneration success of the Fagaceae species is demonstrated by the number of seedlings, saplings, pole trees and adults that attain dominance in the stand. To facilitate interpretation, the proportion of seedlings and sapling to that of pole-size trees and adult trees were calculated to study the potential of a Fagaceae species to regenerate and recruit into the overstory. A population structure with a higher percentage of seedlings and saplings compared to larger classes suggests strong regeneration and recruitment potential.

We finally used generalized linear models (GLMs) to study the influence of anthropogenic disturbances, biotic and abiotic factors, and elevation on the restoration potential of Fagaceae species. The regeneration potential of Fagaceae species was used as the target/response variables and all the anthropogenic disturbances, biotic factors, and abiotic factors were modelled as the independent variables. We used log transformation on the response variables that had error distribution models other than a normal distribution. Spearman correlation was performed on the independent variables to drop autocorrelated variables. Finally, the best general linear models were selected based on the Akaike information criterion (AIC) values.

All data analysis was carried out using MS Excel, PAST 3.0 and SPSS 25.

3. Results

3.1. Species diversity and composition

The forests on the southern slopes are heterogeneous assemblage of different tree species. A total of 144 tree species belonging to 89 genera and 53 families were recorded from the six studied stands. This includes ten tree species that could not be identified in the field. Lauraceae was the dominant family comprising 25 species followed by Rubiaceae and Fagaceae (10 species each), Elaeocarpaceae and Magnoliaceae (7 species each), Araliaceae and Rosaceae (5 species each), Symplocaceae and Aquifoliaceae (4 species each) and Celastraceae, Euphorbiaceae, Anacardiaceae, Myrtaceae, Moraceae and Pentaphyllaceae were represented by 3 species each. Eleven families were bispecific and 17 families were monospecific.

The dominance, evenness, and diversity varied among the six forest stands. High species richness was recorded at Jarain with 51 tree species followed by Laitryngew (45) and was lowest at Weiloi where only ten tree species occurred (Table 2). Shannon diversity was highest at Jarain (2.75) followed by Pynursla (2.72) and Laitkynsew (2.49). The lowest of Shannon's diversity was at Weiloi (0.48). All the forest stands had low evenness index with a maximum value of 0.54 at Pynursla (Table 2).

Table 2: Tree Community characteristic of Fagaceae forests in the study locations

Parameter	Laitkynsew	Jarain	Pynursla	Weiloi	Laitryngew	Upper Shillong
Elevation (m)	903	1132	1368	1599	1636	1873
Species richness	37	51	39	10	45	27
Number of families	23	24	24	8	22	17
Number of genera	37	40	32	10	32	23
Tree basal area (m^2 ha^{-1})	35.3	20.69	16.48	28.69	24.7	20.6
Tree density ha^{-1}	338	524	608	276	868	478
Shannon diversity index	2.49	2.75	2.72	0.48	2.46	1.76
Simpson dominance index	0.12	0.10	0.11	0.81	0.16	0.26
Pielou's Evenness index	0.46	0.46	0.54	0.24	0.36	0.31
Bulk density (g/cm^3)	0.94	1.06	1.39	1.47	0.99	0.65

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3.2. Dominance, Basal area, Tree density and population structure

Based on IVI values, the species of Fagaceae family dominated all the five stands except the Laitkynsew stand where Lauraceae members dominated. The maximum IVI value for Fagaceae was 203.9 at Weiloi and the lowest was 41.7 at Laitkynsew (Appendix A). The other co-dominant families were Theaceae, Myricaceae, and Proteaceae.

The tree basal area in the six forests stands varied between 16.5 m^2 ha^{-1} to 35.3 m^2 ha^{-1} with the mean basal area of 24.4 ± 6.17 m^2 ha^{-1}. The Fagaceae members which had 37.6 % of the total stand density contributed to 47.7% of the total basal area. Fagaceae, Lauraceae, Theaceae, Myricaceae, and Proteaceae together represented 75.6% of the total basal area (Figure 2). Lithocarpus dealbatus was found in all six forest stands and constituted 19.3 % of the total basal area. This was followed by *Quercus lineata* (18.6%), *Schima wallichii* and *Persea odoratissima* (6.2% each), *Myrica esculenta* (3.8%), *Castanopsis indica* (3.6%) and *Castanopsis tribuloides* (2.7%). The rest of the 136 tree species distributed in 38 families contributed 24.4% to the total basal area.

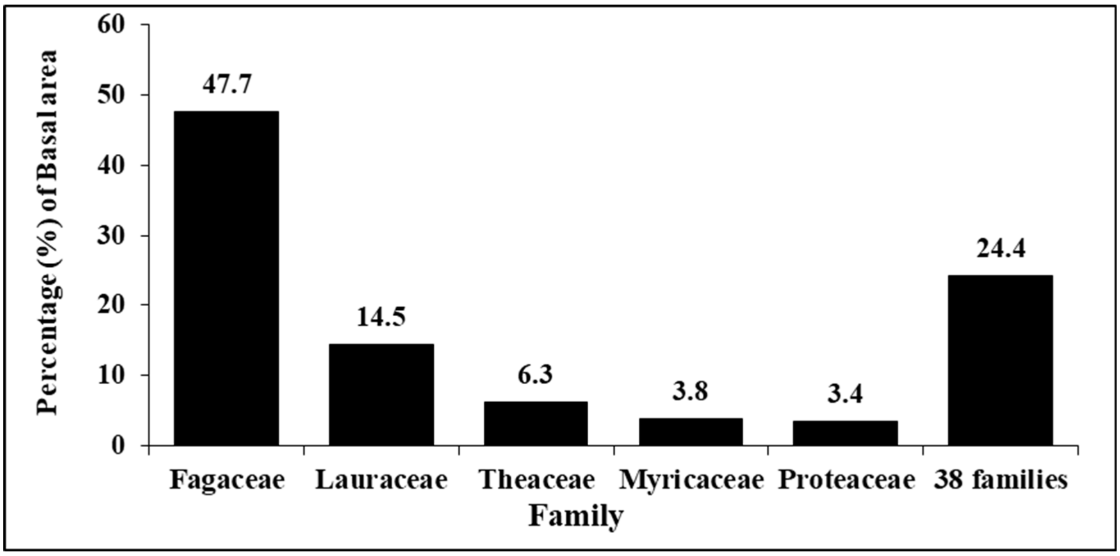

Figure 2: Basal area distribution by families in the six forest stands

In general, both the Fagaceae and Non-Fagaceae members in the fragmented forests showed reverse J-shape distribution (Figure 4 b). The density of trees (dbh ≥ 10 cm) ranged between 276 ha^{-1} and 868 ha^{-1} in the six stands with a mean density of 515±325.8 ha^{-1} (Table 2). Across the stands, the Fagaceae members contributed 37.6% to the total stand density. The other important families were Lauraceae (15.7%), Theaceae (6%), Proteaceae (4.6%), Elaeocarpaceae (4.2%) and Aquifoliaceae (4.1%). *Lithocarpus dealbatus* was the greatest contributor (22.3%) to the overall stand density followed by *Quercus lineata* (8.3%), *Persea odoratissima* (5.8%), *Schima wallichii* (5.7%), *Cinnamomum cassia* (3.9%), *Helicia nilagirica* (3.7%) and *Castanopsis tribuloides* (2.7%). These seven species together constituted 52.4% of the total stand density (Appendix A).

The trees were further categorized into three dbh classes i.e., Pole tree (10-30cm dbh), Middle size tree (30-60 cm dbh) and Canopy trees (≥ 60 cm dbh). The tree population structure revealed that the Pole size trees had the highest percentage of contribution to the overall stand density (83.6%) followed by middle-size trees (14.7%) and least by the canopy trees (1.7%). Similarly, the pole size trees contributed to high stem density (73.5%), followed by Middle size trees (23.7%) and the Canopy trees (2.8%). The basal area was dominated by trees in the middle and canopy tree classes (55.4%). Across the stand, four out of six sites showed a high density of trees in pole and stem category (>80%) with basal cover ranging between 50-72% (Table 3).

Pynursla forest had the highest percentage of pole density i.e., 574 trees ha^{-1}, stem density of 718 stems ha^{-1} and a basal cover of 11.8 $m^2 ha^{-1}$, followed by the Laitryngew site (Table 3). Both these stands did not show canopy trees in their population structure indicating that these forests are strongly regenerating. Whereas, Weiloi forest had the least number of individual among all stands, but had the highest density of tree (130 trees ha^{-1}) and stems (446 stems ha^{-1}) with a basal area of 17.3 m^{2}ha^{-1} in the middle size category followed by Laitkynsew site (Table 3). Weiloi and Laitkynsew had high density of canopy trees (18 and 30 trees ha^{-1} respectively) and stems (84 ha-^{1} and 38 stems ha-^{1} respectively) with a basal cover of 7 m^{2}ha^{-1} and 19.4 m^{2}ha^{-1} respectively. These two sites represent the old-growth forest structure under disturbance regimes.

Fagaceae tree density constituted 28.3% to the total pole size class, whereas, the Non-Fagaceae tree species constituted 55.3% in the same category. Consequently, the contribution of pole size tree to the total basal cover by the Fagaceae members was lower (17.2%) as compared to Non-Fagaceae tree (27.5%). However, Fagaceae members with 9.4% trees in the middle and canopy class contributed 30.5% to the total basal area and, the Non-Fagaceae trees in the same category with 7.1% tree density contributed 24.9% to the total basal cover. Overall, the Fagaceae members showed high stem density (19.7%) above 30cm dbh class as compared to Non-Fagaceae trees (6.8%) (Table 3) & Figure 3.

Table 3: Population structure, Stem density and Basal area in three diameter classes: Pole (10-30 cm, Middle size tree (30-60 cm) and Adults (≥60 cm) from six study sites.

Sites		Pole (10-30)			Middle Size (30-60)			Canopy (≥60)		
		Tree	Stem	BA	Tree	Stem	BA	Tree	Stem	BA
Laitkynsew	Fag	16	16	0.5	18	18	2.5	8	12	4.0
	Non-Fag	202	214	6.7	72	76	9.9	22	26	11.7
	Total	218 (64)	230 (64)	7.1 (20)	90 (27)	94 (26)	12.5 (35)	30 (9)	38 (10)	19.4 (55)
Jarain	Fag	170	214	5.4	40	82	4.0	0	0	0
	Non-Fag	290	320	7.6	22	26	2.8	2	2	0.8
	Total	460 (88)	534 (83)	13 (63)	62 (12)	108 (17)	6.8 (33)	2	2	0.8 (4)
Pynursla	Fag	170	236	3.5	18	56	2.9	0	0	0
	Non-Fag	404	482	8.3	16	18	1.8	0	0	0
	Total	574 (94)	718 (91)	11.8 (72)	34 (6)	74 (9)	4.7 (28)	0	0	0
Weiloi	Fag	98	148	3.9	116	396	15.8	18	84	6.5
	Non-Fag	30	36	0.5	14	50	1.5	0	0	0.6
	Total	128 (46)	184 (26)	4.3 (15)	130 (47)	446 (62)	17.3 (60)	18 (7)	84 (12)	7 (24)
Laitryngew	Fag	226	428	6.9	40	190	4.2	0	0	0
	Non-Fag	580	708	11.9	22	46	1.8	0	0	0
	Total	806 (93)	1136 (83)	18.8 (76)	62 (7)	236 (17)	6 (24)	0	0	0
Upper Shillong	Fag	194	224	5.0	30	34	4.2	2	2	0.6
	Non-Fag	204	236	5.3	48	58	5.6	0	0	0
	Total	398 (83)	460 (83)	10.2 (50)	78 (16)	92 (17)	9.8 (47)	2	2	0.6 (3)

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Grand Total	2584 (83.6)	3262 (73.5)	65.3 (44.6)	456 (14.7)	1050 (23.7)	57.0 (38.9)	52 (1.7)	126 (2.8)	24.1 (16.5)
Total Fagaceae	874 (28.3)	1266 (28.5)	25.2 (17.2)	262 (8.5)	776 (17.5)	33.6 (22.9)	28 (0.9)	98 (2.2)	11.1 (7.6)
Total Non-Fagaceae	1710 (55.3)	1996 (45.0)	40.3 (27.5)	194 (6.3)	274 (6.2)	23.4 (16.0)	24 (0.8)	28 (0.6)	13.1 (8.9)

*Number in the parentheses is the percentage contribution

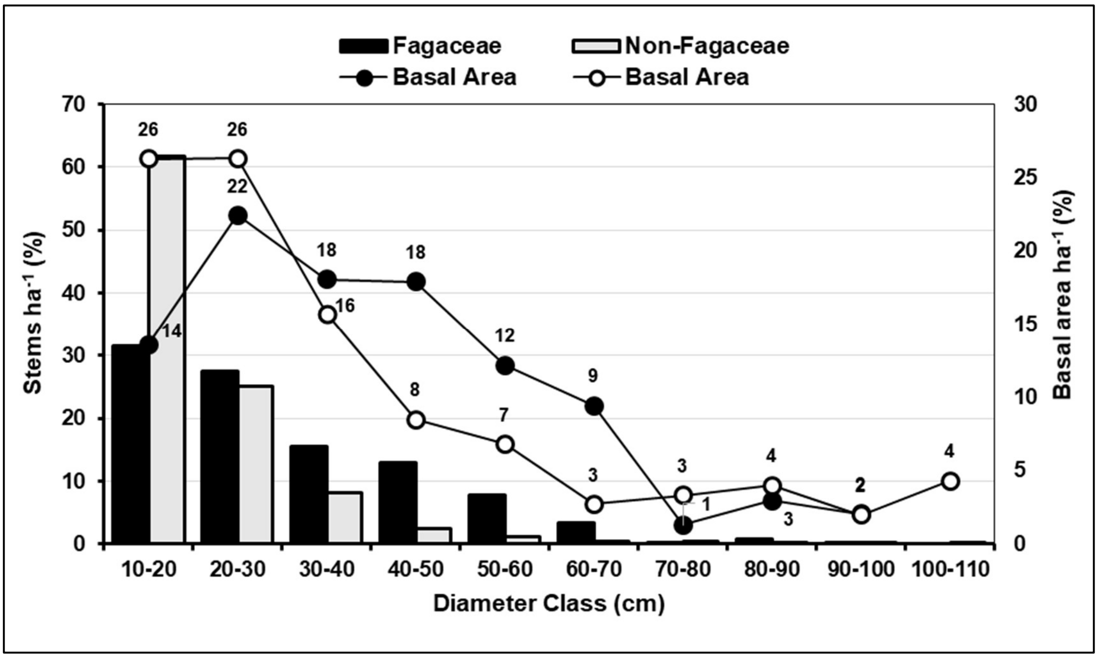

Figure 3: Diameter class vs. average Basal area of Fagaceae and Non-Fagaceae tree species from six forest stands

3.3. Distribution and Regeneration potential of Fagaceae members

At Laitkynsew, Jarain and Pynursla the Fagaceae was represented by five species each, Laitryngew with four species whereas, Weiloi and Upper Shillong were represented by three species each. *Lithocarpus dealbatus* was the most widely and frequently occurring species and was recorded from all the study sites. *Castanopsis tribuloides* occurred in five sites whereas, *L. elegans*, and *Quercus glauca* occurred in three sites. *Castanopsis purpurella* and *Quercus lineata* were present in two sites and, *Castanopsis indica, Castanopsis lanceifolia* and *Q. semiserrata* were rare in occurrence and present only at Laitkynsew site and *Q. griffithii* was only recorded from Upper Shillong (Table 4).

The regeneration potential of the Fagaceae members varied across the stands. The proportion of adult trees (>60 cm dbh) were very poorly represented (≤5%) in all sites. Across the stands, 60 % of the Fagaceae members showed strong regeneration potential. Four percent of the Fagaceae members showed fair regeneration while 8% showed poor regeneration, 12% of members fall under no regeneration category and 16% showed early regeneration phase. Laitkynsew forest had the highest percentage of small sapling (60.5%) and the lowest proportion of pole trees.

The Fagaceae members at Jarain, Pynursla, Laitryngew and Upper Shillong forest stands were strongly regenerating. *Lithocarpus dealbatus* was the only species which occurred in all the six sites showed good regeneration potential. *Castanopsis purpurella* (Jarain and Pynursla), *Quercus semiserrata* and *Castanopsis indica* (Laitkynsew) and, *Quercus griffithii* (Upper Shillong) also showed good regeneration potential. *Quercus lineata* showed good to fair regeneration potential in Weiloi and Laitryngew forest respectively.

Castanopsis tribuloides showed good regeneration potential at Jarain site. However, *Castanopsis tribuloides* (Weiloi and Upper Shillong) and *Castanopsis lanceifolia* (Laitkynsew) showed early

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regeneration which may indicate reappearance or migration of the species to colonize a new area. *Castanopsis tribuloides* (Pynursla and Laitryngew) and *Quercus glauca* (Pynursla) lacks seedling and sapling population thus showing no regeneration. *Lithocarpus dealbatus* and *Quercus lineata* together contributed to 69.2% to the total number of individuals of Fagaceae. In Fagaceae, the proportion of the contribution of both the species to seedlings population was 68%, small sapling (57.5%), large saplings (73%), Pole tree (78%) and adult trees (81.4%).

Table 4: Regeneration status of Fagaceae species in six study sites. Species wise individuals' (density ha^{-1}) in five size classes at the six study sites (*Seed.* Seedlings (<20cm height), *Sm. Sap.* Small Saplings (20-150 cm height), *L. Sap.* Large Saplings (>150 cm height but <10 cm DBH), *Pole* Pole Size Trees (10-30cm DBH), *L. Tr.* Large Trees (>30 cm DBH)

Study sites	Species name	Basal Area (%)	Density ha^{-1}					Regeneration Status
			Seed	Sm. Sap.	L. Sap.	Pole	L. Tr.	
Laitkynsew	*Castanopsis indica*	14.7	22	154	58	4	18	Good
	Castanopsis lanceifolia	-	2	48	18			New
	Lithocarpus dealbatus	3.3	2	44	6	12	6	Good
	Lithocarpus elegans	-	4	46	34			New
	Quercus semiserrata	1.7	6	78	48		2	Good
Relative Proportion (%)		19.7	5.9	60.5	26.8	2.6	4.2	
Jarain	*Castanopsis purpurella*	1.2	2	26		6		Good
	Castanopsis tribuloides	13.3	46	120	62	44	14	Good
	Lithocarpus dealbatus	21.2	10	98	286	80	20	Good
	Lithocarpus elegans	1.4		14	84	4	2	Poor
	Quercus glauca	8.4	2	18	26	36	4	Good
Relative Proportion (%)		45.6	6	27.5	45.6	16.9	4	
Pynursla	*Castanopsis purpurella*	2.3	8	22	16	4	2	Good
	Castanopsis tribuloides	3.9				4	2	None
	Lithocarpus dealbatus	26.6	72	122	220	118	14	Good
	Lithocarpus elegans	5.6	34	38	14	42		Good
	Quercus glauca	0.3				2		None
Relative Proportion (%)		38.9	15.5	24.8	34.1	23.2	2.5	
Weiloi	*Castanopsis tribuloides*	-		2	2			New
	Lithocarpus dealbatus	1.4	26	62	24	6	2	Good
	Quercus lineata	89.8	64	34	22	92	132	Fair
Relative Proportion (%)		91.2	19.2	20.9	10.3	20.9	28.6	
Laitryngew	*Castanopsis tribuloides*	3.5				18	2	None
	Lithocarpus dealbatus	35.6	42	218	206	178	32	Good
	Quercus glauca	0.2			4	4		Poor
	Quercus lineata	5.7	4	18	44	26	6	Good
Relative Proportion (%)		44.9	5.7	29.4	31.7	28.2	5	
Upper Shillong	*Castanopsis tribuloides*	-			2			New
	Lithocarpus dealbatus	44.1	58	290	240	190	30	Good
	Quercus griffithii	3.3	2	12	12	4	2	Good
Relative Proportion (%)		47.4	7.1	35.9	30.2	23	3.8	

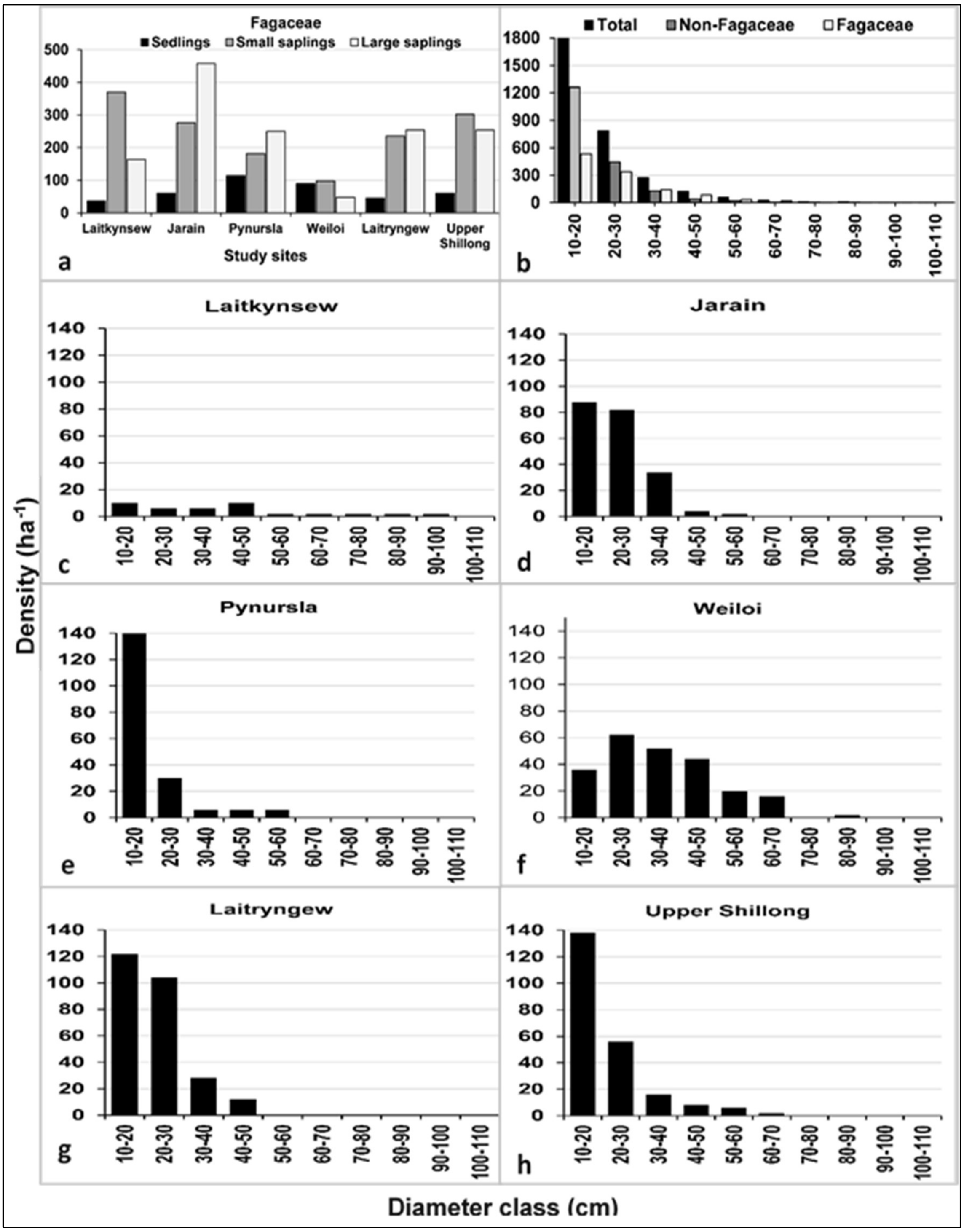

Figure 4: Regeneration potential of Fagaceae in six sites (a), the Population structure of Fagaceae and Non-Fagaceae (b), Site wise population structure of Fagaceae (c-h)

The analysis of the age structure of Fagaceae seedlings, small saplings and large saplings showed that seedling population was low in all sites. In three out of six sites (Jarain, Pynursla and Laitryngew) the distribution of individuals in respective age structure followed J-shaped distribution and in other three (Laitkynsew, Weiloi and Pynursla) sites normal distribution (Figure 4 a). In Laitkynsew and Upper Shillong sites the distribution was skewed towards the right and in Weiloi population, the distribution was skewed towards left (Figure 4 a). The overall analysis of diameter distributions of Fagaceae species also revealed that all sites almost all sites had strong regeneration i.e., seedlings > or < saplings > adults (total number of seedling and saplings) but low recruitment to the pole-size tree and

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adult trees (Figure 4). The population structure of Fagaceae differ markedly between the sites (Figure 4 c-h) and ranged from reverse J-shaped to bimodal distribution. Jarain, Laitryngew, Pynursla and Upper Shillong sites showed reverse J-shaped curve. The number of individuals was concentrated in lower dbh classes that gradually declines in the successive dbh classes. Weiloi site showed normal bell-shaped distribution with high tree density skewed to the right and the number of greater proportion of individuals was distributed in the intermediate and older dbh classes and, Laitkynsew site with least number of Fagaceae members across all sites showed bimodal distribution indicating bimodal age distribution for episodic regeneration.

3.4. Adaptation strategy to disturbance stress by Fagaceae species

Laitryngew, Jarain, and Weiloi were categorized with a high level of disturbance based on the disturbance scores generated from disturbance indicators (signs of cutting, grazing, burning and trampling). Weiloi forest had the highest levels of the cut-stems and stumps, and Laitkynsew had the lowest level of disturbance by wood/tree extraction (Table 5).

Table 5: Indicators of anthropogenic disturbances in the six forest stands

Stands	Disturbance score class	Distance from the nearest village (Km)	Proportion of stumps (%)	Proportion of cut stem (%)	Gini index
Laitkynsew	1	0.83	7.08	1.00	0.59
Jarain	3	1.26	17.84	18.42	0.44
Pynursla	3	0.47	24.06	10.51	0.46
Weiloi	3	0.59	35.20	71.28	0.47
Laitryngew	2	0.51	18.59	32.80	0.40
Upper Shillong	2	1.07	32.28	23.87	0.47

Mild =1, Moderate=2 and High=3

Across all study stands, 61% of the stems were healthy, 36% were cut and 3% were damaged due to natural cause. Non-Fagaceae stems (42%) showed a higher percentage of healthy stems then the Fagaceae stems (19%). The Fagaceae stems were thrice as much damaged by cutting and twice by natural causes then the Non-Fagaceae stems (Table 6). However, damage due to natural cause in both the Fagaceae and Non-Fagaceae trees was < 5%. Fagaceae members which constituted 37.6 % of the tree density showed high stem sprouting following disturbance. It was observed that with an increase in the cutting of stems the stem sprouting increased in Fagaceae. The Fagaceae trees produced 1.84 times more stems as compared to Non-Fagaceae trees (1.19) (Table 6). The percentage of sprouting was 16.1 % in Non-Fagaceae trees in response to stem cutting and 45.6% in Fagaceae trees (Table 6). Among the Fagaceae trees, only *Castanopsis purpurella* and *Quercus semiserrata* showed no sign of damage. Three Fagaceae members viz., *Quercus lineata, C. tribuloides* and *L. dealbatus* together constituted *88%* of the total Fagaceae tree density were the most damaged due to anthropogenic and natural disturbances. The extent of damage in these three species varied from 49% in *L. dealbatus*, 67% in *C. tribuloides* to 84% in *Q. lineata*. Correspondingly these three species showed high coppicing/sprouting ability following disturbance (Table 6). *Quercus lineata* (2.95) had the highest number of stems per tree followed by *C. purpurella* (2.17), *C. tribuloides* (1.74), *L. dealbatus* (1.54) and *Q. glauca* (1.39) and, the rest of the four Fagaceae members had <1.21 stem turnover rate per tree (Table 6).

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Table 6: Damage information on Fagaceae and Non-Fagaceae and their coppicing ability (%) in response to the Damage

Components	Mean tree ha^{-1} (T)	Mean Stems ha^{-1} (S)	Healthy stems ha^{-1}	Cut Stems ha^{-1}	Natural damage Stem ha^{-1}	Coppice/ Sprouting (%) (S-T)/S	Stems /Tree
Castanopsis indica	3.7	4.3	3.7 (85)	0 (0)	0.7 (15)	15.4	1.2
Castanopsis purpurella	2	4.3	4.3 (100)	0 (0)	0 (0)	53.8	2.2
Castanopsis tribuloides	14	24.3	8.0 (33)	16.3 (67)	0 (0)	42.5	1.7
Lithocarpus dealbatus	114.7	176.3	90.7 (51)	76.0 (43)	9.7 (6)	35.0	1.5
Lithocarpus elegans	8	9.7	9.3 (97)	0.3 (3)	0 (0)	17.2	1.2
Quercus glauca	7.7	10.7	4.7 (44)	4.3 (41)	1.7 (16)	28.1	1.4
Quercus griffithii	1	1	0.3 (33)	0.7 (67)	0 (0)	0.0	1.0
Quercus lineata	42.7	125.7	19.7 (16)	102.3 (81)	3.7 (3)	66.0	2.9
Quercus semiserrata	0.3	0.3	0.3 (100)	0 (0)	0 (0)	0.0	1.0
Fagaceae	194	356.7	141.0 (19)	200 (27)	15.7 (2)	45.6	1.8
Non Fagaceae	321.3	383	310.0 (42)	64.7 (9)	8.3 (1)	16.1	1.2
Grand Total	515.3	739.7	451 (61)	264.7 (36)	24 (3)	30.3	1.4

* Values in the parenthesis are the percentage value of each component

Stem coppice percentage was calculated by taking the difference between individuals of the stem (S) and tree (T) to the total sum of the differences from Table 6. Proportionately *Lithocarpus dealbatus* and *Quercus lineata* had high stem density and also were the two most damaged trees species with 24.0 % and 29.7% among the Fagaceae by both Natural and anthropogenic agents. *Lithocarpus dealbatus* showed 37.9% coppicing ability and *Q. lineata* 51% coppicing ability. This result indicates that both of the species are highly preferred by the locals and they were frequently damaged for fuelwood and timber collection in these forests (Figure 5). This indicates that *Lithocarpus dealbatus* and *Quercus lineata* have well adapted to the prevailing harsh conditions of this region, and they have adopted sprouting and coppicing mechanism to counter these disturbances by nature and humans.

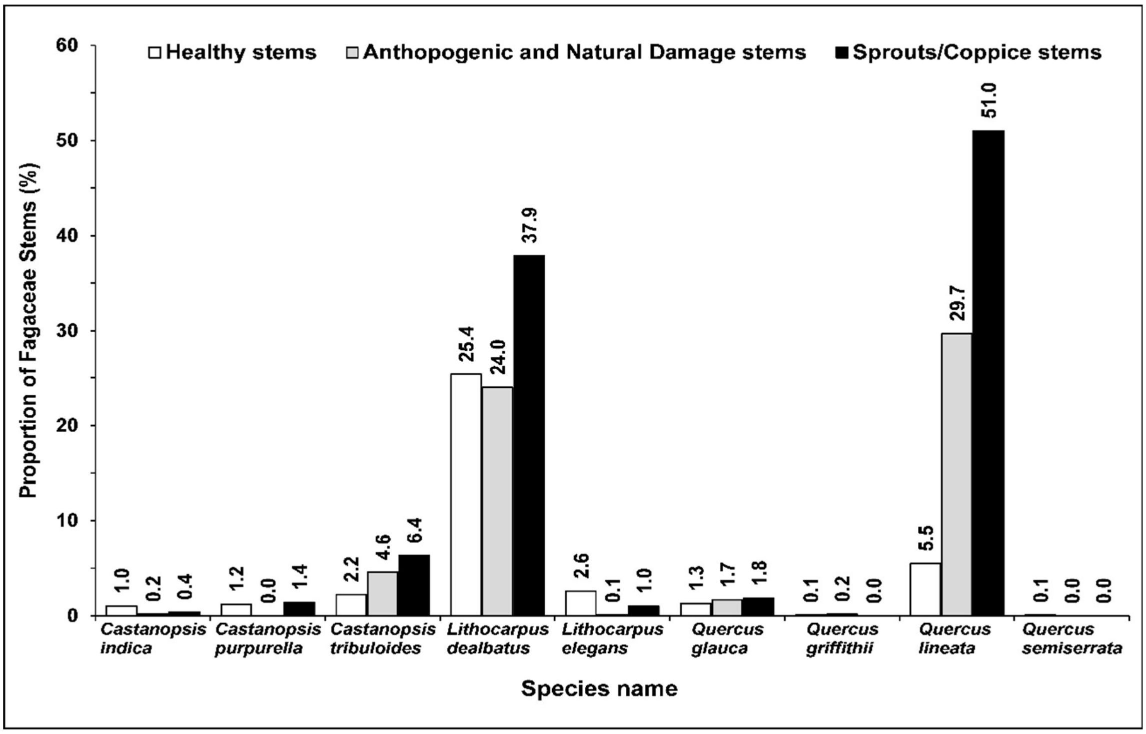

Figure 5: Proportion of stems (coppice/sprouts) from a tree vs. damage information (Sign of cutting, broken stem, dying tree, and pathogen attack) due to Natural and anthropogenic disturbance.*3.5. Influence of biotic and abiotic factors on the regeneration of Fagaceae*

The results from GLM analyses are presented in tabulated form in Table 7. The adjusted R^2 between observed and predicted values from five GLM analyses ranged from 0.50 to 0.98 (Figure 6) reflecting a moderate to high accuracy of GLM analyses. The increase in the disturbance was positively related to the higher number of seedlings, small saplings, and pole size trees. Here, disturbance intensity of a plot was assessed mild, moderate and high levels of disturbance. It was calculated from the summation of the present or absent score (i.e., 0 or 1) of signs of cuts on trees, grazing, burning, and trampling in each plot. The interactions between elevation, the proportion of cut stem, and stumps had a negative effect on the frequency of seedlings but a positive effect on the frequency of the pole size trees. The frequency of small saplings, large saplings, and pole size trees increased significantly as the distance between the plots and nearest villages extended. The interaction between structural diversity (Gini index) and stand density had a positive effect on the frequency of seedlings, small saplings, large saplings and pole size trees of Fagaceae family. However, the interactions between tree species diversity and stand density had a negative effect on the frequency of seedlings, small saplings, and large saplings. The interaction between the proportion of the cut basal area between Fagaceae trees and other trees had a positive effect on the frequency of seedlings and trees but a negative effect on the frequency of small saplings, large saplings, and pole size trees. Bulk density had a positive effect on the occurrence of large saplings but didn’t influence other height cohorts.

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Table 7: Influence of biotic and abiotic variables on the frequency of seedlings, small saplings, large saplings, pole size trees, and big trees. The autocorrelated variables were fitted as interesting terms in the model (N=12 plots, df = degree of freedom, SE=standard error, Sig. = p values)

Target variable	Independent variables	Parameter estimates	SE of parameter estimates	95% Wald Confidence Interval of SE		Hypothesis Test		
				Lower limit	Upper limit	Wald Chi-Square	df	Sig.
Frequency of Fagaceae seedlings per plot	Intercept	-0.2924	1.3844	-3.0058	2.4210	0.0446	1	0.8327
	Disturbance intensity	0.5444	0.1342	0.2814	0.8075	16.4556	1	0.0000
	Elevation * % of stumps * % of cut stem	-0.000001	0.0000002	-0.0000014	-0.0000004	13.0753	1	0.0003
	Distance to nearest village	0.1500	0.4537	-0.7392	1.0392	0.1094	1	0.7409
	Bulk density	0.0565	0.4864	-0.8969	1.0098	0.0135	1	0.9075
	Gini index * Stem density	0.0593	0.0176	0.0248	0.0937	11.3527	1	0.0008
	Tree species diversity * Tree density	-0.0057	0.0018	-0.0092	-0.0022	10.2920	1	0.0013
	% of basal area of Fagaceae trees * % of cut stem	0.0005	0.0001	0.0003	0.0008	16.8173	1	0.0000
	Omnibus test: Likelihood Ratio Chi Square = 43.38, df = 7, $p < 0.05$ AIC value = 103.47							
Target variable	**Independent variables**	**Parameter estimates**	**SE of parameter estimates**	**95% Wald Confidence Interval of SE**		**Hypothesis Test**		
				Lower limit	**Upper limit**	**Wald Chi-Square**	**df**	**Sig.**
Frequency of Fagaceae small saplings per plot	Intercept	4.0018	0.5353	2.9526	5.0510	55.8836	1	0.0000
	Disturbance intensity	-0.0899	0.0651	-0.2175	0.0376	1.9109	1	0.1669
	Elevation * % of stumps * % of cut stem	-0.0000002	0.0000001	-0.0000004	0.0000001	1.6553	1	0.1982
	Distance to nearest village	0.3997	0.1929	0.0215	0.7778	4.2909	1	0.0383
	Bulk density	-0.2580	0.2303	-0.7095	0.1934	1.2549	1	0.2626
	Gini index * Stem density	0.0188	0.0077	0.0036	0.0340	5.8792	1	0.0153
	Tree species diversity * Tree density	-0.0022	0.0009	-0.0039	-0.0005	6.1223	1	0.0133
	% of basal area of Fagaceae trees * % of cut stem	-0.0001	0.0001	-0.0002	0.0001	0.4266	1	0.5137
	Omnibus test: Likelihood Ratio Chi Square = 118.79, df = 7, $p < 0.05$							

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AIC value = 104.52

Target variable	Independent variables	Parameter estimates	SE of parameter estimates	95% Wald Confidence Interval of SE		Hypothesis Test		
				Lower limit	Upper limit	Wald Chi-Square	df	Sig.
Frequency of Fagaceae large saplings per plot	Intercept	-0.9063	0.6198	-2.1211	0.3084	2.1385	1	0.1436
	Disturbance intensity	0.2723	0.0652	0.1446	0.4000	17.4605	1	0.0000
	Elevation * % of stumps * % of cut stem	0.0000001	0.0000002	-0.0000002	0.0000004	0.1817	1	0.6699
	Distance to nearest village	1.7619	0.1753	1.4182	2.1055	100.9570	1	0.0000
	Bulk density	0.8462	0.1967	0.4606	1.2317	18.5036	1	0.0000
	Gini index * Stem density	0.0482	0.0094	0.0297	0.0667	26.0291	1	0.0000
	Tree species diversity * Tree density	-0.0023	0.0010	-0.0042	-0.0003	4.9953	1	0.0254
	% of basal area of Fagaceae trees * % of cut stem	-0.00021	0.00010	-0.00040	-0.00002	4.4837	1	0.0342

Omnibus test: Likelihood Ratio Chi Square = 253.58, df = 7, $p < 0.05$

AIC value = 250.88

Target variable	Independent variables	Parameter estimates	SE of parameter estimates	95% Wald Confidence Interval of SE		Hypothesis Test		
				Lower limit	Upper limit	Wald Chi-Square	df	Sig.
Frequency of Fagaceae pole size trees per plot	Intercept	-3.6595	1.2668	-6.1424	-1.1766	8.3450	1	0.0039
	Disturbance intensity	0.4936	0.1191	0.2602	0.7269	17.1798	1	0.0000
	Elevation * % of stumps * % of cut stem	0.000001	0.0000002	0.0000006	0.0000013	27.6601	1	0.0000
	Distance to nearest village	1.7098	0.3327	1.0577	2.3618	26.4131	1	0.0000
	Bulk density	0.4754	0.2948	-0.1023	1.0532	2.6014	1	0.1068
	Gini index * Stem density	0.0558	0.0136	0.0291	0.0825	16.7853	1	0.0000
	Tree species diversity * Tree density	0.0005	0.0011	-0.0017	0.0027	0.2204	1	0.6387
	% of basal area of Fagaceae trees * % of cut stem	-0.0003	0.0001	-0.0005	-0.0001	7.2466	1	0.0071

Omnibus test: Likelihood Ratio Chi Square = 126.08, df = 7, $p < 0.05$

AIC value = 98.14

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Target variable	Independent variables	Parameter estimates	SE of parameter estimates	95% Wald Confidence Interval of SE		Hypothesis Test		
				Lower limit	Upper limit	Wald Chi-Square	df	Sig.
Frequency of Fagaceae adult trees per plot	Intercept	1.8435	1.5448	-1.1842	4.8712	1.4241	1	0.2327
	Disturbance intensity	-0.2652	0.1896	-0.6367	0.1064	1.9567	1	0.1619
	Elevation * % of stumps * % of cut stem	-0.0000001	0.0000003	-0.0000007	0.0000004	0.3044	1	0.5811
	Distance to nearest village	0.5935	0.5339	-0.4529	1.6400	1.2358	1	0.2663
	Bulk density	0.0171	0.5853	-1.1300	1.1642	0.0009	1	0.9767
	Gini index * Stem density	-0.0108	0.0216	-0.0532	0.0316	0.2487	1	0.6180
	Tree species diversity * Tree density	0.0019	0.0024	-0.0028	0.0066	0.6174	1	0.4320
	% of basal area of Fagaceae trees * % of cut stem	0.0004	0.0001	0.0001	0.0007	8.5302	1	0.0035

Omnibus test: Likelihood Ratio Chi Square = 81.16, df = 7, $p < 0.05$

AIC value = 67.96

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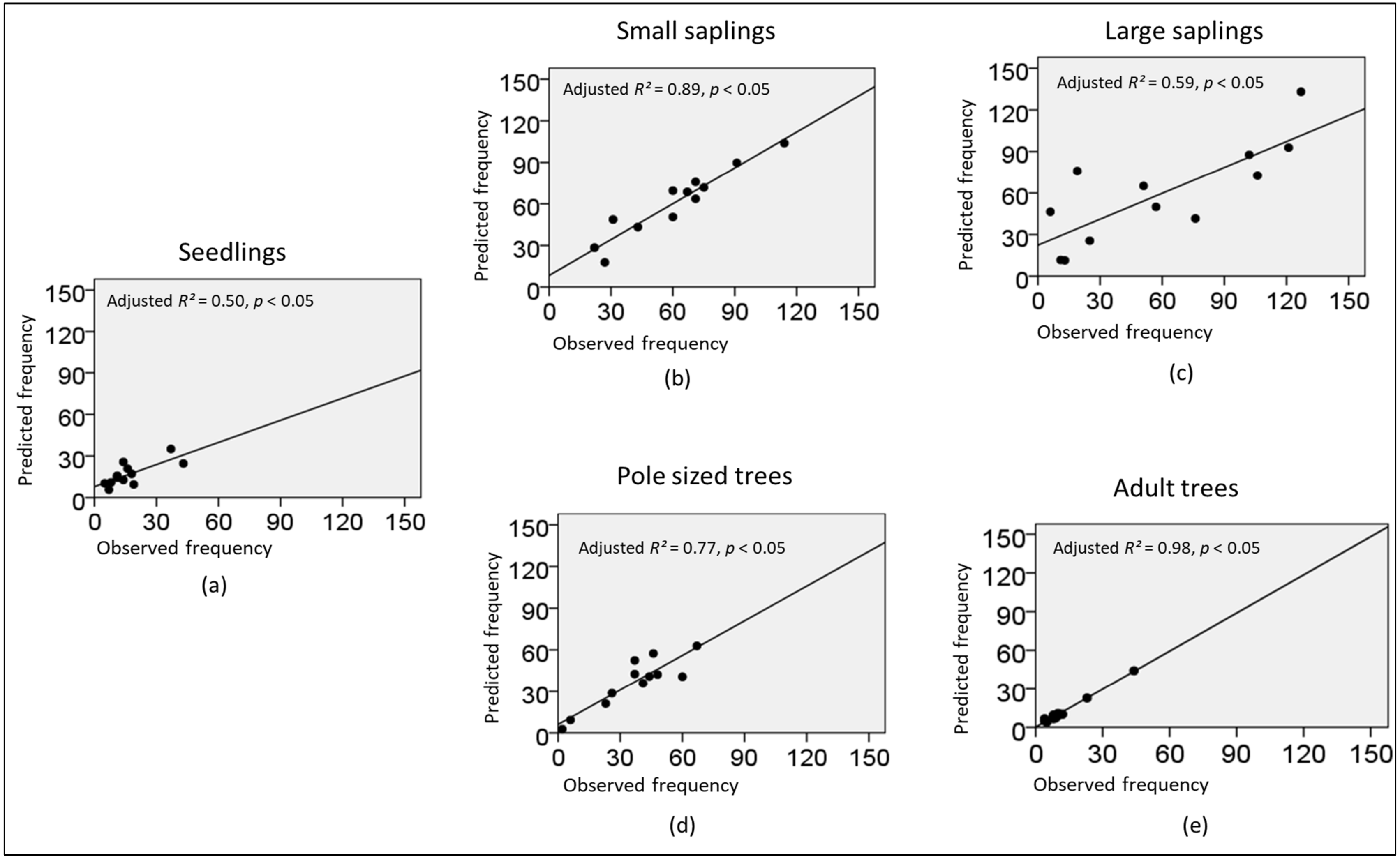

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4 Figure 6: The relations between observed and predicted frequency values from GLM analyses (Table 7) for seedlings (a), small saplings (b), large saplings (c), pole size
5 trees (d) and adult trees (e).

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4. Discussion

The degraded and fragmented subtropical broad-leaved humid forests on southern slopes of Meghalaya are exposed to numerous biotic and abiotic disturbances. These forests are the remnants of the continuous forests of the past and harbour high species richness and diversity [41,46]. The presence of 143 trees species (10 unidentified trees species included) distributed in 78 genera and 43 families is comparable with the findings reported by Pao and Upadhaya (2017) from fragmented forests of Jaintia Hill district in Meghalaya. This heterogeneous, diverse assembly of plants is largely a result of the unique geographical location, topography, and seasonality in the climate. The tree species diversity of these remnant forests are also comparable with some of the well-protected old-growth forest in sacred groves of the region [38,39]. It was also observed that the species richness did not show any linear relationship with the increase in forest fragment size. This trend corroborates the finding of Pao & Upadhaya (2017) in the fragmented subtropical forests of Meghalaya and in the temperate forest of Chile [69]. Such fragmented forest does not supports the idea that larger fragments harbors a high number of species [70]. On the contrary, these remnant fragmented forest are under severe threat due to anthropogenic activities which may impoverished disturbance sensitive species from the forests and serve as the potential area for conservation of remnant native resilient species [71].

Lauraceae was the dominant family with 25 species followed by Rubiaceae and Fagaceae (10 species each), similar distribution of families are also recorded from sub-tropical and lower-temperate forests of South-east Asia [72–76]. The range of species recorded from different sites (10 – 51 tree species) in the present study was higher than Oak-dominated forest of Mid-Appalachians of the Eastern United States (4-12 tree species) and the Kumaun Himalaya of Northern India (1-9 tree species) [36].

Except for the Weiloi forest which was predominantly dominanted by Fagaceae (91.2% of total basal area), all the other forests were characterised low dominance index (0.10-0.26) and high Shannon's diversity (1.76-2.75). The negative relationship between dominance and evenness index indicates a diverse community assemblage and the importance of these remnants forests in the conservation of plant diversity in the fragmented landscape [53,77]. Fagaceae was the dominant family followed by Lauraceae, Theaceae, Myricaceae and Proteaceae. Together these families constituted 75.6 % of the total basal cover from all the six study sites, of which Fagaceae alone contributed 47.7% to the total basal cover. These families are widely distributed in the entire landscape of sub-tropical forests of Meghalaya [41,74,78]. Fagaceae members plays an important role as keystone species in sustainability of these fragmented remnant forest. *Lithocarpus dealbatus* was the dominant species accounting for 19.3% of the total basal cover across the study sites followed by *Quercus lineata*, *Schima wallichii*, *Persea odoratissima*, *Myrica esculenta*, *Castanopsis indica* and *Castanopsis tribuloides*. Together these seven species constituted for 60.4% of the total basal area cover. These dominant native species have co-evolve and coexisted for a long time in these remnant patches.

Landscape-level restoration for inter-connecting the fragmented patches may be achieved if these dominant species, together with some fast-growing native species, are planted together [79]. The fast-growing species such as *Alnus nepalensis*, *Betula alnoides* etc., can grow fast and provide forest products and services in a short time which may be utilised by the local people to meet their requirement [79]. Although, the natural regeneration of late successional species (Fagaceae members) under natural condition is poor as reported in our present study and also seen in many oak forest around the world [44,80,81]. Adopting such measures may decrease the dependency on these slow-growing trees, which may provide the time these dominant native species need to undergo natural regeneration and establish themselves into the canopy trees [6,82–84].

Community characterstics

Across the study sites, the range of total basal area cover varies from 16.48 to 35.3 m^2ha^{-1} and the total tree density from 276 to 868 trees ha^{-1} were comparable to the temperate pine-Oak mixed forest of Qinling mountains in north-western China [85], tropical forest of Kenya [86] and fragmented subtropical forest of Meghalaya [53], but had lower basal cover and tree density than the sub-tropical and temperate oak forest of central Himalaya [87,88]. The stem density showed no linear relationship with the fragment size, it, however, increased significantly with disturbance. The increase in stem density with disturbance may be attributed to the resilience and plorific sprouting ability of the fragments following disturbance [89]. Recruitments of individuals in gaps created due to selective extraction of trees of large dbh classes may also have release stems with lower dbh class thereby increasing stem density as reported [90] from the subtropical forest of Meghalaya. Consequently, in the present study high density of stems showed reduced basal area cover at Jarain, Pynursla, Laitryngew and Upper Shillong as compared to old-growth forests at Laitkynsew and Weiloi. These finding agree with recent studies in a disturbed dry tropical forest of northern India [91].

In general, across the remnants forests, we observed that 83.6% of trees were recorded between 10cm-30 cm dbh class showing a reverse J-shaped distribution. The preponderance of young trees clearly indicates that these forests are regenerating forests [39,53,86]. In the undisturbed forest, such distribution indicates a high density of lower diameter class and less tree mortality [92]. However, in disturbed forest, such distribution is largely due to the extraction of larger girth class trees [37]. The relative density of pole trees (10-30cm dbh) in Fagaceae (28.3%) was lower than Non-Fagaceae (55.3%) trees. Selective extraction of Fagaceae members has led to increases in the number of Non-Fagaceae species with lower dbh class within the forests. Consequently, the slow-growing Fagaceae trees are being replaced by the fast-growing, more competitive Non-Fagaceae species under disturbance regime [37,88].

In the present study, the population structure of Fagaceae (dbh>10cm) in four out of six remnant forests viz., Laitryngew, Jarain, Upper Shillong and Pynursla showed a reverse J-shaped distribution indicating the populations are strongly regenerating with fewer number of individuals in higher girth class and more in lower girth class [53,86]. However, at Weiloi which is predominately Fagaceae dominated forest (91.2% total basal cover) shows a reverse trend. The population structure follows a bell-shaped distribution which is skewed towards the right and with highest concentration of trees in the intermediate dbh class. Indicating infrequent recruitment of lower dbh class trees and removal of high dbh class tree. Such population will naturally have a decline in recruitment of young tree thereby are at the risk of local extinction [37,93]. However, the presence of large dbh class tree in this forest may act as a counterforce to balance between natural regeneration and local extinction of the forest species. Therefore, to understand the principles governing the dynamics of such frequently disturbed forests, long term study is prerequisite for assessing the status and population dynamics in these forests [94]. The Laitkynsew population structure shows bimodal distribution which may be due to episodic regeneration that results in two or more bimodal age distribution over a period of time [95]. Among the Fagaceae members, the contribution of *Lithocarpus dealbatus* and *Quercus lineata* to the population structure was by far greater than all other species of Fagaceae. This result illustrates the importance of these two species to the overall structure of the Fagaceae dominated subtropical forests.

Regeneration Potential

The proportion of seedlings of Fagaceae were lower in all sites as compared to that of sapling populations, this may be due to over-grazing pressure on seedlings, removal of acorns as fruits and extraction of mature trees for timber and fuelwood by anthropogenic activities in these forests [37,44]. Fagaceae tree species also suffer from seed losses due to pest and predation. Hence, the abundance of seedlings in these forests is low, which conforms to the study by Barik et al (1996) from the sub-tropical forest in Meghalaya. However, the ratio between successive age structure shows a good number of seedlings that translated into saplings and trees which shows the reproductive success of the family Fagaceae [94,96,97]. Fagaceae contributed to 37.6 % of the total tree density and their population structure showed sufficient recruitment of saplings to pole trees (60%) which suggest good regeneration potential of Fagaceae in these remnants forest which strengthen their sustainability in the future forest [7,39].

Due to removal of seeds and seedling in the early phase of the establishment of Fagaceae by various kind of disturbances, a J-shaped distribution with more saplings individuals than seedlings was observed in fragmented forests of Jarain, Pynursla, Laitryngew and Upper-Shillong. Similar results were seen from the study by Rao et al., (1990) at the different intensity of disturbance. Whereas, in Laitkynsew and Weiloi sites the age group structure shows a bell-shaped distribution with a higher density of small saplings than the seedlings and large sapling. Such distribution is frequent in disturbed forests where removal or infrequent recruitment of seedlings occurs [37,43,95]. The reduced number in large sapling population is due to its over-harvesting by local people for various purposes and also due to overcrowding by stem density which negatively affects the large sapling regeneration [98].

In general, the Fagaceae members across the sites showed good regeneration potential. Similar results were also reported from the oak-dominated forest in Garhwal Himalaya [99]. *Lithocarpus dealbatus* which was present in all the six sites showed good regeneration potential. Similarly, *Castanopsis purpurella, Quercus semiserrata, Castanopsis indica* and *Quercus griffithii* also showed good regeneration potential. Rest of all other species showed variation in their ability to regenerate at different sites.

Response of Fagaceae to disturbance

A large percentage of the human population live in rural areas of Meghalaya, who depends entirely on forest products such as timber, firewood and NTFPs to meet their daily requirements [55]. Unscientific and over-harvesting of these forest resource in just one decade have reduced the forest cover by 202 km^2 and its on continuous decline leaving the entire landscape in the sub-tropical broad leaved hill forest degraded and fragmented condition [51,52,100].The Fagaceae tree species particularly *Quercus lineata*, *Lithocarpus dealbatus* and *Castanopsis tribuloides* are preferred by the indigenous community for its high timber and fuelwood quality. In addition to such rampant deforestation, overgrazing and browsing, frequent forest fires, seed predation and adverse environmental condition have severely affected the inherent capacity of these forest to regenerate naturally through seeds in these forests [39,42,44,101,102]. However, Natural regeneration by means of stems sprouting following are less susceptible to environmental condition and other source of disturbances [20,42]. Stem regeneration ability under disturbance regime varies from species to species and it has been documented in many species of Fagaceae [103–105] and Non-Fagaceae trees in tropical forests [16,106]. In the present study, we found that Fagaceae trees has better sprouting ability than the Non-Fagaceae trees. We also observed that Fagaceae trees were more damaged due both by natural and anthropogenic causes than the Non-Fagaceae trees. The damage due to anthropogenic activity i.e., by cutting in Fagaceae members was three times higher than of Non-Fagaceae trees. However, the Fagaceae members have adapted to such adverse condition over the period of time. They have adopted the strategy of coppicing/sprouting, which has helped them to grow multiple stems and maintain their dominance over the Non-Fagaceae species. The cutting in Fagaceae trees increased the stem density by almost three times than that of non-Fagaceae and the number of stems per tree was higher in Fagaceae (1.84) than Non-Fagaceae (1.19). This result indicates that the Fagaceae species produced much more stems than the Non-Fagaceae trees in response to disturbance due to cutting which indicates disturbance favours Fagaceae regeneration through stem sprouting in these remnants forest. Among the nine Fagaceae species, *Quercus lineata* and *Lithocarpus dealbatus* were the two most damagend species and showed better coppicing ability with high stems sprouting per tree than all the other species in the forest. Thus, indicating that both the species have well adapted to the prevailing harsh conditions of this region, and they are prolific sprouters that dominate the entire degraded and fragmented landscape [20,42,44].

Influence of biotic and abiotic variables

Disturbance plays a very important role in shaping the species composition, structure and regeneration status of the forest [37,107,108]. Our study shows a positive interaction of disturbance intensity on seedling, large sapling and pole size tree density. Similarly, the distance from the nearest village to the study site showed a positive interaction. The finding of our results suggests that the Fagaceae seedlings grow better in sites where a moderate level of disturbance occur, which corroborates the finding Barik et al. (1996). The study reports that the seeds of Litocarpus dealbatus and Quercus spp produce heavy seeds in such moderately disturbed sites thereby increasing their chances for seedling establishment. Fagaceae species such as *Lithocarpus dealbatus, Quercus glauca* and *Quercus griffithii* are growing better light condition created by small tree gaps in the forest canopy [42,43], this may be the reason why disturbance which creates gaps in forests shows better survival of saplings and pole trees of Fagaceae [14,42]. Distance from the nearest village directly relates to the frequency of anthropogenic disturbance by which forest is thin down to allow sufficient light condition for regenerating population [53]. However, the interaction between elevation, percentage of cut stump and percentage of the cut stem had a negative effect on seedling regeneration. This relationship may develop as a result of selective felling of tree of higher girth class by the locals to meet their need for timber and fuelwood from the forest. Along the elevation, Fagaceae seedlings followed a bell-shaped distribution. Excessive grazing pressure at a higher elevation [109]. Low seedling density at lower elevation can be explained in the light of competition by abundance of competing Non-Fagaceae species and low abundance of Fagaceae members as they are predominantly distributed at an elevation above 1000 m.a.s.l [61,63].

The bulk density had a positive interaction on the large sapling. In our present study, the bulk density ranges from 0.65 to 1.47 (g/cm^3) which is similar to bulk density reported by Pao and Upadhaya (2017) from the fragmented forest in Jaintia hill district of Meghalaya. They reported that across the different fragment size *Castanopsis purpurella* was the dominant species both in term of basal area and density and, 55-74% of individuals were distributed in 5-15 cm dbh class which corroborates with our results.

The interaction between the percentage of basal area and percentage of cut stems shows a positive relationship with seedling and adult tree population and negatively impacts the large saplings and pole size trees. This may be due to higher basal area translates into greater resources utilization ability by the Fagaceae and percentage of cut stem positively increase stem regeneration through sprouting in mature trees [89]. However, it negatively affects the large saplings and pole size trees due to their low basal cover and susceptibility to injury by cutting that may lead to infection and increase mortality rate in the lower girth class [92]. Large sapling and pole trees also suffer to a great extent due to suppression under the canopy and poor light condition [42]

The interaction between the Gini index and stem density had a positive impact on the regeneration potential of Fagaceae. Gini index in all the six sites ranged from 0.4-0.59 which suggest the forests are structurally heterogeneous and diverse. Regeneration potential increased with increased in structural heterogeneity and stem density as these fragmented forests are strongly regenerating with 83% of the density of the trees in 10-30 cm dbh class [53]. Thus allowing sufficient penetration for seedling establishment in late successional species (Fagaceae) in some sites where the tree canopy is interrupted or lacks complete closure. Consequently, more numbers of large sapling and pole size tree are produced. From the present study, we see that one single-family (Fagaceae) produces higher number of stem and pole size tree density compared to 52 (Non-Fagaceae) families.

The interaction between tree species diversity and tree density had a negative impact on Fagaceae seedlings, small saplings and large saplings. This result indicates that the increase in species diversity results in an increase in competing species and competition for available resources which are always in limited supply. This intensifies the interspecific completion for light, moisture, space and nutrients which results in high seedling and sapling mortality. Similar results were seen in Pine-Oak mosaic mixed forest in the Qinling Mountains in Northwestern China [85].

5. Conclusions

From our study, it is evident that the Fagaceae populations in the forest were strongly influenced by the human-modifications to structural diversity and composition. For proper management and sustenance of disconnected remnant forests, it is necessary to adopt scientific means of forest management and utilization and, the forests should be allowed to undergo natural regeneration and recruitment into the overstory. As these, fragmented and degraded forests have the potential to naturally regenerate with management that ensures high regeneration potential in desired species such as Fagaceae. Efforts should be made to undertake sustainable forest management at the landscape level to promote reconnecting fragmented patches, enlarging existing forests, and improve the stocking of desired species in degraded forests. The involvement of the local community as stewards of the forests and commitment from governmental agencies to supply management guidance and demonstrate best management practices are essential to sustainably manage Fagaceae forests for biodiversity conservation and maintaining the flow of ecological services. However, if the current trend of anthropogenic forest degradation continues, the existing remnants forests may continue to shrink in size, be degraded by loss of desired species, and will eventually significantly lose their ecological resilience.

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Appendix A

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Appendix A : List of tree species and IVI values in study sites. Unindentified species were marked as UNK.

Species Name		Laitkynsew			Jarain			Pynursala			Weiloi			Laitryngew			Upper Shillong		
	Family	IVI	BA/ ha	D/ ha	IVI	BA/ ha	D/ ha	IVI	BA/ ha	D/ ha	IVI	BA/ ha	D/ ha	IVI	BA/ ha	D/ ha	IVI	BA/ ha	D/ ha
Gynocardia odorata R.Br.	Achariaceae	2.6	0.05	2															
Brucea javanica (L.) Merr.	Anacardiaceae																	0.02	2
Rhus javanica L.	Anacardiaceae																3.3	0.04	2
Rhus succedanea L.	Anacardiaceae				12.4	1.0	24										3.3	0.04	2
Miliusa roxburghiana Hook.f. & Thomson	Annonaceae	2.7	0.08	2															
Ilex embelioides Hook.f.	Aquifoliaceae							2.5	0.1	2				8.8	0.5	32			
Ilex excelsa (Wall.) Voigt	Aquifoliaceae				2.8	0.2	2	2.7	0.0	4									
Ilex khasiana Purkay	Aquifoliaceae																8.6	0.23	10
Ilex venulosa Hook.f.	Aquifoliaceae							21.9	1.0	74				2.3	0.1	2			
Macropanax dispermus (Blume) Kuntze	Araliaceae	2.6	0.04	2															
Merrilliopanax alpinus (C.B.Clarke) C.B.Shang	Araliaceae	6.7	0.42	6															
Pentapanax sp.	Araliaceae				2.0	0.0	2							3.9	0.1	4			
Schefflera hypoleuca (Kurz) Harms	Araliaceae				5.2	0.2	6	7.2	0.3	12	8.0	0.0	2	7.3	0.4	22			
Schefflera sp.	Araliaceae	10.4	1.33	16															
Betula alnoides Buch.-Ham. ex D.Don	Betulaceae																4.0	0.09	4
Carpinus viminea Wall. ex Lindl.	Betulaceae							3.8	0.2	4									
Euonymus sp1	Celastraceae	2.5	0.02	2															
Euonymus sp.	Celastraceae							2.4	0.0	2									
Microtropis discolor (Wall.) Arn.	Celastraceae				2.0	0.0	2												
Calophyllum polyanthum Wall. ex Planch. & Triana	Clusiaceae	21.1	2.78	32	7.9	0.3	18												
Garcinia cowa Roxb. ex Choisy	Clusiaceae													2.0	0.1	2			
Daphniphyllum himalayense (Benth.) Müll.Arg.	Daphniphyllaceae							2.5	0.1	2							3.2	0.02	2
Diospyros sp.	Ebenaceae				1.9	0.0	2												
Elaeocarpus sp1	Elaeocarpaceae				20.0	1.6	48												
Elaeocarpus acuminatus Wall. ex Mast.	Elaeocarpaceae													4.5	0.2	6			
Elaeocarpus bracteatus Kurz	Elaeocarpaceae																3.3	0.04	2
Elaeocarpus floribundus Blume	Elaeocarpaceae							4.7	0.3	6									
Elaeocarpus lanceifolius Roxb.	Elaeocarpaceae													15.2	1.4	56			
Elaeocarpus prunifolius Wall. ex Müll.Berol.	Elaeocarpaceae				5.9	0.2	10												
Elaeocarpus sp2	Elaeocarpaceae	2.6	0.03	2															
Lyonia ovalifolia (Wall.) Drude	Ericaceae																4.7	0.15	6
Rhododendron arboreum Sm.	Ericaceae													1.9	0.0	2	16.8	1.41	22

Croton oblongus Burm.f.	Euphorbiaceae							3.8	0.2	6									
Macaranga peltata (Roxb.) Müll.Arg.	Euphorbiaceae	3.5	0.16	4															
Ostodes paniculata Blume	Euphorbiaceae	16.8	0.85	36															
Castanopsis indica (Roxb. ex Lindl.) A.DC.	Fagaceae	25.1	5.20	22															
Castanopsis purpurella (Miq.) N.P.Balakr.	Fagaceae				3.8	0.2	6	5.1	0.4	6									
Castanopsis tribuloides (Sm.) A.DC.	Fagaceae				27.3	2.8	58	6.7	0.7	6				8.8	0.9	20			
Lithocarpus dealbatus (Hook.f. & Thomson ex Miq.) Rehder	Fagaceae	12.4	1.16	18	43.3	4.4	100	51.9	4.4	132	18.6	0.4	8	62.9	8.8	210	95.5	9.08	220
Lithocarpus elegans (Blume) Hatus. ex Soepadmo	Fagaceae				5.5	0.3	6	16.1	0.9	42									
Quercus glauca Thunb.	Fagaceae				19.0	1.7	40	2.5	0.1	2				2.2	0.0	4			
Quercus griffithii Hook.f. & Thomson ex Miq.	Fagaceae																10.0	0.69	6
Quercus lineata Blume (Quercus kamproopii)	Fagaceae										185.3	25.8	224	12.5	1.4	32			
Quercus semiserrata Roxb.	Fagaceae	4.2	0.61	2															
Exbucklandia populnea (R.Br. ex Griff.) R.W.Br.	Hamamelidaceae							3.0	0.1	2				5.3	0.6	12			
Itea macrophylla Wall.	Iteaceae	8.2	0.30	12															
Engelhardtia spicata Lechen ex Blume	Juglandaceae							3.4	0.1	6				1.8	0.0	2	3.5	0.08	2
Callicarpa arborea Roxb.	Lamiaceae	2.8	0.10	2															
Alseodaphne khasyana (Meisn.) Kosterm.	Lauraceae	8.5	0.62	10															
Beilschmiedia assamica Meisn.	Lauraceae							11.4	0.8	18									
Cinnamomum cassia (L.) J.Presl (Neolitsea cassia)	Lauraceae							2.3	0.0	2				26.9	2.5	118	3.3	0.04	2
Cinnamomum glanduliferum (Wall.) Meisn.	Lauraceae																9.3	0.37	10
Cinnamomum sp.	Lauraceae				10.8	0.7	22												
Cinnamomum tamala (Buch.-Ham.) T.Nees & Eberm.	Lauraceae	14.6	1.52	22				11.3	0.7	20									
Cinnamomum verum J.Presl	Lauraceae													1.8	0.0	2			
Iteadaphne caudata (Nees) H.W. Li	Lauraceae																3.2	0.02	2
Lindera caudata (Nees) Hook. f.	Lauraceae																3.7	0.04	4
Lindera latifolia Hook. f.	Lauraceae	11.3	2.25	4	1.9	0.0	2												
Lindera latifolia Hook. f.	Lauraceae				1.9	0.0	2												
Lindera nacusua (D. Don) Merr.	Lauraceae							2.5	0.1	2									
Litsea sp1	Lauraceae													2.4	0.1	2			
Litsea sp2	Lauraceae				2.2	0.1	2												
Litsea sp3	Lauraceae				2.0	0.0	2												
Litsea elongata (Nees) Hook. f.	Lauraceae				2.3	0.1	2	8.0	0.5	10				6.0	0.3	14			
Litsea sp4	Lauraceae													2.0	0.1	2			
Litsea sp5	Lauraceae	2.8	0.11	2															
Machilus duthiei King	Lauraceae	2.8	0.10	2															
Neolitsea cassia (L.) Kosterm.	Lauraceae				2.7	0.1	4												
Ocotea lancifolia (Schott) Mez	Lauraceae													5.2	0.3	8			

Persea sp3	Lauraceae							3.6	0.1	6									
Persea odoratissima (Nees) Kosterm.	Lauraceae	27.8	5.96	24	2.2	0.1	2	18.4	1.1	50				22.4	1.9	102	3.3	0.04	2
Persea sp1	Lauraceae										8.0	0.0	2						
Persea sp2	Lauraceae																3.9	0.08	4
Albizia sp.	Leguminosae				1.9	0.0	2												
Pongamia pinnata (L.) Pierre	Leguminosae	2.9	0.15	2															
Magnolia sp4	Magnoliaceae							7.0	0.3	10									
Magnolia sp3	Magnoliaceae													2.0	0.1	2			
Magnolia insignis Wall.	Magnoliaceae				3.1	0.1	6							15.6	1.3	62			
Magnolia punduana (Hook.f. & Thomson) Figlar	Magnoliaceae				6.7	0.8	6												
Magnolia sp2	Magnoliaceae				3.1	0.1	6												
Magnolia sp1	Magnoliaceae													2.3	0.1	2			
Manglietia caveana Hook.f. & Thomson	Magnoliaceae	2.6	0.05	2															
Sterculia roxburghiana Wall.	Malvaceae	7.4	1.73	2															
Ficus auriculata Lour.	Moraceae							2.2	0.0	2									
Ficus curtipes Corner	Moraceae	3.9	0.52	2															
Ficus neriifolia Sm.	Moraceae													6.1	0.3	14	3.2	0.02	2
Ficus nervosa B.Heyne ex Roth	Moraceae													4.9	0.2	8			
Myrica esculenta Buch.-Ham. ex D. Don	Myricaceae				3.0	0.2	2	8.8	0.5	12	21.1	0.9	10	8.1	0.7	18	25.9	3.18	24
Knema sp.	Myristicaceae				2.7	0.1	4												
Syzygium sp1	Myrtaceae				2.0	0.0	2												
Syzygium tetragonum (Wight) Wall. ex Walp.	Myrtaceae				5.1	0.1	8	5.0	0.1	6				1.8	0.0	2			
Olea salicifolia Wall. ex G.Don	Oleaceae				3.3	0.2	4												
Eurya acuminata DC.	Pentaphylacaceae																6.5	0.06	4
Eurya cerasifolia (D.Don) Kobuski	Pentaphylacaceae													1.9	0.0	2			
Eurya japonica Thunb.	Pentaphylacaceae							2.3	0.0	2	7.9	0.0	2	2.2	0.1	4			
Glochidion acuminatum Müll.Arg.	Phyllanthaceae													2.8	0.1	8			
Glochidion sp.	Phyllanthaceae				3.2	0.1	6												
Pinus kesiya Royle ex Gordon	Pinaceae										9.0	0.3	2				31.9	2.35	72
Ardisia sp.	Primulaceae							2.3	0.0	2									
Myrsine semiserrata Wall.	Primulaceae				2.1	0.1	2	5.9	0.1	10									
Helicia nilagirica Bedd.	Proteaceae				12.5	0.8	30	23.8	1.3	76				4.5	0.1	8			
Helicia robusta (Roxb.) R.Br. ex Blume	Proteaceae	20.0	2.79	28															
Docynia indica (Wall.) Decne.	Rosaceae													1.9	0.0	2			
Eriobotrya sp.	Rosaceae													2.1	0.1	2			
Photinia integrifolia Lindl.	Rosaceae							2.9	0.1	2									
Prunus cerasoides Buch.-Ham. ex D.Don	Rosaceae																3.2	0.02	2

Prunus phaeosticta (Hance) Maxim.	Rosaceae													1.9	0.0	2			
Hyptianthera sp.	Rubiaceae				2.1	0.1	2												
Meyna spinosa Roxb. ex Link	Rubiaceae	2.8	0.11	2															
Psychotria sp.	Rubiaceae				4.1	0.1	4												
Psychotria symplocifolia Kurz	Rubiaceae													2.1	0.1	2			
Wendlandia sp2	Rubiaceae				1.9	0.02	2												
UNK 11	Rubiaceae				8.9	1.37	4												
UNK 12	Rubiaceae				2.0	0.03	2												
Randia sp.	Rubiaceae	5.5	0.20	4															
Tarennoidea wallichii (Hook.f.) Tirveng. & Sastre	Rubiaceae													2.5	0.1	6			
Wendlandia sp.	Rubiaceae	2.6	0.057	2															
Acronychia pedunculata (L.) Miq.	Rutaceae							8.0	0.4	12									
Casearia glomerata Roxb.	Salicaceae	6.0	0.15	6				7.0	0.2	12									
Acer laevigatum Wall.	Sapindaceae				6.4	0.3	10							4.2	0.1	6	3.3	0.04	2
Aesculus assamica Griff.	Sapindaceae	9.0	1.20	6															
Sarcosperma griffithii Hook.f. ex C.B.Clarke	Sapotaceae	6.0	0.16	6	7.2	0.34	14	8.2	0.3	16									
Illicium griffithii Hook.f. & Thomson	Schisandraceae													1.9	0.0	2			
Styrax hookeri C.B. Clarke	Styracaceae							3.2	0.1	4									
Styrax sp1	Styracaceae				5.3	0.2	8												
Styrax serrulatus Roxb.	Styracaceae	3.6	0.18	4	2.0	0.03	2	8.1	0.4	12									
Symplocos sp.	Symplocaceae													1.8	0.0	2			
Symplocos paniculata (Thunb.) Miq.	Symplocaceae													3.2	0.2	8	7.1	0.10	6
Symplocos spicata Roxb.	Symplocaceae				5.1	0.13	8				7.9	0.0	2	5.6	0.2	14	3.4	0.05	2
Symplocos sp1.	Symplocaceae													1.8	0.0	2			
Camellia caudata Wall.	Theaceae										11.3	0.1	10						
Schima wallichii Choisy	Theaceae	28.1	4.18	42	6.1	0.40	14	5.3	0.2	12	22.9	1.0	14	10.7	0.9	34	29.1	2.30	60
UNK 1	UNK 1	2.60	0.04	2															
UNK 10	UNK 10													2.0	0.06	2			
UNK 2	UNK 2	2.64	0.0573	2															
UNK 3	UNK 3				3.0	0.23	2												
UNK 4	UNK 4				2.1	0.06	2												
UNK 5	UNK 5				2.2	0.07	2												
UNK 6	UNK 6				3.2	0.21	4												
UNK 7	UNK 7				2.2	0.08	2												
UNK 8	UNK 8				2.3	0.08	2												
UNK 9	UNK 9							2.4	0.04	2									
Leea alata Edgew.	Vitaceae	2.57	0.03	2															

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Grand Total		300	35	338	300	21	524	300	16	608	300	29	276	300	25	868	300	21	478